Comparison of the Posterior-anterior Approach and Lateral-medial Approach for Complex AO/OTA Type C Intra-articular Fractures of Distal Humerus

Yongchang Chen

Nanjing Qixia District Hospital

Fei Xiao

Nanjing Qixia District Hospital

Jian Chen

The First Affiliated Hospital of Nanjing Medical University

Lin Wei

Nanjing Qixia District Hospital

Guoqing Zheng

Nanjing Qixia District Hospital

Zhongsheng Wei

Nanjing Qixia District Hospital

Jingpu Li

Nanjing Qixia District Hospital

Jialei Tu

Nanjing Qixia District Hospital

Gang Wang

Nanjing Qixia District Hospital

Xiao Wang

Nanjing Qixia District Hospital

Haibo Xu (✉ 522673685@qq.com)

Nanjing Qixia District Hospital

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Abstract

Objective: The aim of this retrospective study was to investigate clinical effects of the treatment of intra-articular distal humeral fractures via the combined posterior olecranon osteotomy and anterior approach and the combined lateral Kaplan approach associated with the medial approach.

Methods: Between July 2010 and September 2019, 28 cases of intercondylar fractures of the distal humerus (AO/OTA type C) were treated by open reduction and internal fixation (ORIF) via the posterior and anterior approach and combined lateral-medial approach, which were divided into the P-A (n = 13) and L-M (n = 15) groups, respectively. The outcomes in terms of function were assessed using the range of motion (ROM) of the elbow and forearm, humerotrochlear (HT) angle, Visual Analogue Scale (VAS) scores, Mayo Elbow Performance Score (MEPS), and efficacy grade evaluated using the scoring system of Orthopaedic Trauma Association (OTA) at the one-year follow-up.

Results: The flexion-extension of elbows and pronation-supination of forearms were respectively $114.1^{\circ} \pm 12.4^{\circ}$ and $157.3^{\circ} \pm 9.6^{\circ}$ in the P-A group and $117.1^{\circ} \pm 14.5^{\circ}$ and $161.3^{\circ} \pm 10.7^{\circ}$ in the L-M group. No significant difference was observed between the two groups for the elbow and forearm ROM ($p > 0.05$). Furthermore, surgery duration, blood loss volume, HT angle, MEPS, VAS scores, OTA rating, and the morbidity of postoperative complications during the one-year follow-up did not differ between groups.

Conclusion: The posterior olecranon osteotomy and anterior approach can be used efficiently for exposure of complex distal humeral injuries with similar clinical efficacy and complications in the treatment of intra-articular distal humeral fractures as compared to the lateral-medial approach.

Introduction

Distal humeral fractures account for 0.5–2.0% of all fractures in the body. Of these, 30% involve the articular surface[1]. There is a well-documented bimodal distribution of these fractures, with an early peak in young individuals resulting from high-energy trauma, predominantly in males aged between 12 and 19 years. A second larger peak accounts for older individuals, mainly women aged 60 years and over, who typically have osteoporosis and whose fractures result from low-energy falls[2]. Although relatively rare, the incidence of these fractures is rising rapidly as the population ages. Pavlanen et al. have reported a five-fold increase in distal humeral fractures between 1970 and 1998 from 12 to 34 per 100,000 people per year[3].

Compared with other humeral fractures, there is a higher percentage of open fractures[4] accompanied by a posterior wound proximal to the elbow joint that was created by protrusion of the humeral shaft through the triceps muscle and posterior skin[5] in patients with distal humeral fractures. Neurological assessment should include examination of the median, radial, and ulnar nerves. The prevalence of preoperative ulnar nerve symptoms in patients with a type-C fracture of the distal portion of the humerus has been reported to be 24.8%[6]. The risk of functional disability following non-operative treatment has been shown to be quite high. Therefore, operative management is generally accepted as the gold

standard for juxta-articular and intra-articular distal humeral fractures[7]. Thus, open reduction and internal fixation (ORIF) of these fractures are now well-recognized management techniques. The goals of surgical treatment are to restore articular congruity and bone alignment, while providing rigid and stable fixation that enables early active motion. Nevertheless, primary total elbow arthroplasty may be considered in rare situations, such as in the elderly (> 65 years of age) patients with comminuted intra-articular fractures and low-demand or sedentary lifestyles[8]. Treatment of these injuries, in particular bicolumnar fractures with intra-articular comminution corresponding to OTA/AO (C3), is challenging due to fracture comminution, poor bone quality, and difficulty in restoring the complex anatomy of the distal humerus[9], which predisposes to unsatisfactory results. Over 25% of such fractures result in significant complications during treatment, a few of them requiring further surgery[10]. Hence, exposure of fracture fragments to anatomic reconstruction of the articular surface and stable fixation of all fracture fragments become paramount for restoration of satisfactory elbow function and good outcomes. To achieve this objective, surgical exposure to all critical structures is of great importance, and consequently the surgical approach becomes crucial.

