

Morphology-Guided Approach Selection for AO/OTA 13-C3 Distal Humeral Fractures: A Comparative Study of the Flip-Triceps Dislocation Approach versus Olecranon Osteotomy

Chengpu Zhong

Nanjing Medical University

Haoyue Qin

Nanjing Medical University

Yonghui Zhao

Nanjing Medical University

Dawei Cai

Nanjing Medical University

Tangbo Yuan

yuantangbo@njmu.edu.cn

Nanjing Medical University

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Abstract

Background

The optimal surgical approach for AO/OTA 13-C3 distal humeral fractures remains debated. This study compared the flip-triceps dislocation (FTD) approach with the olecranon osteotomy (OO) approach and evaluated whether fracture morphology (PAD-type vs. non-PAD-type) influences the outcomes of each approach.

Methods

Thirty-seven patients with AO/OTA 13-C3 distal humeral fractures were retrospectively reviewed, including 18 treated with OO and 19 with FTD. Fractures were classified as PAD-type (n = 20) or non-PAD-type (n = 17) based on preoperative three-dimensional CT. Operative time, intraoperative blood loss, flexion-extension arc, extension deficit, MEPS, DASH score, and elbow stiffness were compared between groups and subgroups.

Results

The FTD group had significantly shorter operative time and lower blood loss than the OO group ($P < 0.001$). At final follow-up, overall flexion–extension arc, extension deficit, MEPS, and DASH scores were comparable between groups. In PAD-type fractures, the FTD group achieved significantly lower extension deficit than the OO group ($4.8 \pm 3.2^\circ$ vs. $10.2 \pm 5.4^\circ$, $P = 0.018$), whereas no difference was observed in non-PAD-type fractures.

Conclusion

The FTD approach reduces surgical trauma compared with OO while achieving comparable overall functional outcomes. In PAD-type fractures, FTD was associated with superior terminal extension, suggesting that fracture morphology may inform surgical approach selection.

Level of evidence

III, retrospective study.

Introduction

Distal humerus fractures comprise only around 1% to 2% of all fractures and have an estimated annual incidence rate of 5.7 per 100,000 people; however, their prevalence is increasing steadily owing to

population aging^[1, 2]. As per the AO/OTA classification system, 13-C type fractures are those which have completely disrupted the articular region and the column of the distal humerus bone and, therefore, pose a considerable challenge in terms of therapy^[3]. Type 13-C3 fractures are characterized by complete articular comminution with multiple displaced fragments, rendering this subtype the most unpredictable in terms of prognosis. Doornberg et al^[4] reported long-term outcomes of patients with intra-articular distal humeral fractures treated with open reduction and internal fixation (ORIF) at a follow-up ranging from 12 to 30 years. Despite satisfactory functional outcomes being observed, the incidence rates of elbow joint stiffness, chronic pain, and heterotopic ossification were significantly high in type C3 compared with type C1 and C2 fractures.

In terms of treatment for reconstructable AO/OTA type 13-C fractures, ORIF continues to be the standard approach, with aims at attaining accurate anatomical reconstruction of the articular surface, restoring bicomminar stability, and providing bony support to allow early functional movement after surgery^[5, 6]. Although developments in fixation technique have greatly enhanced construct stability, it should be emphasized that these advancements cannot compensate for good articulation access. Indeed, in C3 type fractures, the level of reduction of the articular surface is crucial for post-surgical outcomes, while the selection of approach plays a vital role in visualization of the articular surface^[5, 6].

The olecranon osteotomy (OO) approach provides the most extensive direct visualization of the distal humeral articular surface among posterior surgical exposures. As a result, the OO approach has long been viewed as one of the major exposure techniques for complicated distal humeral fractures^[7]. Nevertheless, the increased costs associated with the surgery itself have continued to remain a significant disadvantage in clinical practice with regard to this procedure. Osteotomy-related risks consist mainly of either delayed or non-unions at the osteotomy site, irritation caused by implants used for internal stabilization, such as tension band wiring or screws, persistent pain within the olecranon area, and eventually the requirement of a further surgery to remove the implants^[8]. In addition, Wilkinson and Stanley proved, via their comparative anatomic studies on posterior surgical approaches, that osteotomy adds structural injury to the extensor mechanism and is therefore a limiting factor in restoring elbow extension after surgery^[9].

Based upon the core principle of preservation of the extensor mechanism, various types of triceps-sparing surgery have been gradually evolved for treating distal humeral fractures in adults. Bilateral tricipital approach, initially reported by Alonso-Llames in 1972, is a technique whereby two independent surgical portals are made along the medial and lateral aspect of the triceps for performing reduction without compromising triceps tendon, thus marking the anatomical basis of all non-osteotomy approaches^[10]. The extensor mechanism-sparing paratricipital posterior approach, proposed by Schildhauer et al.^[11], has gained popularity since 2003 in selective cases of complex distal humerus fractures with the ability of providing outcomes similar to those achieved via olecranon osteotomy without encountering complications associated with osteotomy. Modified variants of these techniques such as expanded paratricipital approach and flip-dislocation of the bicomminar approach have also

been devised. Flip-dislocation of bicolumnar approach enables obtaining an intra-articular exposure with bilateral triceps portals without undergoing olecranon osteotomy by utilizing the principle of natural dislocation of bony segments. Recently in 2023, a comparative evaluation of AO/OTA type 13-C3 fractures proved that bicolumnar technique provides equal clinical outcomes to the traditional olecranon osteotomy while reducing operative duration and intraoperative blood loss considerably^[12].

