Comparison of Efficacy Between the Bilateral Triceps-Sparing and Olecranon Osteotomy Approaches With Double-Plate Internal Fixation for AO Type C3 Distal Humeral Fractures

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AIM: This study aims to compare the efficacy of the bilateral triceps approach (BTA) versus the olecranon osteotomy approach (OOA) with orthogonal double plating in managing Arbeitsgemeinschaft für Osteosynthesefragen (AO) Foundation type C3 distal humeral fractures, providing evidence for selecting optimal surgical approaches and fixation methods.

METHODS: This retrospective analysis included 31 patients with AO type C3 distal humeral fractures treated at the Department of Orthopaedic Trauma, Orthopaedic Center, the First Hospital of Jilin University between June 2018 and May 2024. All patients underwent open reduction and internal fixation with orthogonal double plates placed dorsally on the radial column and medially on the ulnar column. Based on surgical approach, patients were divided into the BTA group (n = 16) and OOA group (n = 15). The parameters evaluated during this study included injury-to-surgery interval, operative time, intraoperative blood loss, postoperative complications (iatrogenic nerve injury, wound infection, elbow stiffness), and Mayo Elbow Performance Score (MEPS) at 6 and 12 months postoperatively.

RESULTS: All patients achieved bony union and their fractures healed with complete follow-up. No statistically significant differences were observed in gender, age, or injury-to-surgery interval between groups ($p > 0.05$). Operative time was significantly shorter in the BTA group compared to the OOA group ($p < 0.05$). Similarly, there were no significant differences between the groups regarding intraoperative blood loss, postoperative complication rates, or excellent/good rates of MEPS at 6 or 12 months (all $p > 0.05$).

CONCLUSIONS: For AO type C3 distal humeral fractures without metaphyseal defects, orthogonal double plating provides rigid fixation enabling early postoperative mobilization. For fractures with intact trochlear articular surfaces (no coronal/horizontal split) where fragments can be directly fixed by distal screws from the plates, the bilateral triceps approach may be prioritized. For severely comminuted trochlear fractures with articular fragmentation (coronal/horizontal split) requiring separate fixation of split fragments with headless compression screws, the olecranon osteotomy approach may provide better exposure.

Keywords: distal humeral fracture; triceps brachii; olecranon osteotomy; surgical approach; double-plate internal fixation; efficacy comparison

Introduction

Distal humeral fractures are relatively uncommon in adults, accounting for approximately 2% of all fractures [1]. Among these, Arbeitsgemeinschaft für Osteosynthesefragen (AO) Foundation type C3 fractures are even rarer, representing 7.8% of distal humeral fractures [2]. This pattern involves complete intra-articular comminution, and inappropriate management can lead to elbow stiffness and post-traumatic arthritis, significantly compromising elbow function and patient quality of life [3].

Open reduction and internal fixation (ORIF) is a standard approach for managing AO type C3 distal humeral fractures. The fundamental principles of treatment include anatomical fracture reduction, stable internal fixation, and early postoperative elbow mobilization [4]. However, the complex anatomy of the distal humeral articular surface, its articulation with the proximal radius and ulna, and the proximity of critical neurovascular structures make adequate surgical exposure and anatomical reduction technically challenging [1].

The primary surgical approaches for managing these fractures are broadly categorized into two approaches: extensor mechanism-preserving strategies (such as the bilateral triceps approach) and techniques that disrupt the extensor mechanism (such as olecranon osteotomy). These approaches differ substantially in technical aspects and clinical outcomes, and selecting the optimal strategy remains an active area of investigation [5].

This study comparatively evaluates the clinical efficacy of the bilateral triceps approach versus the olecranon osteotomy technique for the treatment of AO type C3 distal humeral fractures. Each approach involved dual plating fix-

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ation, where plates are placed vertically on the posterolateral surface of the radial column and the medial surface of the ulnar column. The study further assesses the rationale behind the choice of selected fixation construct and surgical exposure. By assessing intraoperative indices, postoperative complications, and functional recovery between the two groups, the study aims to guide the selection of the surgical approach for ORIF with dual plates in managing AO type C3 distal humeral fractures.

Methods

General Data

This retrospective analysis enrolled 31 patients with AO type C3 distal humeral fractures who received ORIF with vertically oriented double plates at the First Hospital of Jilin University between June 2018 and May 2024. The surgical approach was selected based on intraoperative fracture morphology, particularly the degree of trochlear comminution, and the surgeon's clinical judgment. Patients were allocated into two groups: the bilateral triceps approach group (n = 16) and the olecranon osteotomy approach group (n = 15). The bilateral triceps group comprised 11 males and 5 females, with ages ranging from 23–78 years (47.13 $\pm$ 16.87) and an injury-to-surgery interval of 1–18 days (5.38 $\pm$ 4.62). However, the olecranon osteotomy group included 10 males and 5 females, with ages ranging from 28–73 years (48.40 $\pm$ 13.07) and an injury-to-surgery interval from 1–16 days (7.07 $\pm$ 4.69).