The fractures involving articular surfaces are typically approached from the posterior side, and various posterior approaches have been utilized. These include triceps-reflecting anconeus pedicle, Bryan and Morrey's triceps reflecting, Campbell's triceps-splitting, olecranon osteotomy, and the combined medial and lateral approach, which have been described in terms of pros and cons of each[7, 9, 11–17]. Owing to the complex anatomy of the distal humerus and the fracture patterns, each approach offers different advantages in terms of exposure and soft tissue disruption. Thus, controversy still exists regarding the surgical approach in the management of intra-articular distal humeral fractures. The olecranon osteotomy approach, which provides maximum articular surface visualization, provides a better command of fracture fragments and has minimal consequences on the extensor mechanism. It is often employed for the types of fracture, where 40% of the anterior surface remain unvisualized[18]. Therefore, the present study investigated whether it is possible to increase the exposure of the articular surface of the distal humerus through supplemental anterior approach to obtain a better clinical effect by combining the olecranon osteotomy approach.

To the best of our knowledge, there have been no previous reports on the comparison of function recovery and complication rate of the combined lateral and medial approach or olecranon osteotomy combined with anterior approach for the treatment of complex distal humeral fractures (OTA/AO, type C). The present study evaluated clinical outcomes in 28 cases of complex intra-articular distal humeral fracture, which were treated using ORIF with the above two approaches. Clinical effects were also compared in order to provide a reference for clinical practice.

Materials And Methods

Patients

A retrospective study was conducted in the department of Orthopedics, Nanjing Qixia District Hospital involving 28 patients with intercondylar fracture of the humerus between July 2010 and September 2019. Ethical approval and patient consent were obtained. The displaced intra-articular fractures in adults served as the inclusion criteria. The exclusion criteria were as follows: patients with pathologic fractures, adolescent fractures, and patients who could not tolerate surgery due to other medical problems. Systemic comorbidities of the patients, such as diabetes and hypertension, interval time from trauma to surgery, intraoperative blood loss, and surgery duration, were recorded. All patients presented with AO/OTA type C intercondylar fractures of the distal humerus. Only one case was associated with olecranon fracture. Before surgery, a routine plaster support was used for immobilization, and symptomatic treatments, such as dehydration and pain relief, were provided. The cohort (n = 28) treated using ORIF was stratified into the posterior-anterior (P-A) and lateral-medial (L-M) groups according to the different treatment approaches. Of these, 13 cases were treated with olecranon osteotomy combined with the anterior approach, and 15 cases were treated with the combined lateral Kaplan and medial approach. All patients were followed up for 12 months post-operatively.

Operative approach

In all cases, the patients under brachial plexus or general anesthesia were placed in a supine position on the operating table with an inflated tourniquet on the affected arm. After satisfactory anesthesia was administered, an elbow joint varus test was performed to check the stability of the medial and lateral ligaments. The elbow to be operated on was positioned at 90° of abduction and supported on a lucent operating table.

Posterior-anterior (P-A) approach (Fig. 1)

In the P-A group, a longitudinal incision was made under the posterior elbow and slightly curved toward the radial side in the coronal plane (Fig. 1A). The subcutaneous tissue was bluntly dissected and the flaps were raised and retracted bilaterally. The ulnar nerve was identified proximally to the medial triceps, dissected within the cubital tunnel, and protected at all times by wrapping with penrose drain and through the flexor pronator aponeurosis to the level of its first anterior motor branch (Fig. 1B). After marking the osteotomy plane and clearing the soft tissue in order to fully expose the bone surface, an inverted V-shaped Chevron osteotomy was performed 2 cm distal to the olecranon tip and oriented to exit in the bare area of the trochlear groove. Finally, part of the distal humerus, radial head, and coronoid process of ulna were exposed when the olecranon and extensor device were raised during elbow flexion. Next, the anterior auxiliary approach was initiated proximally 5 cm up the elbow flexion crease, along the border just lateral to the biceps brachii muscle. Then, the longitudinal skin incision crossed over the elbow crease and extended distally along the lateral border of the flexion crease at approximately 2 cm distal to it. Dissection was performed in the interval between the biceps brachii and the brachialis muscle, which was then split longitudinally to expose the fracture site followed by the Henry's elbow surgical approach[19] (Fig. 1C). Distally, the radial nerve was identified in the space between the brachialis and brachioradialis muscles. The split brachialis muscle was retracted laterally, protecting the radial nerve. The position of