Nevertheless, existing comparative studies harbor important limitations. First, the majority of controlled trials and systematic reviews have pooled AO/OTA C1, C2, and C3 subtypes indiscriminately, precluding definitive approach recommendations specifically for the most complex C3 subtype^[6, 8, 12, 13]. Second, type C3 fractures are not morphologically homogeneous—some cases are characterized by a large posterior coronal articular fragment, a tendency toward posterior ulnohumeral dislocation, and posterior column-dominant fragmentation (defined in the present study as the posterior articular dominant, or PAD, pattern), whose natural displacement of fracture fragments aligns closely with the operative logic of the flip-dislocation approach; whereas other cases, typified by symmetric bicolumnar comminution or central trochlear collapse, impose distinct exposure requirements. Such individualized approach-matching strategies based on fracture morphology have not been systematically elaborated in the literature. Against this background, the present retrospective study enrolled adult patients with AO/OTA type 13-C3 distal humeral fractures treated at our institution via chevron olecranon osteotomy (OO group, n = 18) or the flip-triceps dislocation approach (FTD group, n = 19). By introducing a simplified fracture morphology classification based on preoperative three-dimensional CT reconstruction (PAD versus non-PAD pattern), we systematically compared the two approaches with respect to operative efficiency, terminal functional recovery, and associated complications, with the aim of preliminarily exploring whether fracture morphology may provide guidance for individualized approach selection and thereby furnish more precise clinical evidence for surgical decision-making in AO/OTA type 13-C3 distal humeral fractures.

Methods

Inclusion and exclusion criteria

This study retrospectively enrolled patients with distal humeral C3-type fractures who underwent surgical management at the Department of Orthopaedic Surgery of our institution between January 2020 and March 2025. The inclusion criteria were: (1) age ≥ 18 years; (2) definitive diagnosis of AO/OTA type 13-C3 fracture based on plain radiography and three-dimensional CT reconstruction; (3) time from injury to surgery < 14 days; and (4) minimum follow-up of 12 months. The exclusion criteria were: (1) pathologic fracture or Gustilo-Anderson type III open fracture; (2) concomitant ipsilateral upper-extremity fracture or neurovascular injury; (3) history of prior elbow surgery or severe osteoarthritis; and (4) incomplete follow-up data. This retrospective cohort study was approved by the Institutional Review Board of our hospital

Fracture morphology classification

According to the three-dimensional CT reconstruction obtained preoperatively, three types of imaging features were taken into account to classify the morphology of the fractures, which were: (1) a posterior coronal articular fragment of the distal humerus; specifically, an osteochondral fragment of the posterior trochlea or posterior capitellum, relatively large and intact in nature, that had rotated or shifted posterolaterally; (2) a pattern of ulnohumeral dislocation or posterior tilting, characterized by the posterior displacement of the ulna to the distal humerus, global posterior tilt of the articular surface, and posterohingement of the articular surface due to the fractures; and (3) posterior column dominance with posterior trochlear collapse, which meant fractures that showed the posterior column fragment as the main element of the medial and lateral columns, along with rotation or compressive displacement of the posterior trochlear articular surface. Patients with ≥ 2 of the aforementioned 3 radiographic signs were classified as the posterior articular dominant (PAD) pattern, whereas those who did not meet these criteria (characterized primarily by symmetric bicolumnar comminution or central trochlear collapse) were classified as the non-PAD. The morphological classification was made independently by two senior trauma orthopedic surgeons based on preoperative imaging. In cases of disagreement, a third surgeon made the final determination. Kappa analysis demonstrated statistically significant interobserver agreement.

Surgical technique

All surgical procedures were performed by a consistent surgical team (the primary surgeon had 15 years of experience in elbow surgery). The choice of approach was determined by the senior surgeon based on preoperative CT assessment of fracture morphology, patient age, and bone quality. The patient was placed in the prone position with the affected limb positioned on an arm support, and a pneumatic tourniquet was applied to the upper arm.

Olecranon osteotomy approach

A posterior midline longitudinal incision (15–18 cm) was made centered over the distal humerus extending to the olecranon tip, with surgical planes developed along the medial and lateral borders of the triceps and the ulnar nerve identified and protected (anterior transposition or local decompression performed when necessary). A chevron osteotomy was created approximately 2 cm proximal to the olecranon articular surface using an oscillating saw, with the apex directed proximally and the limbs angled at 45° to 60° toward the bare area; the olecranon fragment was then reflected proximally en bloc with the triceps tendon to provide a broad view of the articular surface and bicolumnar architecture. The articular fragments were reduced anatomically under direct visualization and provisionally stabilized with Kirschner wires, followed by sequential bicolumnar fixation with anatomically precontoured locking plates placed in orthogonal planes. After fluoroscopic confirmation of satisfactory reduction and hardware positioning, the olecranon osteotomy was secured with tension band wiring and an

intramedullary Kirschner wire, the extensor mechanism was repaired, and the wound was closed in layers.