Inclusion and Exclusion Criteria

Inclusion criteria for patient selection were as follows: ① age $\geq$18 years; ② diagnosed with AO type C3 distal humeral fracture [6]; ③ injury-to-surgery interval of $\leq$3 weeks; ④ no history of surgical contraindications; ⑤ good general health to tolerate surgery; and ⑥ normal pre-injury elbow function.

However, patients were excluded if they had ① a pathological fracture, ② an old fracture, ③ severe dysfunction of vital organs, ④ a previous surgical history involving the affected elbow, ⑤ a known psychiatric disorder, or ⑥ incomplete follow-up data.

Surgical Procedures

Patients presenting with open fractures underwent emergency debridement, wound suturing, and dressing on the day of admission. Preoperative evaluations included personalized laboratory testing and essential imaging, including anteroposterior and lateral elbow radiographs and a computed tomography (CT) plain scan with three-dimensional reconstruction, to determine fracture morphology and location, guide surgical approach selection, and formulate an individualized surgery plan. Under General anesthesia, patients were positioned in the lateral decubitus posture with the affected side uppermost, and intravenous antibiotics and hemostatic agents were administered 30 minutes before skin incision.

During the bilateral triceps approach, a posterior midline incision of approximately 15–20 cm was made, with a gentle radial curve over the olecranon. The skin and subcutaneous layers were opened, and medial and lateral flaps were raised to expose both epicondyles. The ulnar nerve was identified in the cubital tunnel, carefully mobilized, and protected. The distal humerus was accessed through the medial and lateral intervals of the triceps. The articular fragments of the distal humerus were reduced under direct vision and temporarily fixed with K-wires, converting the type C fracture to a supracondylar type A structure. The supracondylar segment was then reduced and fixed with crossed K-wires. Definitive fixation was conducted with dual plates applied to the medial and lateral columns under C-arm fluoroscopic guidance. After confirming fracture reduction and implant position, hemostasis was achieved, a single drain was placed, and the wound was closed in layers.

During the olecranon osteotomy approach, a posterior midline incision was utilized. The ulnar nerve was exposed, mobilized, and protected. A chevron (V-shaped) osteotomy of the olecranon was performed to enhance visualization of the distal humeral articular surface. The intercondylar fracture was addressed first, followed by reduction of the supracondylar segment. After fracture reduction, articular reconstruction was performed, and then plates were applied to the medial and lateral aspects of the humerus. Screw holes were drilled, depths measured, and screws inserted sequentially. The olecranon osteotomy site was fixed with tension-band wiring and intramedullary K-wires. C-arm fluoroscopy confirmed satisfactory reduction and implant position. A single drain was placed, and the wound was closed in layers.

Postoperative Management

For patients with open injuries, antibiotics were initiated on admission and continued for 72 hours postoperatively. For those with closed injuries, antibiotics were administered 30 minutes preoperatively and continued for 72 hours postoperatively. The drainage tube was removed after 48 hours. No plaster support was applied; the affected limb was supported in a forearm sling or bandage. After drain removal, patients were instructed to begin gentle passive flexion-extension and rotation exercises, avoiding excessive intensity or frequency in the early stage. After postoperative week 4, radiographs were obtained; based on the fracture status and healing, patients were encouraged to initiate active functional exercises. Weight-bearing was prohibited until evident signs of fracture healing. A second radiographic evaluation was performed 8 weeks after the procedure. Once bone union was confirmed, patients progressed to resisted elbow exercises to gradually restore muscle strength.

Outcome Measures

Elbow function was evaluated using the Mayo Elbow Performance Score (MEPS) at 6 and 12 months postoperatively [7]. MEPS involves four domains: pain (45 points), range of motion (20 points), stability (10 points), and daily function (25 points), with a total of 100 points. Outcomes were graded as excellent ($\geq$90 points), good (75–89 points), fair (60–74 points), or poor ($<$60 points). For both groups, recorded parameters included the injury-to-surgery interval, operative time, intraoperative blood loss, fracture-healing status of the distal humerus (and the olecranon osteotomy site where applicable), and postoperative complications such as iatrogenic nerve injury, surgical site infection, and elbow stiffness.

Statistical Analysis

Statistical analyses were performed using IBM SPSS (version 22.0; IBM Corp.). The two experimental groups were compared regarding gender, age, injury-to-surgery interval, operative time, intraoperative blood loss, postoperative complications, and elbow function at the 6-month and 12-month follow-ups. Normality of continuous variables was assessed using the Shapiro-Wilk test. Age and operative time followed a normal distribution in both groups and were presented as mean $\pm$ standard deviation ($\bar{x} \pm s$), with between-group comparisons performed using an independent samples *t*-test. The injury-to-surgery interval and intraoperative blood loss were severely deviated from a normal distribution in both groups; these variables were expressed as median (interquartile range) [M (P_{25}, P_{75})] and analyzed using the Mann-Whitney U test.