the elbow and the areas of soft tissue were changed to expose the articular surface. The exposed articular surface was marked by drilling holes along its margin with a 0.5-mm Kirschner (K)-wire.

Lateral-medial (L-M) approach

In the L-M group, lateral exposure of the distal humeral fracture was performed using a Kaplan approach[20]. First, a lateral incision was extended proximally 2 cm up the humerus and distally 5 cm down the forearm centered over the lateral epicondyle. With the elbow flexed at about 30° and forearm pronation, the interval of the extensor digitorum communis and the extensor carpi radialis brevis (ECRB) was developed and incised at the midpoint of the anterior radial head. The deep capsule was then incised anterior to the radial collateral ligament and lateral ulnar collateral ligament (LUCL) through the annular ligament. The extensor carpi radialis longus/ECRB combined with the incised capsule were elevated forward from the lateral epicondyle to broaden the exposure of the radiocapitellar joint. If the fracture extended to the trochlea, the origin of the wrist extensors could be partially peeled off. Second, the medial incision[21] at about 5 cm from the medial epicondyle to the proximal humerus with the elbow flexed at ~60° was initiated and extended obliquely along the brachial artery from the inside to the outside. The distal humeral medial and anteromedial side was exposed through the incision between the brachial muscle and the medial intermuscular septum. The ulnar nerve was exposed behind the medial intermuscular septum but not isolated. The brachialis muscle were reflected laterally along the medial neurovascular bundle of the elbow joint. With the anterior capsule cut, the front of the trochlea part and medial epicondyle, as well as the brachioradial joint, were exposed.

Fixed technique

Any hematoma among the fragments was debrided, and the number and displacement of articular fragments were identified. Headless screws, K-wires, and Ethicon sutures were used for fixation depending on the complexity of the fracture and stability of the reduction. The articular fragment was then attached to the condyle and temporarily fixed with K-wires. Fracture sites were stabilized with orthogonal plating: one plate on the medial side and the other on the posterolateral side, roughly perpendicular to each other according to the AO principle (Fig. 1D). Reduction in the articular surface and screw lengths was checked using a C-arm.

An oscillating or fret saw was used to perform the osteotomy. The posterior elbow capsule was dissected, and the distal humeral fracture fragments were reduced and then temporarily fixed using K-wires. While reaching the anatomical reduction, the double plates were used to fix the fracture fragments. The olecranon osteotomy fragment was restored and fixed using a tension band and two K-wires. It was convenient to perform assisted reduction and fixation and observe reduction of the articular surface via the anterior approach.

Lateral collateral ligamentous complex tears and avulsion fracture of epicondyle were repaired primarily using drill-holes and a locking suture technique or suture anchors. No excessive movement of the fracture fragments under the elbow motivation was confirmed under direct observation. The elbow was then

subjected to a full range of motion to assess the safety of fixation. If the fixation was stable enough, the wound was closed.

Postoperative protocol

Post-operatively, routine antibiotics were administrated intravenously to prevent infection for 24 h. Celecoxib was used orally to relive acute pain. Patients treated with a combined lateral and medial approach were routinely subjected to progressive functional exercise under the protection of elbow brace after surgery. Oral indomethacin was recommended for three weeks to prevent possible development of myositis ossificans or heterotopic ossification (HO). Wound suture removal was performed 12 days postoperatively. Full weight-bearing motion was allowed when fracture healing was verified radiologically.

Clinical observation

All patients were followed up and reviewed by an independent surgeon one, three, and 12 months after the operation. Follow-up indicators, including non-union, plate location, HO, ischemic osteonecrosis, elbow stiffness, and traumatic osteoarthritis (TOA), were evaluated by anteroposterior X-ray and lateral film. Postoperative complications, including wound infection or functional disturbance of the ulnar or radial nerve, were recorded. Union was defined as the absence of pain, obscurity of the fracture line between fragments in the metaphyseal region, and the absence of articular fragments on the distal humerus on the radiographs four months post-operation. The range of motion (ROM) of the elbow and the forearm, humerotrochlear (HT) angle, Visual Analogue Scale (VAS) scores, Mayo Elbow Performance Score (MEPS), and efficacy grade evaluated via the Orthopaedic Trauma Association (OTA) scoring system for distal humeral fractures were noted at the one-year follow-up.

