

Research Article

COMPARATIVE ASSESSMENT OF ARTICULAR EXPOSURE IN POSTERIOR SURGICAL APPROACHES TO THE ELBOW

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Article History

Received: 30.04.2026
Revised: 12.05.2026
Accepted: 20.05.2026
Published: 28.05.2026

Citations:

Mathew, K. C., Mohamed, Z. H., Madhankumar, M., Annamalai, T. T., Rohin, G., Raja, K., & Baisil, S. G. J. (Year). Comparative assessment of articular exposure in posterior surgical approaches to the elbow. *J Surg Radiol*, V5(5) 154-159

Abstract: Introduction: Articular exposure is critical in successfully treating fractures of the distal humerus. Numerous posterior surgical exposures of the elbow joint have been described; nonetheless, objective assessment comparing the degree of articular exposure provided by each approach is scarce. **Aim** To compare the percentage of distal humeral articular surface exposure achieved through the bilaterotricipital approach, triceps splitting approach, and olecranon osteotomy in a cadaveric model. **Materials and Methods** The prospective and observational cadaveric study was performed at the Department of Orthopedics, Sree Mookambika Institute of Medical Sciences, Kanyakumari, Tamil Nadu, India, between February 2024 and January 2025. A total of 30 elbows were included in this study, which were collected from 15 cadavers of adult males. All three techniques were divided equally, and hence, all three approaches had equal numbers of 10 elbows each, including the bilateral tricripital approach, the triceps splitting approach, and the olecranon osteotomy approach. After the process of surgery, the articular surface of the distal humerus was highlighted, and the remaining unexposed surface was observed by disarticulating the elbow joint. The percentage of articular exposure of each approach was measured by the mesh method. Data were analysed using SPSS version 27.0 and expressed as frequency, percentage, and mean values. **Results** Among the 30 elbow specimens studied, 15 were right-sided and 15 were left-sided. Each posterior surgical approach was performed on 10 elbow specimens. Olecranon osteotomy demonstrated the highest mean articular exposure of 52%, followed by the triceps splitting approach with 37% exposure. The bilaterotricipital approach provided the lowest mean articular exposure at 26%. **Conclusion** Olecranon osteotomy provides the greatest distal humeral articular exposure among the posterior surgical approaches evaluated, whereas triceps-preserving techniques offer comparatively lower exposure with reduced disruption of the extensor mechanism. The findings of this study may assist surgeons in selecting the most appropriate posterior elbow approach according to fracture complexity, required articular visualisation, and operative requirements.

Keywords: distal humerus; elbow; olecranon osteotomy; triceps splitting; cadaveric study

INTRODUCTION

The elbow is a complex synovial joint whose distal humeral articular surface, comprising the trochlea and capitellum, plays a critical role in flexion-extension and forearm rotation. Surgical exposure of this region is technically challenging because of the close relationship of the ulnar and radial nerves and the importance of preserving the triceps extensor mechanism for postoperative functional recovery [1]. Posterior surgical approaches provide versatile access to the distal humerus and are commonly employed to facilitate direct visualisation of the articular surface, fracture reduction, and implant placement [2].

Intra-articular distal humeral fractures are complex injuries that require accurate anatomical reduction to restore joint congruity, minimise post-traumatic arthritis, and permit early rehabilitation [3]. Open reduction and

internal fixation remain the preferred treatment modality in active adults, with adequate articular exposure being an important determinant of surgical outcome [4]. In elderly patients with osteoporotic bone, total elbow arthroplasty has emerged as an alternative treatment option and similarly necessitates sufficient posterior exposure [4, 5].

Of the commonly employed posterior exposures, olecranon osteotomy is considered to offer the most extensive joint visualization because of the reflection of the triceps mechanism via an osteotomy. Nevertheless, this approach is known to be complicated by problems including delayed union, non-union, hardware complications, and requirement of implant removal during the second surgery [1, 6, 7]. Triceps splitting exposes the distal humerus without causing any complications related to the osteotomy because the procedure divides the triceps tendon longitudinally [8].

Bilaterotricipital exposure preserves the continuity of the triceps mechanism by retraction of the muscle laterally and medially, which leads to decreased extensor disruption but still provides visualization of both columns [1, 2]. Moreover, previous anatomical and histological experiments have indicated that triceps-sparing approaches offer better posterior joint visualization compared with conventional procedures [9].