When the theoretical frequency (T) was between 1 and 5 with a total sample size (n) $\geq$30, the Chi-square test with Yates' Correction was adopted. This corrected Chi-square test was used for differences in gender, postoperative complications, and the percentage of patients with excellent/good or fair/poor MEPS outcomes at the 6-month postoperatively. For the 12-month excellent/good MEPS rate, Fisher's Exact Test was used since the theoretical frequency (T) $<$1 (which does not meet the assumptions of the Chi-square test with Yates' Correction). A *p*-value of $<$0.05 was considered statistically significant.

Results

Based on surgical approach, study participants were divided into a bilateral triceps approach group (n = 16) and an olecranon osteotomy approach group (n = 15). Observed variables in both cohorts, including baseline characteristics, operative metrics, postoperative complications, and elbow functional scores, are summarized in Table 1. A detailed analysis of each metric is presented below.

Comparison of Preoperative Baseline Characteristics Between the Two Groups

No statistically significant between-group differences were observed in gender distribution (Chi-square test with Yates' Correction, χ^2 = 0.068, p = 0.795) or age (t = 0.234, p = 0.817). The injury-to-surgery interval was 4.5 (2, 6.8) days in the bilateral triceps approach group and 7 (3, 9) days in the olecranon osteotomy approach group (n = 15), exhibiting no significant difference (Z = –1.411, p = 0.158). These findings indicate that the baseline characteristics were comparable across the two groups.

Comparison of Operative Time Between the Two Groups

The mean operative time was 178.38 $\pm$ 37.10 minutes in the bilateral triceps approach group and 217.87 $\pm$ 59.41 minutes in the olecranon osteotomy approach group. Operative time was significantly longer in the olecranon osteotomy approach group than in the bilateral triceps approach group (t = 2.236, p = 0.033 $<$ 0.05).

Comparison of Intraoperative Blood Loss Between the Two Groups

The average intraoperative blood loss was 200 [50, 300] mL in the bilateral triceps approach group and 150 [100, 300] mL in the olecranon osteotomy approach group. Because the intraoperative blood loss showed a significant non-normal distribution in both groups, the Mann-Whitney U test was applied. Median (IQR) intraoperative blood loss did not differ significantly between the two groups: 200 [50, 300] mL for the bilateral triceps groups versus 150 [100, 300] mL for the olecranon osteotomy approach group (Z = –0.060, p = 0.952). The absence of statistical significance does not suggest clinical equivalence; potential differences may not be detected due to the small sample size, and clinical decision-making should be guided by clinical context.

Comparison of Postoperative Complications Between the Two Groups

Fracture achieved union in all patients, and all olecranon osteotomy sites healed. In the bilateral triceps approach group, iatrogenic nerve injury was reported in three cases; all of which resolved with neurotrophic supportive management. Moreover, two cases developed elbow stiffness in this cohort.

In the olecranon osteotomy approach group, one case of elbow stiffness was observed. The overall postoperative complication rate was 31.25% in the bilateral triceps approach group versus 6.67% in the olecranon osteotomy approach group. Although the overall postoperative complication rate was higher in the former group, this difference was not statistically significant (Chi-square test with Yates' Correction, χ^2 = 1.629, p = 0.202). Absence of a statistically significant difference does not imply clinical equivalence.

Table 1. Comparison of observed metrics between the two groups of patients with AO type C3 distal humeral fractures.

Indicator	BTA group (16 cases)	OOA group (15 cases)	Statistical value	*p*-value
Gender (cases, male/female)	11/5	10/5	Chi-square test with Yates' Correction = 0.068	0.795
Age (years)	47.13 ± 16.87 (23–78)	48.40 ± 13.07 (28–73)	$t = 0.234$	0.817
Time from injury to surgery (days)	4.50 (2.00, 6.80) (1–18)	7.00 (3.00, 9.00) (1–16)	Z = –1.411	0.158
Operation time (minutes)	178.38 ± 37.10	217.87 ± 59.41	$t = 2.236$	0.033
Intraoperative blood loss (mL)	200.00 (50.00, 300.00) (50–700)	150.00 (100.00, 300.00) (50–700)	Z = –0.060	0.952
Postoperative complications (cases, incidence rate)	5 cases (31.25%) (3 cases of iatrogenic nerve injury, 2 cases of elbow stiffness)	1 case (6.67%) (1 case of elbow stiffness)	Chi-square test with Yates' Correction = 1.629	0.202
Excellent/good rate of Mayo Score at 6 months postoperatively	13 cases (81.25%) (11 excellent, 2 good, 2 fair, 1 poor)	14 cases (93.33%) (13 excellent, 1 good, 1 fair)	Chi-square test with Yates' Correction = 0.218	0.638
Excellent/good rate of Mayo Score at 12 months postoperatively	14 cases (87.50%) (11 excellent, 3 good, 1 fair, 1 poor)	15 cases (100.00%) (13 excellent, 2 good)	Fisher's Exact Test	1.000

Notes: age and operation time are expressed as "mean ± standard deviation (range)", and were compared using the independent samples *t*-test. The injury-to-surgery interval and intraoperative blood loss are expressed as "median (interquartile range) (range)", and were compared using the Mann-Whitney U test. Gender, postoperative complications, and excellent/good rate of Mayo Score at 6 months postoperatively are expressed as "cases (percentage)", and were compared using the Chi-square test with Yates' Correction. For the 12-month MEPS excellent/good rate, expressed as "cases (percentage)", the Fisher's Exact Test was used because the theoretical frequency was less than 5, which does not meet the assumptions for the Chi-square test with Yates' Correction. A p-value < 0.05 was considered statistically significant. AO type C3, Arbeitsgemeinschaft für Osteosynthesefragen (AO) Foundation type C3; MEPS, Mayo Elbow Performance Score; OOA, olecranon osteotomy approach; BTA, bilateral triceps approach.