Statistical analysis

Analysis was performed using the statistical software SPSS 20.0. All parameters were expressed as mean $\pm$ standard deviation for each group. Categorical variables and proportions were analyzed using the chi-square test. The demographic characteristics and clinical efficacy scores were compared according to the different approaches (L-M and P-A groups) with analysis of variance and the Wilcoxon rank test for continuous variables. Statistical significance was defined as $p < 0.05$.

Results

Demographic characteristics (as shown in Table 1) for 28 patients, including 13 men and 15 women aged from 34 to 65 years (mean 44.4 ± 11.8 years) who were stratified into P-A or L-M groups, are reported in Table 1. The left elbow was affected in 16 patients and the right in 12 patients. Fracture types according to the OTA/AO classification included C1 in nine patients, C2 in 13 patients, and C3 in six patients. The cause of injury was a car accident in eight patients, high-altitude fall in four patients, and an electric-bicycle fall in 16 patients. All patients were operated on between five and ten days after injury (mean 7.2 ± 3.0 days). Surgery duration and blood loss volume were 3.4 ± 1.1 h and 244.3 ± 59.4 mL, respectively. A

total of nine patients in each group had one or more comorbidities (diabetes and hypertension). Surgery duration time and blood loss volume in the P-A group were greater than those in the L-M group, although no significant differences were observed ($p > 0.05$). Furthermore, there were no significant differences in gender, age, time from the incident until surgery, distribution of cases in the affected side, OTA/AO classification, mechanism of injury, and comorbidities between the groups ($p > 0.05$).

Table 1
Demographics

Variable	Total cases	P-A approach	L-M approach	<i>P</i> value
Patient (n)	28	13	15	
Gender				0.98
Male	13	6	7	
Female	15	7	8	
Age (years)	44.4 ± 11.8	45.3 ± 11.3	43.5 ± 12.1	0.78
Affected side				0.74
Left	16	7	9	
Right	12	6	6	
OTA/AO classification				0.98
C1	9	4	5	
C2	13	6	7	
C3	6	3	3	
Mechanism of injury				0.65
Car accident	8	4	4	
high-altitude fall	4	1	3	
Electric- bicycle fall	16	8	8	
Systemic disease				0.97
Only diabetes	4	2	2	
Only hypertension	3	1	2	
Two comorbids	2	1	1	
Time from hurt to surgery (d)	7.2 ± 3.0	7.2 ± 3.1	7.1 ± 3.0	0.93
Surgery duration (h)	3.4 ± 1.1	3.6 ± 1.3	3.2 ± 0.9	0.42
Blood loss (ml)	244.3 ± 59.4	250.8 ± 65.3	238.7 + 53.3	0.51
The values are shown as mean ± SD				
Differences are considered significant at $p < 0.05$				

The mean flexion-extension motion of the elbow was $114.1^{\circ} \pm 12.4^{\circ}$ (range 83° – 142°) in the combined P-A group and $117.1^{\circ} \pm 14.5^{\circ}$ (range 85° – 143°) in the L-M group (Table 2). No significant difference was found between the two groups when comparing flexion-extension motion of the elbows. Moreover, there were no significant differences in pronation-supination of the forearms, HT angle, MEPS, or VAS. Excellent and good ratings according to the OTA scoring system were noted between the two groups ($p > 0.05$; Table 2).

