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Research article

Accelerated rehabilitation in treating neer type V distal clavicle fractures using anatomical locking plates with coracoclavicular ligament augmentation

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ABSTRACT

Background: There is still no gold standard treatment for Neer type V distal clavicle fractures. This study was designed to evaluate the therapeutic effects of accelerated rehabilitation in treating Neer type V fractures using anatomical locking plate (ALP) fixation with additional coracoclavicular (CC) ligament augmentation.

Methods: In this retrospective study, patients who underwent ALP fixation with additional suture anchor fixation of acute Neer type V distal clavicle fracture from January 2016 to January 2021 were reviewed. Injury radiography and computed tomography (CT) were performed to determine the Neer classification. All patients performed standardized early rehabilitation exercises after surgery and were followed up for more than 12 months. The Constant–Murley score (CMS); the disabilities of the arm, shoulder, and hand (DASH) questionnaire; visual analog scale (VAS); and the percentage of modified CC distance (MCCD%) were evaluated at the last follow-up.

Results: Thirty-two patients were included in this study. The mean follow-up time was 31.1 ± 10.4 months. All patients achieved bone union 6–8 weeks (7.2 ± 0.7 weeks) after surgery and were allowed to return to normal daily life. No surgery-related complications occurred in any case. The MCCD% value at the last follow-up (104.7% ± 8.5%) significantly decreased compared with preoperative MCCD% value (162.8% ± 7.2%) ($p < 0.001$), indicating that all patients achieved ideal fracture reduction. And all patients obtained satisfactory shoulder joint function with a mean CMS of 97.1 ± 2.6, a mean DASH score of 1.6 ± 1.3, and a mean VAS score of 0.4 ± 0.6.

Conclusion: This study has demonstrated that ALP fixation with additional suture anchor fixation is a promising strategy for accelerated rehabilitation in treating patients with Neer type V fracture.

Abbreviations: ALP, anatomical locking plate; CC, coracoclavicular; CT, computed tomography; CMS, Constant–Murley score; DASH, the disabilities of the arm, shoulder, and hand; VAS, visual analog scale; MCCD%, the percentage of modified CC distance; ERAS, enhanced recovery after surgery.

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1. Introduction

Distal clavicle fractures account for approximately 21%–28% of all clavicle fractures [1]. Initially, Neer has developed a classification of fractures, and Allman subsequently classified them into five types [2]. Neer type V fractures are unstable and characterized by a free inferior fragment connected to the coracoclavicular (CC) ligaments [3]. Surgical treatments are recommended for unstable distal clavicle fractures, including Neer type V and II fractures, due to the high nonunion rates after nonoperative treatments [4,5]. Various surgical procedures have been proposed for unstable distal clavicle fractures, including K-wire fixation, tension band fixation, CC fixation using sutures or screws, plate and screw fixation, and arthroscopy-assisted technique [6,7]. Among these treatments, fixation using a clavicular hook plate or anatomical locking plate (ALP) is the most popular method among orthopedic surgeons because of its stable fixation effect, guaranteed therapeutic effect, and lower learning curve [8,9].

Whether to recreate CC ligament stability remains controversial during surgery for unstable distal clavicle fractures [10–12]. Some scholars have suggested that reconstructing ligament stability can shorten the CC distance and enhance the fixation stability of clavicle fractures [9,13–15]. However, others believe that there is no significant difference in the final fracture healing effect and shoulder function between treatments using plate fixation alone and plate fixation with additional CC ligament augmentation [10,11,16,17]. Almost all reports have evaluated Neer type V and II fractures together as unstable distal clavicle fractures or only Neer type II fractures. No article has analyzed Neer type V fractures alone, which may be attributed to the relatively rare incidence of Neer type V fracture. However, when clavicular hook plates or ALPs were applied, patients with Neer type V fracture had a higher rate of complications and postoperative stiffness than those with Neer type II fractures [3]. Therefore, more stable fixation of the CC ligament and fracture is required in treating Neer type V fractures, which is conducive to reduce complications and immobilization time [18,19].