Elbow Function at 6- and 12-Month Follow-up in the Two Groups

At the 6-month follow-up, MEPS rating in the bilateral triceps approach group was as follows: excellent in 11 cases, good in 2, fair in 2, and poor in 1. In the olecranon osteotomy approach group, 13 cases were rated excellent, 1 good, and 1 fair. The excellent-to-good rate was 93.33% for the olecranon osteotomy approach group versus 81.25% for the bilateral triceps approach group; however, the difference did not achieve statistical significance (Chi-square test with Yates' Correction, $\chi^2 = 0.218$, $p = 0.638$).

At 12-month postoperatively, MEPS rating in the bilateral triceps approach group excellent in 11 cases, good in 3, fair in 1, and poor in 1. In the olecranon osteotomy approach group, 13 cases were graded as excellent and 2 as good. The excellent-to-good rate was 100.00% for the olecranon osteotomy approach group and 87.50% for the bilateral triceps approach group; however, the difference did not reach statistical significance (Fisher's Exact Test, $p = 1.000$).

The absence of statistical significance does not indicate identical clinical outcomes between the two groups.

Representative Cases

A Case of AO Type C3 Distal Humeral Fracture Treated With Vertical Double-Plate Internal Fixation via the Bilateral Triceps-Sparing Approach

A 78-year-old woman presented with swelling, pain, deformity, and limited mobility of the right elbow. Preoperative radiographs and CT imaging revealed a comminuted intra-articular fracture of the distal humerus, with a relatively intact articular surface of the trochlear fragment (Fig. 1A–D). She received open reduction and internal fixation with vertically oriented dual plates via the bilateral triceps approach. Postoperative imaging demonstrated satisfactory fracture reduction and optimal implant positioning without loosening or displacement (Fig. 1E,F).

A Case of AO Type C3 Distal Humeral Fracture Treated With Vertical Double-Plate Internal Fixation via the Olecranon Osteotomy Approach

A 73-year-old woman presented with swelling, pain, deformity, and limited mobility in the left elbow. Preoperative radiographic and CT imaging confirmed a comminuted intra-articular fracture of the distal humerus with partial loss of the trochlear articular surface (Fig. 2A–D). Internal fixation was performed through an olecranon osteotomy approach using dual plates in a vertical configuration. Postoperative evaluation showed excellent fracture reduction, an anatomically aligned olecranon osteotomy, and appropriate implant positioning with no evidence of loosening or migration (Fig. 2E,F).

Discussion

AO type C3 distal humeral fractures represent complex intra-articular injuries, resulting from high-energy trauma. The mechanism is closely related to elbow flexion: such fractures occur more often when the elbow is highly flexed (>110°), whereas less flexion (≤90°) more commonly causes fractures of the olecranon, radial head, or coronoid process [1]. Before the 1960s, these injuries were primarily treated non-surgically; with the widespread adoption of AO principles, open reduction and internal fixation became the gold standard of care. The primary goals of treatment are to restore articular anatomy, achieve biomechanically stable fixation, and facilitate early functional rehabilitation [8,9]. With advancements in internal fixation techniques, K-wires, single plates, and Y-shaped plates have gradually been abandoned due to inadequate mechanical strength [10,11].

A dual plating approach, tailored to the humeral anatomy, is now the preferred strategy owing to its significant biomechanical advantages, such as suppression of micromotion at the fracture site, reduction of the risk of fixation failure, and improvement in bone healing [12,13]. Despite consensus the use of dual-plate fixation, the optimal spatial configuration (orthogonal versus parallel plating) remains controversial [14]. Orthogonal construct (90° configuration) demonstrates greater stability under anteroposterior bending and torsion [15], whereas parallel plating performs better in complex models with metaphyseal defects [16]. In this study, none of the 31 AO type C3 distal humeral fractures had metaphyseal bone defects; therefore, an orthogonal dual-plating technique was consistently used in all cases. This approach provided rigid fixation and enabled early postoperative elbow mobilization.