Table 2
Surgical outcome

Variable	Total cases	P-A approach	L-M approach	<i>P</i> value
Flexion-extension of elbow (°)	115.7 ± 13.6	114.1 ± 12.4	117.1 ± 14.5	0.61
Pronation-supination of forearm (°)	159.5 ± 10.4	157.3 ± 9.6	161.3 ± 10.7	0.35
HT angle (°)	92.7 ± 4.82	92.2 ± 4.9	93.2 ± 4.7	0.58
MEPS	84.9 ± 13.2	83.5 ± 12.34	86.1 ± 13.8	0.61
VAS scores	2.9 ± 1.2	3.2 ± 1.4	2.76 ± 0.9	0.39
OTA rating	28	13	15	0.88
Excellent	8	3 (16.7%)	5 (33.3%)	
Good	15	8 (61.5%)	7 (46.7%)	
Fair	5	2 (15.4%)	3 (20.0%)	
Complications	9	5 (38.5%)	4 (26.7%)	0.78
Wound healing complication	2	1 (7.7%)	1 (6.7%)	
Ulnar nerve symptoms	1	1 (7.7%)	0	
Delayed union	1	1 (7.7%)	0	
HO	3	2 (15.4%)	1 (6.7%)	
Joint stiffness	1	0	1 (6.7%)	
Symptomatic hardware	1	0	1 (6.7%)	
Flexion-extension of elbow and pronation-supination of forearm represent the range of motion (ROM) of the elbow and the forearm; HT, humerotrochlear; MEPS, Mayo Elbow Performance Score; VAS, Visual Analogue Scale; OTA, Orthopaedic Trauma Association; HO, heterotopic ossification				
The values are shown as mean $\pm$ SD				
Differences are considered significant at $p < 0.05$				

Common complications of the distal humeral fractures in this study were delayed union, wound healing complication, ulnar nerve injury, joint stiffness, and HO. There was only one patient in each of the P-A and L-M groups (7.7% and 6.7%, respectively) with infected incision three days postoperatively, which was treated using dressing changes and antibiotics. Ulnar nerve paresthesia was present in one case (7.7%) in the P-A group and was resolved by mecobalamin and functional exercise in 3 months. During a four-month follow-up, one patient (7.7%) developed a delayed union of the fracture in the P-A group. After early diagnosis and additional cast fixation, the fracture healed 5–6 months post-surgery. HO occurred in two cases (15.4%) in the P-A group and in one case (6.7%) in the L-M group 3 months after surgery, which suggests that adequate postoperative drainage of the joint cavity and the use of indomethacin are essential. In the L-M group, one patient (6.7%) developed joint stiffness 3 months postoperatively, which was eventually resolved via elbow adhesiolysis. Symptomatic hardware pain occurred in one patient in the L-M group and was relieved after the implant was removed 5 months post-surgery. None of the other complications, such as internal fixation displacement, ischemic osteonecrosis, and TOA, occurred during the one-year follow-up. There was no significant difference in the complication rate between the two groups ($p > 0.005$; Table 2). A typical case is represented in Fig. 2.

Discussion

The present study demonstrated that the posterior olecranon osteotomy and anterior approach had no significant differences in clinical efficacy and operation-related complications compared to the combined lateral and medial approach. However, the combined medial-lateral approach exposed only 46.9% of the whole distal humeral articular surface, which is lower than the maximal visible size of 61.3% reported for the olecranon osteotomy approach[15]. Another research study has reported that the average percentage of the exposed articular surface for the anterior approach was 45.7% [22], which is also lower than 53.9% for the olecranon osteotomy. According to our experiences and previous studies[15, 18, 22], it is difficult to entirely expose the complex distal humeral fractures for any single approach, which is insufficient for treatment, especially for severe intra-articular fractures. The anterior (Henry) approach to the elbow has been widely used in upper limb surgery. It has been described as a valuable choice for the synthesis of proximal radial fractures, reinsertion of the distal biceps tendon, excision of anterior elbow tumors, and debridement in case of soft-tissue infections[23]. However, due to the anatomical characteristics of the area and because the elbow can be approached from other directions that involve lower surgical risk, the anterior approach is rarely used in everyday practice. Despite the fact that radial nerve lesions have been reported in association with the approach, we recommend the use of a wide-blade separator to retract the mobile wad of Henry laterally along with the radial nerve[23], thus minimizing the possible insult to the nerve. Additionally, the anterior approach, which passes through the interval between the brachioradialis and the biceps or the biceps and the medial brachial neurovascular bundle, can avoid releasing the LUCL in combination with the olecranon osteotomy[24] or the lateral approach[9, 25] in situations necessitating anterior exposure, such as a coronal capitellum or trochlear fracture. Because the anterior auxiliary approach combined with the olecranon osteotomy approach can expand the exposure area, it can further assist in the reduction and fixation of the coronal fracture from the front, especially when the patient was