Furthermore, accelerated rehabilitation has gradually aroused the interest of several orthopedists. Most patients hope to accelerate the recovery of the function of the affected limb under the premise of ensuring the therapeutic effect to return to normal work and daily life as soon as possible. With the development of the concept of accelerated rehabilitation, enhanced recovery after surgery (ERAS) was proposed, including preoperative, intraoperative, and postoperative interventions during recovery after surgery [20,21]. Studies have

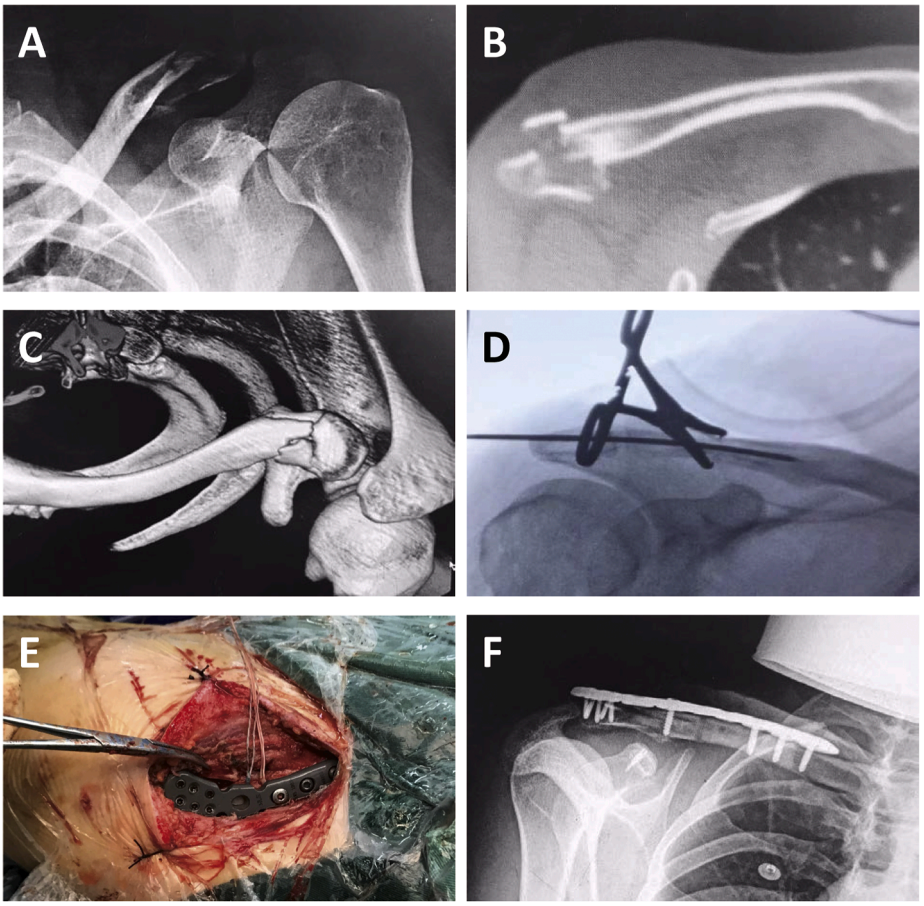

Fig. 1. (A) Preoperative X-ray image. (B) Cross-sectional image of CT scan. (C) 3D reconstruction image of CT scan. (D) Temporary fixation using a 2.0 mm Kirschner wire and clamp. (E) Intraoperative image of anatomical locking plate fixation with additional suture anchor fixation (F) Postoperative X-ray image immediately showed good reduction of clavicle fracture.

reported that the clinical application of ERAS in the artificial joint replacement domain and treatments of pelvic fractures contributed to accelerated rehabilitation [22,23,24]. There is no ERAS strategy in treating clavicle fractures. For treating unstable distal clavicle fractures, especially Neer type V fractures, stable fixation of the CC ligament and fracture and early functional exercises are the key elements of accelerated rehabilitation [25].

Therefore, we preliminarily explored the therapeutic effects of intraoperative ALP fixation with additional CC ligament augmentation and postoperative standardized early rehabilitation exercises in treating Neer type V fractures. In this study, ALPs, which are more suitable for early rehabilitation exercises than hook plates, were applied to avoid hook plate-related complications, including impingement syndrome, subacromial osteolysis, acromioclavicular joint arthrosis, and proximal clavicular fracture [26,27]. A suture anchor was fixed to the coracoid to augment the stability of the CC ligament and distal clavicle fracture. This study was designed to reduce complications and accelerate rehabilitation while treating Neer type V fractures.