However, despite the frequent use of such techniques, the paucity of objective comparisons in terms of articular exposure between these surgical approaches in the form of prospective cadaveric trials cannot be ignored. These studies have been conducted using diverse methods and techniques of assessment, thus making comparative analysis very difficult [10, 11]. This makes the selection of the posterior technique purely subjective, based on the personal experience of the surgeons performing these operations. Since insufficient exposure may lead to poor fracture reduction, it becomes crucial for its proper evaluation [3, 8].

The present study was therefore undertaken to prospectively compare the percentage of distal humeral articular surface exposed by the bilaterotricipital approach, triceps splitting approach, and olecranon osteotomy using a standardised cadaveric model and mesh-based quantification technique. The study aimed to objectively assess and compare the articular exposure provided by these commonly used posterior surgical approaches to the elbow.

MATERIALS AND METHODS

This prospective observational cadaveric study was conducted in the Department of Orthopaedics at Sree Mookambika Institute of Medical Sciences, Kanniyakumari, Tamil Nadu, India, from February 2024 to January 2025.

A total of fifteen adult male cadavers were used for this experiment. Right and left elbows were equally used and consisted of fifteen right and fifteen left elbows. Any

cadaver with gross traumatic deformity, history of surgical procedure, congenital malformation, or pathology in the elbow joint was not included in the experiment.

The cadavers were placed in the prone position with their upper extremities lying on the sides of the body. An incision along the posterior midline of the elbow joint was made to expose the distal triceps tendon and olecranon process.

Three posterior surgical approaches to the elbow were evaluated:

1. Bilaterotricipital approach
2. Triceps splitting approach
3. Olecranon osteotomy approach

For each surgical technique, 10 different elbow joints were utilized. After completion of the surgical approach, the elbow joint was flexed to its maximum extent to visualize the distal humeral joint surface. The exposed joint surface, which could be seen through the surgical approach, was outlined by applying colored paint. Next, disarticulation of the elbow joint was done, and the unexposed joint surface was marked by a different colour.

The painted articular surfaces were then covered using a synthetic mesh net with uniform square meshes. The number of meshes corresponding to exposed and unexposed articular surfaces was counted separately. The percentage of articular exposure was calculated using the formula:

$$S = 100N_y / (N_y + N_b)$$

Where:

- N_y = number of meshes over exposed surface
- N_b = number of meshes over unexposed surface
- S = percentage of articular exposure

The mean percentage of articular exposure was calculated for each surgical approach. The collected data were entered into Microsoft Excel and analysed using Statistical Package for the Social Sciences (SPSS) software version 27.0. Descriptive statistics were expressed as frequency, percentage, and mean values.

RESULTS

A total of 15 adult male cadavers were included in the study, accounting for 100% of the study samples. No female cadavers were included. Among the 30 elbow specimens evaluated, 15 were right-sided, and 15 were left-sided, representing an equal distribution of 50% each.

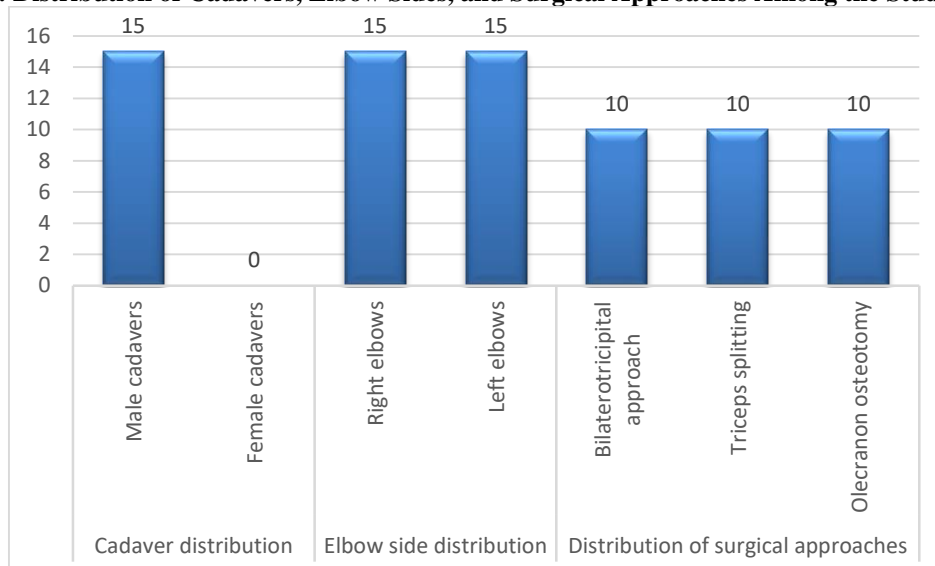
The three posterior surgical approaches assessed in the study were the bilaterotricipital approach, triceps splitting approach, and olecranon osteotomy. Each approach was performed on 10 elbow specimens, with an equal distribution of 33.33% for each surgical technique (Table 1, Figure 1).