The primary challenge in AO type C3 distal humeral fractures is achieving adequate visualization of intra-articular fragments to facilitate anatomic reduction, making the selection of the surgical approach crucial. The bilateral triceps approach, introduced by Schildhauer *et al.* [17] in 2003, preserves triceps tendon integrity, facilitating early rehabilitation and potentially reducing postoperative stiffness. However, its major limitation is the olecranon's obstruction of the surgical field, often requiring extensive retraction of nerves and soft tissues, which may contribute to muscle weakness or neuroparalysis; in comminuted C3 fractures, indirect reduction with limited visualization demands advanced surgical skill [18]. The olecranon osteotomy approach, proposed by Cassebaum in 1952 and now adopted as a chevron osteotomy per AO recommendations [19], offers extensive exposure of the posterior articular surface by removing the olecranon obstruction. A cadaveric study by Wilkinson and Stanley reported articular surface exposure of 35% with the triceps splitting, 46% with the bilateral triceps approach, and 57% with olecranon osteotomy [20]. Although tension-band fixation of the osteotomy enables early mobility, it poses risks of nonunion, fixation failure, and post-traumatic arthritis, especially in osteoporotic bone [21,22]. A meta-analysis by Zhao *et al.* [3] involving 480 patients with the olecranon osteotomy ap-

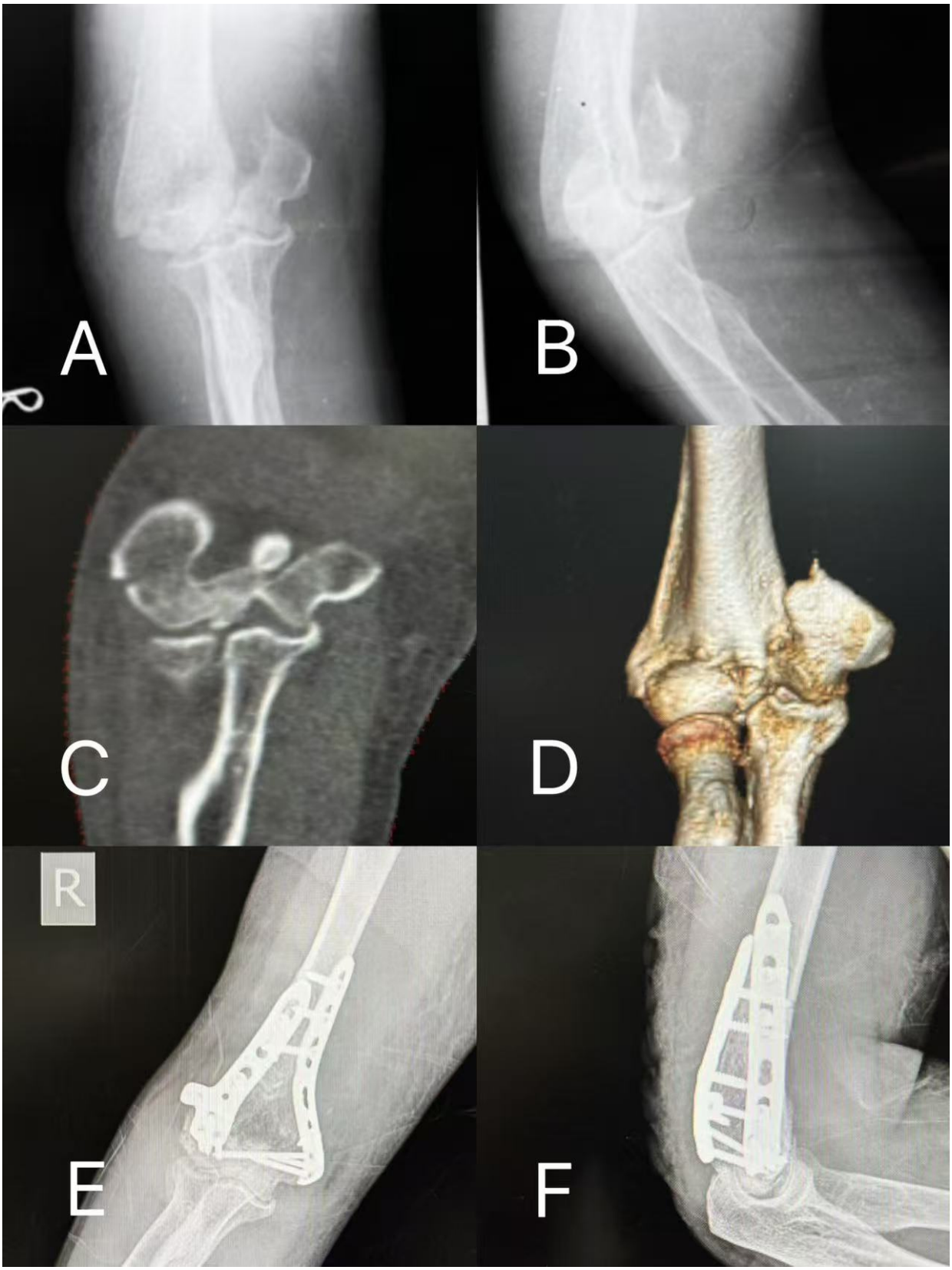

Fig. 1. Preoperative and postoperative imaging of an AO type C3 distal humeral fracture with an intact trochlea treated via the bilateral triceps-sparing approach with vertical double plating. (A,B) Preoperative anteroposterior and lateral X-rays of the right elbow joint. (C,D) Preoperative computed tomography (CT) coronal view and 3D reconstruction images of the right elbow joint. (E,F) Postoperative anteroposterior and lateral X-rays of the right elbow joint.