2. Patients and methods

This retrospective study was approved by the Human and Ethics Committee for Medical Research of our Hospital according to the Declaration of Helsinki. Written informed consent was obtained from all patients before inclusion in the study. We retrospectively reviewed patients from January 2016 to January 2021, and only patients who underwent ALP fixation with additional suture anchor fixation of Neer type V distal clavicle fractures were included. We employed the following inclusion criteria: (1) acute Neer V distal clavicle fracture, (2) minimal follow-up period of 12 months after surgery, (3) history of painless and unrestricted shoulder function before trauma, and (4) standardized early rehabilitation exercises. The exclusion criteria were as follows: (1) previous history of injury or surgery of the affected shoulder and (2) open fracture. Demographic data, injury characteristics, and surgery-related data of the involved patients were extracted from their medical records. Injury radiography and computed tomography (CT) were performed to determine the Neer classification (Fig. 1 A–C). At the time of admission, the affected limb was externally fixed with a sling, and the local soft tissue was treated with disinfection and detumescence. Analgesics were applied according to the patient's condition to relieve the pain of the patient. Corrections of hypoproteinemia, anemia, etc. were performed according to the nutritional status of the patient. Surgery was performed within 2–3 days after injury.

2.1. Surgical procedure

Under general anesthesia, the patients were placed in a beach chair position. An 8–10-cm slightly oblique saber-cut incision centered over the lateral clavicle was made. Full-thickness soft tissue was incised and prepared to ensure an adequate soft tissue envelope for closure. The fracture area was exposed and cleaned carefully, and then, the shape, size, and displacement direction of the fracture were identified. Injury to the CC ligament was explored, and the acromioclavicular joint capsule and ligament were protected to avoid further injury caused by surgery. After the reduction of displaced fragments, a 2.0-mm Kirschner wire and clamp were used to temporarily fix the clavicle fracture, followed by fluoroscopy confirmation (Fig. 1D). Then, the base of the coracoid process was exposed by blunt dissection inferior to the distal clavicle. A 3.5-mm suture anchor (Smith & Nephew, USA) was placed into the base of the coracoid process. The two suture limbs were brought around the posterior aspect of the clavicle in the way of "V" type and tied to the other limbs over the clavicle to prevent the clavicle from shifting backward and upward. Finally, ALP fixation was performed using 5–6 locking screws placed into the distal clavicle and three locking screws placed into the proximal clavicle (Fig. 1E). The wound was routinely closed after fluoroscopy confirmation. The patients were discharged after reconfirmation of ideal fracture reduction using X-ray (Fig. 1F).

2.2. Rehabilitation

Postoperatively, all patients wore a simple sling for 3 weeks. Analgesic pump was used on the first day after operation, and the patient was treated with an oral analgesic in the following week, so that patients could carry out early rehabilitation exercises. The general principle of postoperative rehabilitation exercise is to gradually increase the range of motion of the shoulder joint without obvious pain. Twenty-four hours after surgery, the patients initiated active range-of-motion exercises of the elbow and passive pendulum exercises of the shoulder. Three to seven days after surgery, the patients gradually increased the range of motion of the shoulder joint within tolerable pain. Active shoulder abduction movements were limited to below 60°. Seven to twenty-one days postoperatively, the abduction movements were limited to below 90°, and no weight bearing was permitted. Twenty-one days after surgery, the motion of the shoulder joint was no longer restricted; however, weight lifting activities were limited to below 1 kg. Restrictions were removed at 6–8 weeks when radiological and clinical fracture union was confirmed, and the patients could return to normal daily life.

2.3. Postoperative assessment

All patients were followed up at 1 week, 2 weeks, 4 weeks, 3 months, 6 months, and 12 months and every 6 months after that, and complications were recorded. For assessing shoulder joint function, the Constant–Murley score (CMS) and disabilities of the arm, shoulder, and hand (DASH) questionnaire were used to evaluate the patients at the last follow-up (Table S1 and S2). Visual analog scale (VAS) was used to assess the overall pain perception, and the percentage of modified CC distance (MCCD) (MCCD%) was used to evaluate the fracture reduction [15]. The MCCD is defined as the perpendicular distance from the top of the coracoid process to the

upper border of the clavicle. The MCCD% was calculated as follows: MCCD% = (MCCD of the injured side/MCCD of the healthy side) × 100.

2.4. Statistical analysis

Statistical analyses were conducted with SPSS Version 16.0 software (SPSS Inc., Chicago, IL, USA). All measurement data were tested for normal distribution using the Kolmogorov-Smirnov Z test. Comparisons of variables between baseline and the endpoint were analyzed using paired t-tests when the distribution was normal; otherwise, the Wilcoxon signed-rank test was used. A P value of less than 0.05 was defined as significant.