Table 1: Distribution of Cadavers, Elbow Sides, and Surgical Approaches Among Study Samples

Variable	Category	Frequency	Percentage
Cadaver distribution	Male cadavers	15	100%
	Female cadavers	0	0%
	Total cadavers	15	100%
Elbow side distribution	Right elbows	15	50%
	Left elbows	15	50%
	Total elbows	30	100%

Distribution of surgical approaches	Bilaterotricipital approach	10	33.33%
	Triceps splitting	10	33.33%
	Olecranon osteotomy	10	33.33%
	Total	30	100%

Figure 1: Distribution of Cadavers, Elbow Sides, and Surgical Approaches Among the Study Samples



The olecranon osteotomy approach demonstrated the highest mean articular exposure of 52%, followed by the triceps splitting approach with a mean exposure of 37%. The bilaterotricipital approach showed the lowest mean articular exposure, accounting for 26% of the distal humeral articular surface exposure (Table 2).

Table 2: Mean percentage of articular exposure

Surgical Approach	Mean Articular Exposure
Bilaterotricipital approach	26%
Triceps splitting	37%
Olecranon osteotomy	52%

DISCUSSION

The principal finding of the present cadaveric study was that olecranon osteotomy provided the greatest distal humeral articular exposure among the three posterior approaches evaluated, with a mean exposure of 52%, followed by the triceps splitting approach at 37% and the bilaterotricipital approach at 26%. These findings are clinically significant, as adequate visualisation of the distal humeral articular surface is essential for accurate fracture reduction, restoration of joint congruity, and stable internal fixation.

The extensive articular exposure provided by olecranon osteotomy in the current study is supported by previous anatomical and surgical reports. *France et al.* stated that olecranon osteotomy provides extensive exposure to the distal humerus, providing visualization of the trochlea and both humeral columns when fixing complex intra-articular fractures [1]. Likewise, *Hausman et al.* indicated that olecranon osteotomy is among the most versatile posterior approaches in cases of complex distal humeral fractures needing extensive articular exposure [2].

In addition, the average articular exposure percentage achieved during the course of this study, at 52%, was less than the percentages obtained from other digital cadaveric analysis studies. For instance, a median articular exposure percentage of 62.0% was found after conducting olecranon osteotomy compared to the elbow dislocation technique by *Liu et al.* On the other hand, a median percentage of 63.1% of articular surface exposure was discovered during the comparative study of olecranon osteotomy against medial-lateral exposure approaches conducted by *Wei et al.* [10, 11]. This difference in exposure percentages could be due to the different ways of exposing the surface, the position of the specimen, the angle of elbow flexion, and the methods of quantifying the surface. As opposed to the previous study that made use of digital surface mapping systems, the present study made use of a mesh-based quantification system. Despite differences in absolute exposure values, the overall pattern of findings remains comparable across studies, with olecranon osteotomy consistently demonstrating greater articular visualisation than triceps-preserving or triceps-splitting approaches.

Mean articular exposure by the triceps split was found to be 37% and can be considered an intermediate degree of exposure, compared with olecranon osteotomy and bilaterotricipital approach. Such results suggest that the use of triceps split is justified as an effective method of adequate visualization of posterior articular exposure without compromising the patient's morbidity associated with olecranon osteotomy. A matched-cohort study by **Weber et al.** comparing the outcomes of triceps tongue approach and olecranon osteotomy on AO type 13-C fractures of distal humerus found no difference in fracture reduction and functional outcomes but revealed a better postoperative range of elbow movement and fewer complications related to ulnar nerve palsy in patients with the triceps tongue approach [8].

In a similar vein, **Erickson et al.** found favorable results with triceps split and snip approaches to AO type C distal humeral fractures, with acceptable post-operative elbow motion and Mayo Elbow Performance scores, suggesting that the exposure afforded by a triceps split approach is adequate for intra-articular fixation [12]. In a study on the histology of triceps preservation, **Whitaker et al.** found that the triceps' footprint was smaller than expected by gross anatomy studies, which allowed greater posterior articular access after a longitudinal split without olecranon osteotomy [9].