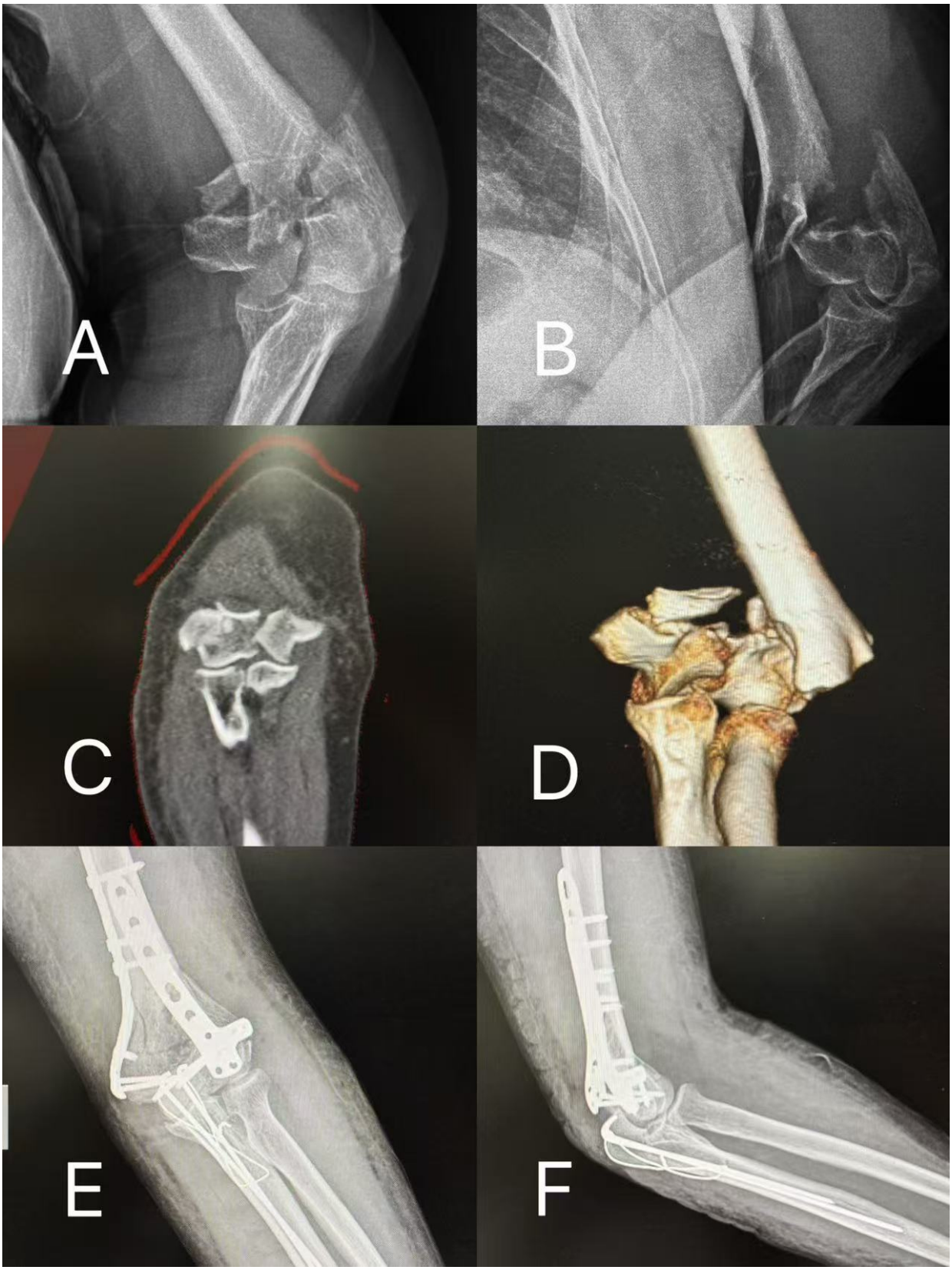

Fig. 2. Preoperative and postoperative imaging of an AO type C3 distal humeral fracture with an incomplete articular surface of the trochlear fragment treated via olecranon osteotomy approach with vertical double-plate internal fixation. (A,B) Preoperative anteroposterior and lateral X-rays of the left elbow joint. (C,D) Preoperative CT coronal view and 3D reconstruction images of the left elbow joint. (E,F) Postoperative anteroposterior and lateral X-rays of the left elbow joint.