Flip-triceps dislocation approach

An identical posterior midline longitudinal incision (14–16 cm) was used. The ulnar nerve was identified, mobilized, and transposed anteriorly when indicated. Independent medial and lateral windows were developed along the respective borders of the triceps tendon without disrupting its olecranon insertion or performing olecranon osteotomy. The medial window was created between the medial head of the triceps and the ulnar nerve to expose the medial epicondyle and medial capsule, whereas the lateral window exposed the capitellum and lateral trochlea after separation along the lateral triceps border. Following bilateral capsulotomy, the articular fragments were mobilized by capitalizing on their natural displacement, using the intact triceps tendon as a hinge-like pivot to accomplish a flip-dislocation maneuver and achieve full intra-articular visualization without osteotomy. The reduction sequence mirrored that of the OO group: anatomic articular reduction with provisional Kirschner wire fixation under direct visualization, followed by orthogonal bicolumnar fixation with anatomically precontoured locking plates. After fluoroscopic confirmation, the joint capsule and triceps fascial layers were reapproximated, and the wound was closed in layers.(Fig. 1)

Postoperative management and outcome evaluation

The postoperative rehabilitation protocol was standardized for both groups. All patients received intravenous prophylactic antibiotics within 24 hours postoperatively. The affected limb was immobilized in a functional splint at 90° of elbow flexion for the first 24 hours. Active-assisted elbow flexion and extension exercises were initiated on postoperative days 2–3 as tolerated, provided that intraoperative stability of the internal fixation had been confirmed. Patients were followed up at 1, 2, 3, 6, and 12 months postoperatively, and thereafter at 6-month intervals. At each follow-up visit, standard anteroposterior and lateral elbow radiographs were obtained, with CT scanning performed when indicated. All radiographic and clinical assessments were conducted independently by three senior orthopaedic trauma surgeons. Examinations included evaluation of elbow pain, swelling, and range of motion, with continuous functional training guidance provided to patients. All complications occurring during the follow-up period were documented, including superficial and deep wound infection, delayed union or nonunion, implant loosening or breakage, transient or permanent ulnar neuropathy, heterotopic ossification, and elbow stiffness.

The primary outcome was operative time and intraoperative blood loss, reflecting perioperative surgical efficiency and soft tissue trauma. Secondary outcomes included functional assessment at final follow-up, comprising the flexion-extension arc of motion, active extension deficit, Mayo Elbow Performance Score (MEPS), and Disabilities of the Arm, Shoulder and Hand (DASH) score. The MEPS is a validated 100-point scoring system evaluating pain, range of motion, stability, and daily function, with scores ≥ 90 classified as excellent, 75–89 as good, 60–74 as fair, and < 60 as poor. The DASH is a validated 30-item

patient-reported outcome measure assessing upper extremity function and symptoms, with lower scores indicating better function. Postoperative elbow stiffness was defined as a flexion-extension arc of less than 100° at final follow-up. All functional assessments were performed by an independent observer not involved in the surgical procedures to minimize assessment bias. Subgroup analyses were conducted according to fracture morphology classification (PAD-type vs. non-PAD-type) to evaluate the differential effect of surgical approach on functional outcomes across fracture subtypes. Typical cases are shown in Figs. 2 and 3.

Statistical analysis

All statistical analyses were performed using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA). Continuous variables were tested for normality using the Shapiro-Wilk test and are presented as mean $\pm$ standard deviation (SD). Categorical variables are expressed as frequencies and percentages. Between-group comparisons of continuous variables were performed using the independent samples t-test for normally distributed data. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate, with Fisher's exact test applied when any expected cell count was less than 5. Subgroup analyses were conducted separately for PAD-type and non-PAD-type fractures using the same statistical methods. All tests were two-tailed, and a P value of less than 0.05 was considered statistically significant.

Results

A total of 37 patients with AO/OTA 13-C3 distal humeral fractures were enrolled, comprising 18 in the olecranon osteotomy (OO) group and 19 in the flip-triceps dislocation approach (FTD) group (Table 1). Baseline characteristics including age, sex, affected side, and time from injury to surgery were comparable between the two groups (all $P > 0.05$), indicating well-matched cohorts. Based on preoperative three-dimensional CT assessment, 20 fractures were classified as PAD type (10 in OO, 10 in FTD) and 17 as non-PAD type (8 in OO, 9 in FTD), with no significant difference in fracture type distribution between groups.