3. Results

Thirty-two patients who underwent open reduction and internal fixation for acute Neer type V fractures using ALP fixation with additional CC ligament augmentation were included in this study, and another 3 cases were lost to follow-up and were excluded because the follow-up time was less than 12 months. All 32 patients included in the study had more than 12 months of follow-up and performed standardized early rehabilitation exercises. Patient characteristics are presented in Table 1. Of these thirty-two patients, twenty were male and twelve were female, with a mean age of 41 years (range, 20–64 years) and body mass index (BMI) of 23.5 kg/m^2 (16.7–29.8 kg/m^2), and fourteen patients had left clavicular fractures and eighteen patients had right clavicular fractures. The initial injuries were caused by traffic accidents in twenty-five cases and falls in seven cases. The mean time to surgery was 7.8 days (range, 2–17 days).

The mean operative time was 67.8 min (range, 51–91 min), and the mean intraoperative blood loss was 63.9 mL (range, 34–100 mL) (Table 2). No patient had wound dehiscence, deep or superficial infection, stiffness, or failure of fixation. Moreover, no complications such as bone nonunion, malunion, and infection occurred in all cases, except for one patient who felt shoulder joint pain after early rehabilitation exercise. The pain was relieved after reducing the frequency of exercises. The mean follow-up time was 31.1 months (range, 12–50 months). All patients obtained bone union with a mean fracture healing time of 7.2 weeks (range, 6–9 weeks). Removal of the ALP fixation was performed in eleven patients because of the psychological discomfort with plate implantation rather than the unfavorable impact on daily life or sports caused by the plate fixation itself. At the last follow-up, all patients showed satisfactory shoulder joint function with a mean CMS of 97.1 (range, 92–100), mean DASH score of 1.6 (range, 0–5), and mean VAS score of 0.4 (range, 0–2) (Fig. 2 A–G). The results of MCCD% evaluation at the last follow-up (i.e., 104.7% ± 8.5%) significantly decreased compared with preoperative MCCD% (i.e., 162.8% ± 7.2%) ($p < 0.001$), indicating that all patients achieved ideal fracture reduction.

4. Discussion

The surgical treatment for unstable distal clavicle fractures yields higher union rates than conservative treatment [28,29]. Various surgical techniques have been developed, including hook or locking plates, Kirschner wires, CC screws, and suture tension band wiring. However, each technique has its own drawbacks. For example, fixation using Kirschner wires may lead to pin migration, infections, and fixation failure; treatment using CC screws is associated with screw backing out and malunion; and fixation using tension band wires could cause delayed union, clavicular erosion, and malunion [19,30]. Besides, although hook plates have been proven to be an effective treatment for many years because the hook portion can resist inferior displacement of the injured arm, thus assisting in fracture reduction maintenance, it can also result in the impingement of the supraspinatus and acromial fracture [31,32,33]. For patients who hope to restore shoulder function and return to normal daily life as soon as possible, ALP, which does not violate the acromioclavicular joint and subacromial space and has a gradually widened lateral shape, allowing more screw implantations to enhance the stability of the distal fracture segment, is an ideal option [34,35].

However, most reports regarding the treatment of unstable distal clavicle fractures using ALP with nice therapeutic effects are related to Neer type II fractures. The detached CC ligaments connected to the free inferior fragment in Neer type V fractures may lead to severer instability than the injured CC ligaments in Neer type II fractures. Therefore, when the fracture is comminuted and the fragments are small, plate fixation alone cannot provide sufficient stability and cannot often provide strong enough fixation for early rehabilitation exercises, contributing to postoperative stiffness [11,17,19]. Biomechanical results showed that the addition of a suture anchor improved the stability of unstable distal clavicle fractures treated using plate fixation [14,36]. To endow patients with better

Table 1
Patient characteristics.

Characteristics (n = 32)	Value
Age, years, mean ± SD	41.5 ± 12.2
Sex, male/female	20/12
Side, left/right	14/18
Time to surgery, days, mean ± SD	7.8 ± 4.1
Body mass index, kg/m^2, mean ± SD	23.5 ± 3.1
Mechanism of injury, traffic accident/fall	25/7

Table 2
Clinical data during perioperative period and postoperative assessment.