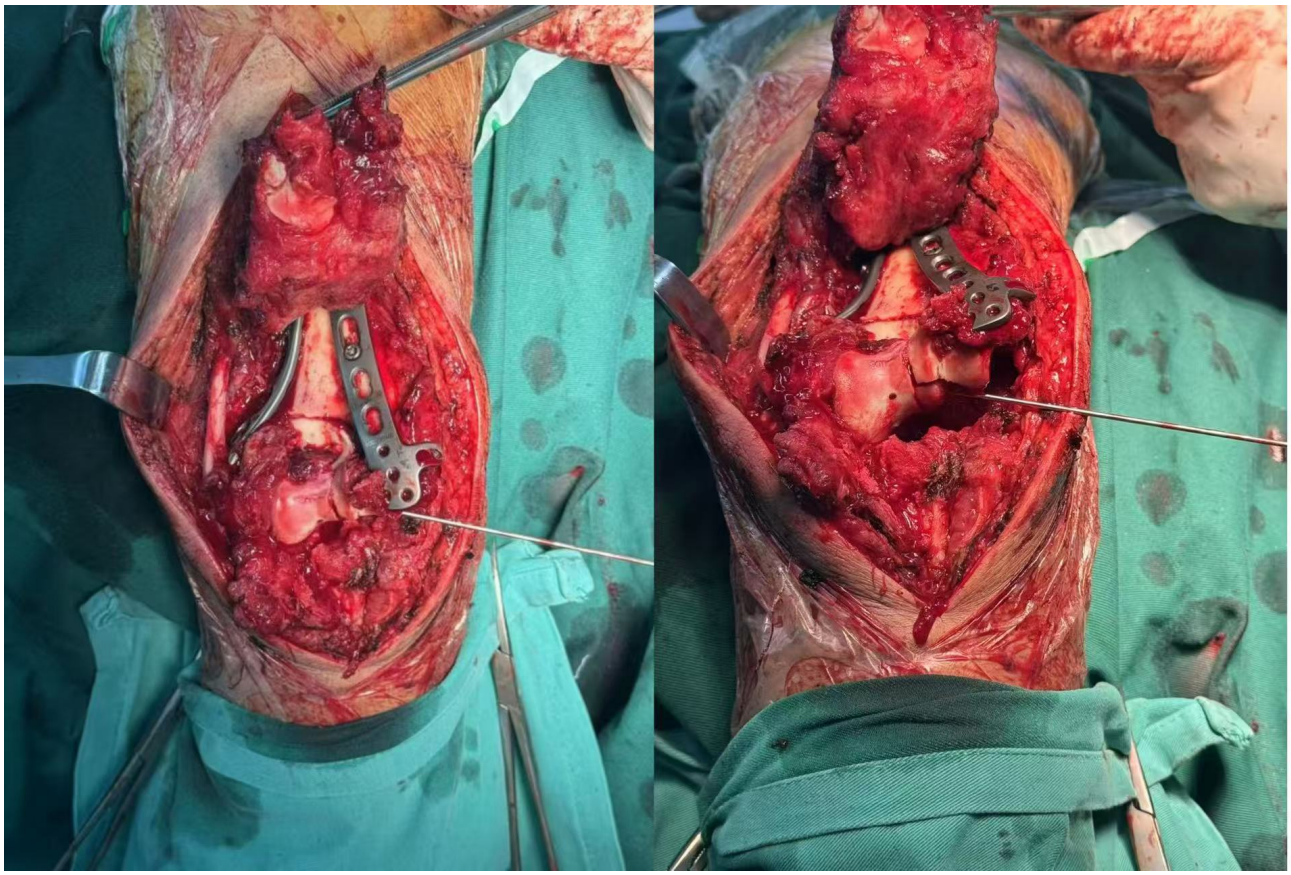

Fig. 3. Intraoperative views of AO type C3 distal humeral fracture with coronal plane trochlear split.

proach and 443 with bilateral triceps approach, reported a longer operative time and greater intraoperative blood loss with the olecranon osteotomy approach but no significant differences in postoperative Mayo Elbow Performance Score, overall complication rates, or time to fracture healing between the two approaches. Similar findings were observed by Zhou *et al*. [23] in a cohort of 65 patients with AO type C3 fractures.

Based on this background, we included 31 patients with AO type C3 distal humeral fractures, categorized by surgical approach to a bilateral triceps group (n = 16) and an olecranon osteotomy group (n = 15). This study systematically compared the technical characteristics and clinical outcomes and conducted a comprehensive comparative analysis of surgical results. Operative time was longer in the olecranon osteotomy, which may be attributed to the additional time required for the osteotomy, fragment reduction, and fixation. Despite this difference, no statistically significant difference in intraoperative blood loss was found between the two groups ($p > 0.05$), which may be related to standardized measures such as routine preoperative intravenous administration of tranexamic acid to reduce bleeding risk associated with both surgical approaches.

In this study, no patients in the olecranon osteotomy approach group reported osteotomy-associated complications such as nonunion or failure of the tension-band construct. This likely indicates a close link between the stable fixation achieved with tension-band wiring and K-wires. Furthermore, postoperative complications developed in 31.25% of the bilateral triceps approach group (3 cases of iatrogenic nerve injury and 2 cases of elbow stiffness) versus 6.67% in the olecranon osteotomy approach group (1 case of elbow stiffness). This difference was not statistically significant, supporting the previous findings. The higher complication rate found with the bilateral triceps approach may be correlated with the limited intraoperative field, which often requires soft-tissue and nerve retraction.