Table 1
All patient demographics, surgical data, and functional outcomes

Age (years)	OO group (n = 18)	FTD group (n = 19)	P
	52.3 ± 15.4	49.8 ± 14.7	0.581
Sex (male/female)	11/7	12/7	0.872
Affected side (right/left)	6/12	9/10	0.508
Time from injury to surgery (days)	3.4 ± 1.8	3.6 ± 2.1	0.728
Operative time (min)	156.4 ± 29.7	124.6 ± 24.8	<0.001
Intraoperative blood loss (mL)	278.3 ± 72.8	192.6 ± 54.2	<0.001
Flexion–extension arc (°)	118.4 ± 14.6	122.8 ± 13.2	0.323
Extension deficit (°)	8.4 ± 5.2	5.6 ± 3.8	0.063
MEPS score	82.6 ± 9.7	85.4 ± 8.5	0.315
DASH score	27.2 ± 11.4	23.5 ± 9.8	0.273
Elbow stiffness	2	1	0.595

Regarding perioperative outcomes, the FTD group demonstrated significantly shorter operative time (124.6 ± 24.8 vs. 156.4 ± 29.7 min, $P < 0.001$) and lower intraoperative blood loss (192.6 ± 54.2 vs. 278.3 ± 72.8 mL, $P < 0.001$) compared with the OO group. These advantages were consistent across both PAD-type and non-PAD-type subgroups.

At final follow-up, overall functional outcomes including flexion-extension arc (122.8 ± 13.2° vs. 118.4 ± 14.6°, $P = 0.323$), MEPS score (85.4 ± 8.5 vs. 82.6 ± 9.7, $P = 0.315$), and DASH score (23.5 ± 9.8 vs. 27.2 ± 11.4, $P = 0.273$) were comparable between the two groups (FTD group vs. OO group). The overall extension deficit showed a trend favoring the FTD group (5.6 ± 3.8° vs. 8.4 ± 5.2°, $P = 0.063$) without reaching statistical significance. Subgroup analysis revealed that in PAD-type fractures, the FTD group achieved a significantly lower extension deficit at final follow-up compared with the OO group (4.8 ± 3.2° vs. 10.2 ± 5.4°, $P = 0.018$) (Table 2), whereas no significant difference was observed in non-PAD-type fractures (6.5 ± 4.3° vs. 6.2 ± 4.5°, $P = 0.889$) (Table 3).

Table 2
Patient demographics, surgical data, and functional outcomes in PAD-type fractures

Age (years)	OO group (n = 10)	FTD group (n = 10)	P
	54.1 ± 14.8	51.2 ± 13.9	0.656
Sex (male/female)	6/4	6/4	1.000
Affected side (right/left)	3/7	5/5	0.361
Time from injury to surgery (days)	3.5 ± 1.7	3.7 ± 2.0	0.812
Operative time (min)	168.2 ± 27.6	127.8 ± 23.4	<0.001
Intraoperative blood loss (mL)	296.5 ± 68.4	196.8 ± 50.6	<0.001
Flexion–extension arc (°)	114.2 ± 15.8	124.8 ± 12.4	0.112
Extension deficit (°)	10.2 ± 5.4	4.8 ± 3.2	0.018
MEPS score	80.4 ± 10.2	87.6 ± 7.8	0.091
DASH score	30.1 ± 12.0	20.8 ± 8.6	0.065
Elbow stiffness	2	0	0.136

Table 3
Patient demographics, surgical data, and functional outcomes in non-PAD-type fractures

Age (years)	OO group (n = 8)	FTD group (n = 9)	P
	50.1 ± 16.3	48.2 ± 15.8	0.812
Sex (male/female)	5/3	6/3	0.855
Affected side (right/left)	3/5	4/5	0.774
Time from injury to surgery (days)	3.3 ± 1.9	3.5 ± 2.2	0.843
Operative time (min)	141.7 ± 24.6	121.0 ± 26.3	0.118
Intraoperative blood loss (mL)	255.5 ± 69.6	187.9 ± 58.5	0.046
Flexion–extension arc (°)	123.7 ± 12.1	120.6 ± 14.4	0.640
Extension deficit (°)	6.2 ± 4.5	6.5 ± 4.3	0.889
MEPS score	85.4 ± 8.6	82.9 ± 8.9	0.566
DASH score	23.6 ± 9.8	26.5 ± 10.4	0.563
Elbow stiffness	0	1	0.336

Complications

In this study, no infection, permanent ulnar neuropathy, internal fixation failure (including screw cut-out, plate breakage, or loosening/displacement), or severe heterotopic ossification requiring surgical intervention occurred in either group. One patient in the olecranon osteotomy (OO) group experienced delayed union at the osteotomy site. The condition was managed conservatively with prolonged protection and serial radiographic follow-up, resulting in eventual radiographic union without revision surgery. No cases of nonunion occurred in either group. One patient in the triceps flipping-dislocation (FTD) group developed transient postoperative ulnar nerve numbness. The sensory symptoms resolved spontaneously within 1 week without additional intervention, and no residual neurological deficits were present at the final follow-up. At the final follow-up, The incidence of postoperative elbow stiffness was 2 patients in the OO group (11.1%) and 1 patient in the FTD group (5.3%), with no statistically significant difference between the groups ($P = 0.595$).