positioned supine with the elbow in full extension. This might explain why the incidence of postoperative complications, bleeding volume, and operation duration did not significantly increase in the case of increased olecranon osteotomy and anterior assisted exposure. It has been reported that intra-articular fractures of the distal humerus can be treated with ORIF through a combined medial-lateral elbow approach, which is useful in the surgical treatment of AO/OTA C1 and C2 with a simple fracture pattern in the posterior distal humerus. It also provides better outcomes for the motion of the elbow, bleeding volume in surgery, and complications than olecranon osteotomy[15, 17, 21]. To achieve a good anatomic reduction and stable internal fixation, it is important to gain enough exposure to the articular surface[26]. Despite the fact that a combined medial-lateral approach can keep the integrity of the elbow extensor and, therefore, does not influence the extension power, which can allow patients to exercise early[17, 21], the major exposed area of the combined medial-lateral approach was limited to the front of the distal humeral articular surface compared to the anteroposterior approach. Thus, the P-A approach is recommended to treat complex articular fractures of the distal humerus, particularly the AO/OTA C3.

In the literature on surgical treatment of intra-articular distal humeral fractures, the posterior olecranon osteotomy approach is considered to be a better one, despite significant complications, such as delayed union, non-union, heterotrophic ossification, ulnar nerve paralysis, symptomatic olecranon fixation, and secondary procedures required for the removal of symptomatic hardware having been reported[14, 15, 18, 27, 28]. It is particularly beneficial for fractures with comminution of the articular surface. It also provides a more optimal visualization of distal articular surfaces. Non-union of osteotomy site has been reported to be as high as 30% when transverse osteotomy was performed[29]. However, the risk of potential non-union complication is reduced with the use of a chevron-shaped osteotomy of the olecranon and proper fixation. Coles et al. have reported that delayed fracture union of chevron-shaped osteotomy occurred in only one out of 67 patients, and the union eventually occurred 10 months later after operation without further intervention[30]. Ring et al. have reported union of the osteotomy in 44 out of 45 patients (98%) [31]. In the present study, two bicortical K-wires and a tension band construct were utilized to fix the osteotomy site. Only one case (7.7%) of delayed healing occurred in the P-A group, which can be attributed to chevron-type osteotomy on the basis of its larger contact area and better rotational stability compared to the transverse osteotomy[32]. The osteotomy site healed after a prolonged cast fixation, which hints that two bicortical K-wires and a tension band construct were able to securely stabilize the osteotomy site. A recent retrospective review of distal humeral fractures treated via a transolecranon approach during a nine-year period showed that there were no differences in osteotomy time to union, elbow motion, or MEPS at final follow-up in patients with olecranon osteotomy fixed with tension band wiring or plate fixation[33]. As compared with another technique to fix olecranon osteotomy with plates and screws, K-wire/tension band technique has become more popular due to limited surgical exposure and inexpensive implants[34].

It has recently been reported that the risk of HO development in association with distal humeral fracture includes central nervous system injury[35], delay in operative intervention[36], and surgery prior to definitive fixation[37], but not surgical approach[38]. Thus, the role of the surgical approach in the development of HO remains controversial. No significant difference in HO was shown between the two

groups in the present study. To date, there has been no Level 1 evidence examining the role of HO prophylaxis in the management of distal humeral fractures treated with ORIF[7, 9]. Nevertheless, indomethacin was used to prevent the development of HO according to its previously recommended dosage and usage[39] in the present study. HO occurred in two cases (15.4%) in the P-A approach and one case (6.7%) in the L-M approach, which is close to previously reported findings[14, 17, 21]. In accordance with prior studies[14], the ulnar nerve was routinely anteriorly transposed in the two groups in order to avoid impingement between nerve and implants during elbow motion. The results indicated that only one case (7.7%) developed ulnar nerve palsy among patients treated using the P-A approach, which was considered to be traction injury to the nerve during surgery. Since the implantation of posterior to anterior headless screws into the anterior articular surface could not be directly observed in the L-M group, improper selection could easily lead to irritation symptoms in the posterior elbow joint. In this approach, we reported one case (6.7%) of irritation symptoms caused by the excessive length of the internal fixation screw, which required a second operation to be removed at 5 months post-surgery. Studies have reported that the rate of symptomatic hardware that necessitated re-operation for removal ranges from 8–13%[30, 31] in osteotomies secured with K-wire/tension band technique. Recently, Wei et al. have reported that a total of ten patients (52.6%) underwent removal of implants, which suggested that the rate of reoperation using K-wire in the treatment of comminuted distal humeral coronal shear fracture was greater than when using other internal fixations[40]. Despite most of the studies emphasizing that the K-wire/tension band technique has a high incidence of symptomatic hardware, its specific time of occurrence is not indicated. The internal fixation in all patients in this study was removed within 10 months to one year, which significantly reduced the occurrence of related symptoms. This suggests that the symptoms related to K-wire/tension band technique may occur in the late stage of the operation.