Nevertheless, meticulous surgical techniques can minimize the risk of approach-related complications. At 6 and 12 months postoperatively, the olecranon osteotomy approach group showed a greater excellent-to-good MOES rate than the bilateral triceps approach group; however, the difference was not statistically significant. These results are consistent with previous findings, indicating that both surgical approaches can achieve satisfactory clinical outcomes. Given the small sample and unequal group sizes, which limit statistical power, future studies should include larger cohorts to validate these findings.

Despite its strength, we acknowledge several limitations to this study. First, its retrospective design, small sample size (n = 31), and lack of a priori sample size calculation limited the statistical power and increased the risk of type II

error, potentially masking the actual differences, such as trends in complication rates and long-term functional outcomes. Second, the non-randomized allocation of patients into groups based on surgical approach may introduce selection bias and surgeon preference bias. Although no significant differences were observed in baseline characteristics between groups, residual confounding cannot be excluded.

When selecting the surgical approach for AO type C3 distal humeral fractures, the priority is to achieve adequate exposure and anatomical reduction of the articular surface. The key difference between the bilateral triceps and olecranon osteotomy approaches lie in their capacity to expose the trochlear region. In this study, grouping by actual surgical approach revealed that all patients in the bilateral triceps group (n = 16) had segmental trochlear fractures with intact articular structures (no coronal or transverse splits). In the olecranon osteotomy approach group (n = 15), 13 patients had comminuted and split segmental trochlear fractures, whereas 2 patients had intact articular surface and still underwent osteotomy. Importantly, compared with the bilateral triceps approach group, this selection did not yield significant clinical benefits and instead added osteotomy-associated risks, including iatrogenic injury and related complications. Therefore, we do not consider this approach the first choice when the trochlear articular surface is intact.

Based on the grouping characteristics and the fundamental role of trochlear comminution in determining exposure requirements, the following approach-selection strategy is proposed: ① In AO type C3 distal humeral fractures where segmental trochlear fragments retain an intact articular surface (without coronal/horizontal plane splits) and can be fixed directly with distal screws from dual plates, both the bilateral triceps approach and the olecranon osteotomy approach can achieve anatomical reduction and stable fixation. Earlier findings reveal no significant differences in postoperative complication rates or long-term clinical outcomes between these two approaches. However, the bilateral triceps approach enhances surgical efficiency by minimizing osteotomy-associated risks and significantly reducing operative time. Consequently, the bilateral triceps-sparing approach may be prioritized in this scenario. ② For severely comminuted trochlear fractures with incomplete articular structure, with presence of coronal or horizontal plane splits (Fig. 3), requiring separate countersunk screw fixation, the bilateral triceps approach, despite providing sufficient exposure of the radial and ulnar columns, offers limited visualization of coronal plane fragments because the olecranon obstructs the critical trochlear groove and central ridge [24]. In such fractures, an olecranon osteotomy is a reasonable option. Reflecting the olecranon offers up to a 270° direct view of the articular surface [20], avoiding obstruction at the central trochlear groove and enabling anatomical reduction under direct visualization.

Conclusions

In summary, for AO type C3 distal humeral fractures without metaphyseal bone defects, vertical double-plate fixation provides rigid stabilization and favorable clinical outcomes. The findings reveal that selected AO type C3 fractures can also be managed through a bilateral triceps approach, achieving anatomic reduction and stable dual-plate fixation while avoiding the additional trauma and potential complications of olecranon osteotomy. Therefore, surgical approaches should be individualized based on the condition of the articular surface. When the articular surface of the segmental trochlear fragments is intact (without coronal or horizontal splits) and can be fixed directly with distal screws from the dual plates, the bilateral triceps approach is a reasonable first choice. When the articular surface is incomplete, with coronal or horizontal splits requiring separate countersunk screws fixation, the olecranon osteotomy approach should be prioritized.

These observations support individualized surgical strategies for AO type C3 distal humeral fractures. However, in clinical practice, surgeons should integrate morphological characteristics with operative expertise to select the most appropriate exposure, aiming to minimize surgical trauma, reduce postoperative complications, and promote functional recovery.

Availability of Data and Materials

The data analyzed are available from the corresponding authors upon reasonable request.

Author Contributions

YL: conceptualization, data curation, formal analysis, investigation, methodology, writing-original draft, and writing-review and editing. DS and GY: conceptualization, methodology, writing-review and editing. All authors have been involved in revising it critically for important intellectual content. All authors gave final approval of the version to be published. All authors have participated sufficiently in the work to take public responsibility for appropriate portions of the content and agreed to be accountable for all aspects of the work in ensuring that questions related to its accuracy or integrity.

Ethics Approval and Consent to Participate

The study was conducted in strict accordance with the guidelines of the Declaration of Helsinki and was reviewed and approved by the Institutional Review Board of the First Hospital of Jilin University (Approval No. 2025-359; Date of approval: 8 July 2025). Written informed consent has been obtained from the patients who participated in this study.

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Conflict of Interest

The authors declare no conflict of interest.

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