Discussion

AO/OTA type 13-C3 fractures of the distal humerus continue to be one of the main challenges in trauma orthopedic surgery owing to comminuted involvement of articular surfaces, metaphyseal dissociation, and soft-tissue damage. The choice of surgical approach determines the quality of exposure, maintenance of integrity of the extensor mechanism, and functional outcomes after surgery. The olecranon osteotomy (OO) technique has long been regarded as the reference standard for surgical treatment of these fractures, given its provision of a panoramic view of the articular surface that facilitates anatomic reduction of complex articular comminution^[7, 14]. However, the additional surgical steps of osteotomy creation and subsequent fixation, along with the potential for osteotomy-related complications—including symptomatic hardware, nonunion or delayed union, olecranon bursitis, and secondary implant removal procedures—have prompted clinicians to explore extensor mechanism-sparing alternatives^[15, 16]. The flip-triceps dislocation approach (FTD) accesses the joint via the medial and lateral triceps fascial intervals while preserving the triceps insertion, thereby circumventing osteotomy-related morbidity. Nevertheless, the clinical applicability and functional outcomes of the FTD approach across different fracture morphologies remain insufficiently evidenced, and the specific circumstances under which the exposure afforded by FTD is equivalent or superior to that of OO have yet to be definitively established.

In the current research, it has been proven that the FTD technique had a significantly lower operative time and blood loss compared to the OO procedure in both PAD and non-PAD groups. These results align broadly with the findings of previous comparative studies evaluating non-osteotomy versus osteotomy techniques^[12, 13, 17, 18], though direct comparison is limited by heterogeneity in fracture subtype inclusion and outcome definitions. The underlying mechanism is intuitive: the FTD approach eliminates the steps of osteotomy creation and subsequent fixation, reduces the extent of soft-tissue dissection, and thereby minimizes surgical trauma and operative duration. These aspects have additional importance in relation to elderly patients or individuals with coexisting diseases since prolonged surgery and high levels of blood loss can lead to postoperative cardiovascular issues^[19].

No statistically significant differences were observed between the olecranon osteotomy (OO) and triceps flipping-dislocation (FTD) groups in the overall cohort across all functional outcome measures. These findings indicate that both approaches provide comparable overall clinical outcomes in the treatment of AO/OTA 13-C3 distal humeral fractures. This result is consistent with previous studies suggesting that extensor mechanism-sparing approaches can achieve outcomes equivalent to those of olecranon osteotomy in appropriately selected patients^[20].

However, subgroup analysis based on fracture morphology demonstrated a differential pattern of outcomes. In the PAD-type subgroup, patients treated with the FTD approach showed a significantly smaller terminal extension deficit compared with those treated with olecranon osteotomy. In contrast, no significant differences were observed between the two approaches in the non-PAD subgroup. These findings suggest that fracture morphology may be associated with variation in specific functional outcomes, particularly terminal elbow extension, even when overall functional scores are comparable.

From a clinical perspective, PAD-type fractures are characterized by posterior displacement of the articular block and varying degrees of posterior column comminution. These patterns are often associated with more complex posterior joint involvement and may require more extensive posterior exposure and reduction maneuvers. Olecranon osteotomy provides wide visualization of the articular surface but involves disruption and subsequent repair of the extensor mechanism. In contrast, the FTD approach preserves the triceps insertion and avoids osteotomy-related injury to the olecranon–triceps complex. The observed difference in extension deficit in the PAD subgroup may therefore reflect differences in extensor mechanism handling between the two approaches.

In non-PAD fractures, both surgical approaches appear to provide sufficient exposure to achieve stable fixation and satisfactory reduction. The absence of differences in functional outcomes in this subgroup suggests that fracture pattern may be a key determinant of whether the additional exposure provided by olecranon osteotomy translates into measurable functional benefit.

The importance of fracture morphology–based surgical decision-making has been highlighted in prior literature on intra-articular distal humeral fractures. The Dubberley classification system, which stratifies coronal shear fractures according to the degree of trochlear involvement and posterior comminution, has been widely used to guide treatment strategy^[21]. More complex fracture patterns, particularly those with posterior comminution, have been associated with less favorable outcomes regardless of surgical approach^[22]. These findings are consistent with the concept that posterior articular involvement is an important factor influencing both surgical difficulty and functional recovery. In this context, the PAD classification used in the present study may provide additional practical information; however, its relationship to established classification systems requires further validation.

Limitations

Several limitations should be acknowledged. First, the sample size was relatively small, which limits the statistical power of subgroup analyses. Although a significant difference in terminal extension deficit was observed in the PAD subgroup, this finding should be interpreted with caution given the width of the confidence intervals. Second, the retrospective design introduces potential selection bias, as treatment allocation was influenced by surgeon preference and patient-specific factors. Third, the PAD classification system has not been formally validated, and its reproducibility requires further evaluation in prospective studies. Finally, all procedures were performed by a single surgical team with extensive experience in both approaches, which may limit the external generalizability of the findings.