Risk factors for elbow joint stiffness include advanced age, more severe soft tissue or bone injury, delayed surgery, and prolonged immobilization following surgery (over 14 days)[41]. All patients underwent necessary rehabilitation exercises in the early postoperative period. Therefore, only one patient (6.7%) in the L-M group developed joint stiffness due to poor compliance, and the range of motion of the elbow was eventually restored after elbow adhesiolysis and active remedial rehabilitation. Superficial infections can be difficult to distinguish from mild wound hematoma or erythema and usually subside with oral antibiotics[41]. They occur in about 20% of patients after ORIF of the distal humerus, commonly after olecranon osteotomy with plate fixation[42, 43]. In the present study, one patient in each of the P-A and L-M groups (7.7% and 6.7%, respectively) had abnormal postoperative wounds that healed after a dressing change and anti-infection treatment.

The present study had several limitations. First, since this was a retrospective study, patient data could not be controlled and the choice of patients was not randomized, creating an unavoidable bias. Second, the present study involved three subtypes (OTA/AO C1, C2, and C3) of distal humeral fractures. Due to the limited sample size, it was not possible to evaluate the clinical efficacy of the two surgical approaches in different subtypes. Third, although the present study emphasized the advantages of the combined anterior and posterior approach in terms of articular surface exposure, no further anatomical study was

conducted to determine the exposure range of the specific articular surface. Finally, the clinical efficacy of a combined P-A approach compared to a single posterior approach was not evaluated because a single olecranon osteotomy approach for the treatment of distal humeral fractures was not utilized in this study.

Conclusion

Taken together, the anteroposterior approach is a successful method of treatment for intra-articular distal humeral fractures that achieves similar outcomes for the elbow motion, bleeding volume during surgery, surgery duration, and complications, compared with the L-M approach at one year follow-up. The combined posterior olecranon osteotomy and anterior approach theoretically provides a better exposure of the posterior and anterior distal humeral articular surface and avoids the incision on the LUCL. This method can be recommended for severely comminuted intra-articular fracture.

Abbreviations

ORIF Open reduction and internal fixation

ROM Range of motion

HT Humerotrochlear

VAS Visual Analogue Scale

MEPS Mayo Elbow Performance Score

OTA Orthopaedic Trauma Association

HO Heterotopic ossification

ECRB Extensor carpi radialis brevis

LUCL Lateral ulnar collateral ligament

P-A Posterior-anterior

L-M Lateral-medial

K Kirschner

Declarations

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Authors' contributions

HX designed the study. YC and FX selected the appropriate patients and included them in this study. YC, FX, GZ, ZW, JL, JT, GW, XW, and HX collected the data and performed the statistical analysis. YC and JC drafted the manuscript. HX critically revised the manuscript. The author(s) read and approved the final manuscript.

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate Approval was granted by the Institutional Review Board of Nanjing Qixia District Hospital.

Consent for publication

The subjects signed informed consent regarding publishing their data and photographs.

Competing interests

The authors declare that they have no competing interests.

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Figures

Figure 1

Fixation of intra-articular distal humeral fracture (C3) through a combined posterior and anterior approach. (A) Body surface location of the olecranon and posterior incision were marked; (B) The ulnar nerve was identified and isolated first, and then the distal humeral articular surface was exposed after olecranon osteotomy; (C) Next, the anterior approach was used as an auxiliary approach to expose the articular surface via interval between biceps brachii and brachialis muscle and assist in reduction and fixation; (D) Two plates and some screws were used to fix the medial and lateral columns.

Figure 2

Representative case of a 64-year-old female who suffered from a closed C3 fracture of the distal humerus. (A) Preoperative X-ray film; (B) Computed tomography (CT) demonstrated that the fracture involved the articular surface; (C) X-ray film three days post-surgery showed that the distal humeral fracture was restored with bi-columnar fixation through a combined posterior olecranon osteotomy and anterior approach; (D) X-ray film after removal of internal fixation 12 months post-surgery; (E) Flexion-extension of elbow and pronation-supination of forearms 12