Results (n = 32)	Value
Operative time, minutes, mean ± SD	67.8 ± 10.8
Intraoperative blood loss, mL, mean ± SD	63.9 ± 17.1
Complications	1
Case of shoulder joint pain after early rehabilitation exercise	1
Follow-up time, months, mean ± SD	31.1 ± 10.4
Fracture healing time, weeks, mean ± SD	7.2 ± 0.7
Constant-Murley score, mean ± SD	97.1 ± 2.6
DASH score, mean ± SD	1.6 ± 1.3
Visual analogue scale score, mean ± SD	0.4 ± 0.6
Preoperative MCCD%, %, mean ± SD	162.8 ± 7.2
MCCD% at the last follow-up, %, mean ± SD	104.7 ± 8.5

DASH, the disabilities of the arm, shoulder, and hand; MCCD, the modified coracoclavicular distance.

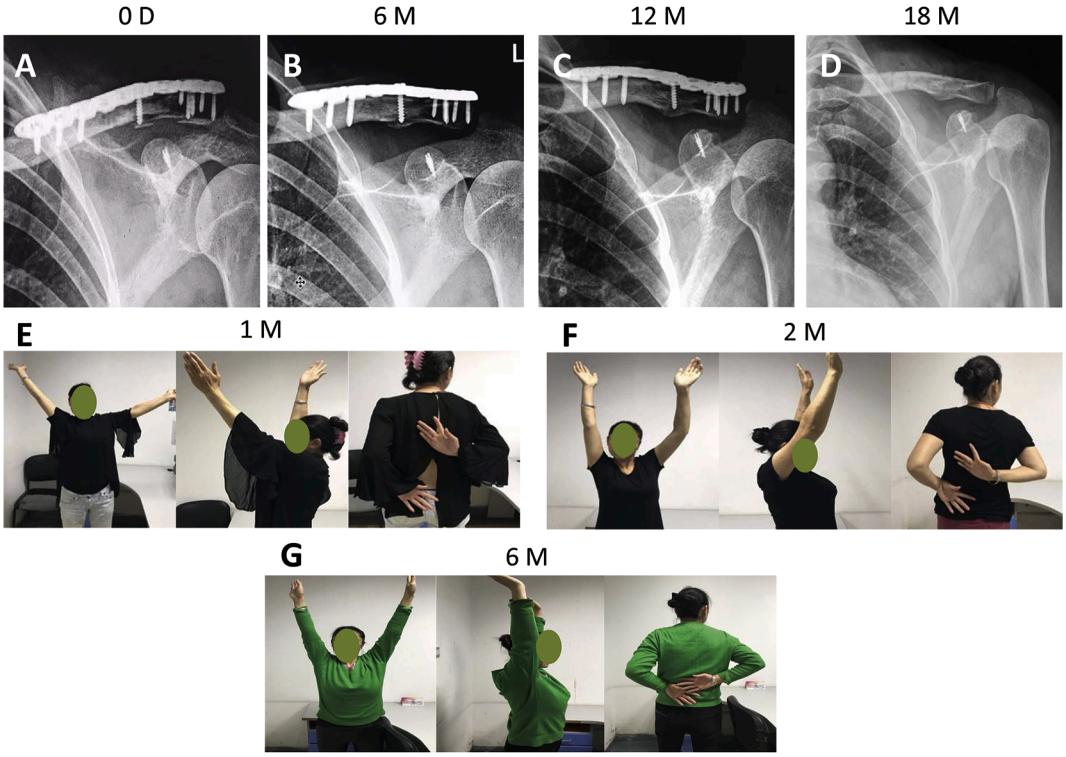

Fig. 2. A 49-year-old female patient with left distal clavicle fracture (Neer type V) caused by falling. (A) X-ray image taken immediately after surgery. (B and C) Postoperative X-ray images at 6 and 12 months after operation. (D) X-ray image after the removal of plate fixation 18 weeks post-surgery. (E–F) Clinical photographs of shoulder joint function at 1, 2, and 6 months after surgery.

reduction and stronger fixation, additional CC ligament augmentation using a suture anchor to strengthen fracture stability of ALP fixation was used in this study. All patients who underwent anchor fixation and can afford standardized early rehabilitation exercises achieved sufficient shoulder joint function for daily life and avoided postoperative stiffness.