Conclusion

The FTD approach reduces surgical trauma compared with OO while achieving comparable overall functional outcomes. In PAD-type fractures, FTD was associated with superior terminal extension, suggesting that fracture morphology may inform surgical approach selection.

Abbreviations

ORIF

open reduction and internal fixation

CT

Computed tomography

OO

olecranon osteotomy

FTD

flip-triceps dislocation

PAD

posterior articular dominant

MEPS

Mayo Elbow Performance Score

DASH

Disabilities of the Arm, Shoulder and Hand

Declarations

Ethics approval

This retrospective study was conducted in accordance with the Declaration of Helsinki. The study protocol was approved by the Clinical Trial Review Committee of the Sir Run Run Hospital of Nanjing Medical University(2026-SR-016). Given that this is a retrospective study, the requirement for informed consent was waived in accordance with relevant regulations.

Funding Declaration

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Author Contribution

All authors had full access to the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Conceptualization, C.Z. and H.Q.; Methodology, C.Z.; Investigation, C.Z., H.Q. and Y.Z.;Data Curation,C.Z. and Y.Z.;Formal Analysis, H.Q. and Y.Z.; Resources, D.C. and T.Y.; Writing - Original Draft, C.Z.; Writing - Review & Editing, D.C. and T.Y.; Visualization, C.Z.; Supervision,T.Y.; Funding Acquisition, D.C. and T.Y.