The bilaterotricipital approach demonstrated the lowest mean articular exposure in the present study, accounting for 26% of the distal humeral articular surface. This finding is anatomically understandable, as preservation of the intact triceps mechanism limits the posterior visualisation window available for articular exposure. **Martinelli et al.** have similarly described paratricipital approaches as being more suitable for extra-articular and partial articular distal humeral fractures rather than highly comminuted intra-articular injuries because of their limited articular access [13]. The findings of the present study are consistent with these observations.

Nevertheless, bilaterotricipital approach is still used in certain clinical situations for its various merits. Preserving the extensor mechanism can help avoid postoperative triceps insufficiency and promote rapid rehabilitation. Furthermore, this technique could be beneficial for surgeries that do not require thorough articular exposure, such as selected cases of metaphyseal fractures and elbow replacement surgery. Indeed, **Touloupakis et al.** showed that combined use of paratricipital and triceps splitting approaches proved to be effective for treatment of distal humeral fractures, indicating that hybrid methods can offer even better exposure opportunities [14]. Thus, while bilaterotricipital approach ensured minimal articular exposure among the ones investigated, its clinical utility still depended on fracture pattern and goals of surgery.

Clinical considerations of the current study findings are crucial for choosing a surgical approach for distal humeral fractures. In case of highly comminuted fractures of AO/OTA type 13-C fractures with complex intra-articular reconstruction, osteotomy of the olecranon process provides the maximum surgical

exposure and should be used when optimal visualization of the articular surface of the distal humerus is essential. Nevertheless, it should be noted that potential advantages of olecranon osteotomy regarding increased exposure should be considered along with possible complications of this surgical procedure, such as delayed and non-unions, hardware irritation, and further need for hardware removal. It was found that the incidence of non-union is about 3.3%, and the rate of hardware removal is 37% [6, 7].

There are many strengths that can be attributed to the current research. The fact that this is a prospective cadaveric study means that comparison of all three posterior techniques was possible within a controlled setting, thus reducing variability due to patient-related factors. These include equal distribution of the number of elbows among all three techniques, use of two elbows for each of the 15 cadavers, posterior midline incision made at the same level, and maximally flexed elbow joints when measuring. Furthermore, a very simple yet accurate measure of exposure involved the use of the mesh technique.

Certain limitations of the present study should also be acknowledged. The exclusive inclusion of male cadavers limits extrapolation of the findings to female anatomical specimens, in whom differences in distal humeral morphology may exist. Furthermore, cadaveric evaluation does not fully reproduce operative conditions encountered during live surgery, including soft tissue oedema, fracture displacement, bleeding, and muscle tension, which may influence intraoperative visualisation. Although the sample size used in the present study is comparable to previous anatomical investigations, a larger specimen population may improve the precision and generalisability of the findings.

The mesh-based quantification technique employed in the study primarily evaluates projected surface area and may not completely account for the complex three-dimensional curvature of the distal humeral articular surface. This could potentially result in slight underestimation of the true articular exposure achieved by each approach. In addition, formal inferential statistical analysis between groups was not performed because the study was primarily descriptive in nature. Future studies incorporating larger sample sizes, statistical comparison, three-dimensional digital mapping, and regional articular surface analysis may provide more detailed evaluation of approach-specific exposure patterns.

In conclusion, the present cadaveric study demonstrated that olecranon osteotomy provided the greatest distal humeral articular exposure among the three posterior approaches evaluated, followed by the triceps splitting and bilaterotricipital approaches. These findings provide objective anatomical evidence that may assist surgeons in selecting the most appropriate posterior elbow approach according to fracture complexity, required articular visualisation, and the need for preservation of the extensor mechanism.

CONCLUSION

The present cadaveric study demonstrated that olecranon osteotomy provides the greatest articular exposure of the distal humerus among the posterior approaches evaluated, followed by the triceps splitting and bilaterotricipital approaches. While maximal exposure remains important in the management of complex intra-articular fractures, the choice of surgical approach should also consider preservation of the extensor mechanism and the potential for approach-related complications. The findings of this study reinforce that each posterior approach has distinct advantages and limitations, and no single technique is universally applicable to all fracture patterns. Olecranon osteotomy appears most suitable when extensive articular visualisation is required, whereas triceps-preserving approaches may offer adequate exposure with reduced soft-tissue disruption in selected cases. By providing reproducible cadaveric data using a standardised assessment method, the present study adds objective anatomical evidence to support surgical decision-making in elbow procedures. Further studies with larger sample sizes and advanced three-dimensional assessment techniques may help refine understanding of regional articular exposure and optimise approach selection in complex distal humeral surgery.

Conflict of interest: None declared.

Funding: No funding is received for this study.

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