Moreover, some studies have confirmed that CC ligament augmentation techniques, including suture anchor, endobutton, autograft, and allograft techniques, improved fracture stability and led to satisfactory final therapeutic results [37,38,39,40]. However, there are some complications related to CC ligament augmentation using a suture anchor, such as anchor pullout, coracoid fracture, and brachial plexus injuries [10]. Similar complications can be found in the application of other techniques for CC ligament augmentation [16,41]. Due to the paucity of literature regarding the comparison of CC ligament augmentation techniques, which technique is superior remains unknown. In this study, no anchor-related complications were observed in all patients. Furthermore, the patients after anchor fixation achieved nice fracture reduction, and the CC distance of the injured side was similar to that of the healthy side, which was proved using X-ray and MCCD% evaluations. The conventional CCD (the perpendicular distance from the top of the coracoid process to the lower border of the clavicle) may not increase in most cases of Neer type V fractures, in which CC ligaments are

connected to the free inferior fragment [15,42]. The MCCD defined as the perpendicular distance from the top of the coracoid process to the upper border of the clavicle is more suitable for evaluating fracture reduction in treating Neer type V fractures [15]. In this study, the follow-up results showed that patients with ALP fixation with additional anchor fixation could perform early rehabilitation exercises and achieve accelerated rehabilitation; however, note that a study has reported that anchor-related complications might occur in patients with osteoporosis or underlying diseases [43]. Besides, the extra expense and operative time of anchor fixation should be considered in each case.

Accelerated rehabilitation is the demand of most patients, and ERAS is a critical concept leading to the development of modern surgery [44]. The principles of treating intra-articular fractures are strong internal fixation and ERAS, so that patients can achieve the best joint function. Neer type V fractures can be considered intra-articular fractures because they affect the stability of the acromioclavicular joint and coracoclavicular ligament. Therefore, both strong internal fixation and ERAS are indispensable and can complement each other. The intervention of the ERAS concept can endow patients with ideal shoulder joint function after surgery. There is no ERAS strategy for treating any type of unstable distal clavicle fracture. Therefore, we evaluated the feasibility of intraoperative ALP fixation with additional CC ligament augmentation and postoperative early rehabilitation exercises for accelerating rehabilitation in patients with Neer type V fractures. In this study, the difference between ERAS and general rehabilitation mainly lies in the formulation of perioperative analgesia program, the selection of the surgical method, and the timing of starting exercise after surgery. We speculate that ALP fixation with additional suture anchor fixation can biomechanically and anatomically reconstruct the acromioclavicular joint and coracoclavicular ligament, provide sufficient conditions for early postoperative exercise, and accelerate the recovery of shoulder joint function. We hope that this study can provide a reference for the complete ERAS strategy for treating unstable clavicle fractures.

This study has several limitations to consider. First, this is a nonrandomized retrospective study without a control group, and the number of patients was small. The reason why we did not set up a control group was to ensure the therapeutic effects on the patients. ALP fixation without additional anchor fixation may not provide sufficient fracture stability for early rehabilitation exercises. Therefore, we applied additional CC ligament augmentation on all patients who hoped to achieve accelerated rehabilitation. Second, for the aforementioned patients, although we thought suture anchor fixation was the appropriate CC ligament augmentation method, other CC ligament augmentation techniques were not compared in this study. Other augmentation techniques may provide other benefits with a low complication rate. Finally, accelerated rehabilitation strategies in the perioperative period were not studied. All preoperative, intraoperative, and postoperative interventions were required to set up a complete ERAS strategy for treating unstable distal clavicle fractures. Further prospective randomized studies are required to determine the optimal strategy for accelerated rehabilitation in treating Neer type V fractures.

5. Conclusions

Six to eight weeks after ALP fixation with additional anchor fixation, patients with Neer type V fracture achieved bone union. Moreover, they obtained accelerated rehabilitation following the standardized early rehabilitation exercises. No surgery-related complications were observed in any case. ALP fixation with additional CC ligament augmentation is a promising strategy for accelerated rehabilitation in treating patients with Neer type V fractures. Further prospective randomized controlled trials are required to determine the details of the CC ligament augmentation techniques and accelerated rehabilitation strategies in the perioperative period.

Authors' contributions

MZ and JS conceived and designed the experiments. XD, MZ, and ML performed the experiments and analyzed and interpreted the data. ML and JS contributed analysis tools or data and wrote the paper. All authors have read and approved the manuscript.

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Availability of data and materials

Data and material related to this study is available from the corresponding author JS on reasonable request.

Ethics approval and consent to participate

This study was approved by the Human and Ethics Committee for Medical Research of Chengdu Second People's Hospital, in accordance with the Declaration of Helsinki. Written informed consent was obtained for all patients prior to the inclusion in the study.

Declaration of competing interest

The authors declare that they have no competing interests.

Acknowledgements

Not applicable.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.heliyon.2022.e12660.

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