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Data Availability

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

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Figures

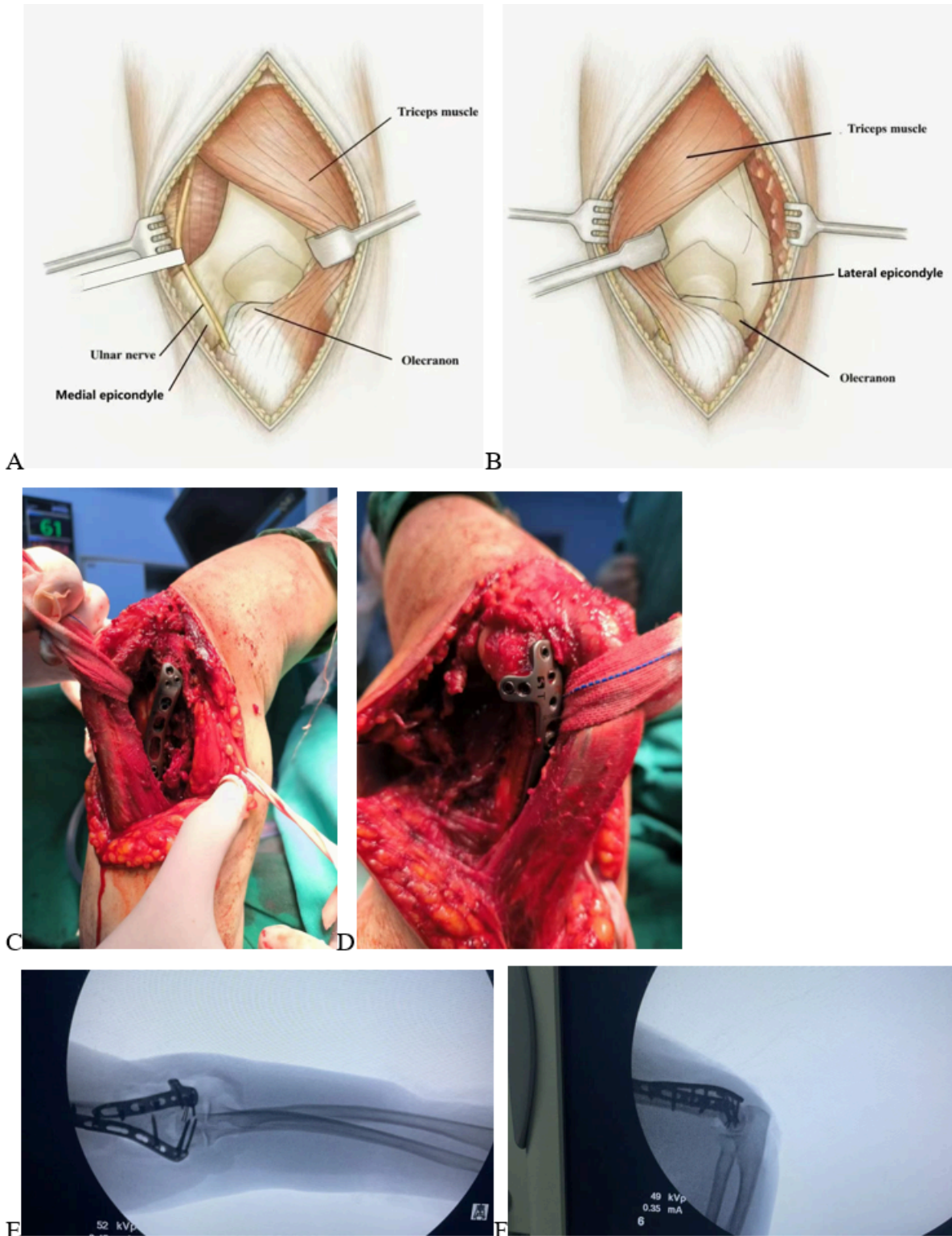


Figure 1

Intraoperative photographs demonstrating the surgical technique of the triceps flipping-dislocation (FTD) approach. (A) Exposure of the fracture site through the medial window. (B) Exposure of the fracture site through the lateral window. (C) Intraoperative appearance following plate fixation through the medial window. (D) Intraoperative appearance following plate fixation through the lateral window. (E, F) Intraoperative fluoroscopic images confirming fracture reduction and implant positioning.

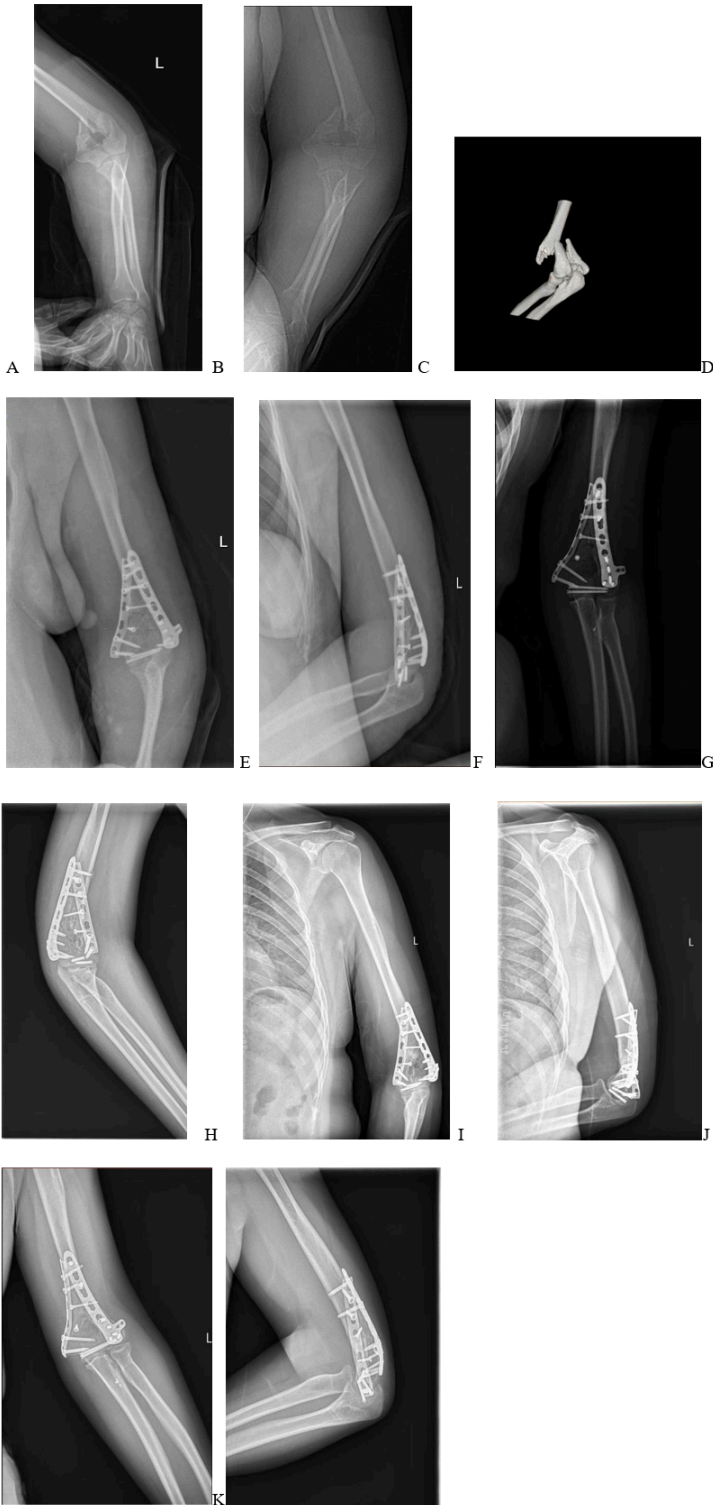


Figure 2

Representative case 1. A 28-year-old female patient sustained a PAD-type AO/OTA 13-C3 distal humeral fracture after a fall from standing height and was treated with the flip-triceps dislocation (FTD) approach. **(A, B)** Preoperative anteroposterior and lateral radiographs of the elbow. **(C)** Preoperative three-dimensional CT reconstruction demonstrating a large coronal-plane articular fragment at the posterior aspect of the distal humerus with posterior displacement or posterior rotational tendency of the ulnohumeral joint. **(D, E)** Postoperative radiographs demonstrating satisfactory fracture reduction and implant positioning. **(F, G)** Radiographic follow-up at 3 months postoperatively. **(H, I)** Radiographic follow-up at 6 months postoperatively. **(J, K)** Radiographs at 12 months postoperatively demonstrating complete fracture union.

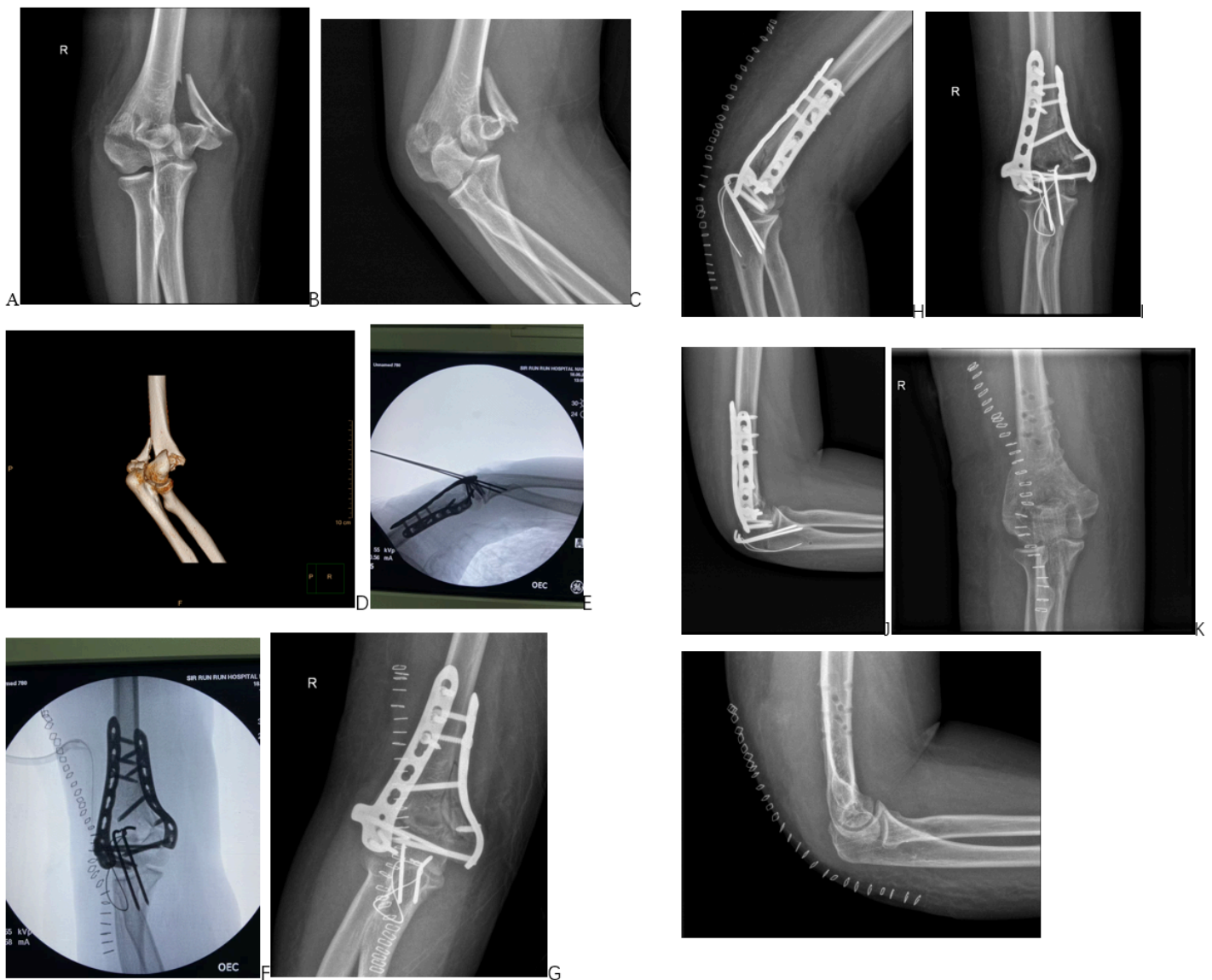


Figure 3

Representative case 2. A patient sustained a posterior articular displacement (PAD)-type AO/OTA 13-C3 distal humeral fracture following a motor vehicle accident and was treated via the olecranon V-osteotomy approach. **(A, B)** Preoperative anteroposterior and lateral radiographs of the elbow. **(C)** Preoperative three-dimensional CT reconstruction demonstrating a large coronal-plane articular fragment at the posterior aspect of the distal humerus with posterior displacement or posterior rotational tendency of the ulnohumeral joint. **(D, E)** Intraoperative photographs showing satisfactory fracture reduction and implant positioning; the olecranon osteotomy site was secured with tension band wiring and an intramedullary Kirschner wire. **(F, G)** Postoperative radiographs demonstrating satisfactory implant positioning. **(H, I)** Radiographs at 12 months postoperatively demonstrating satisfactory fracture union. **(J, K)** 14 months after the operation, the internal fixation was removed.