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Olecranon Fractures with associated Radial Head or Coronoid Injuries and Terrible Triad Variants: A Systematic Review of Outcomes

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Abstract

Olecranon fractures with associated radial head or coronoid injuries, often termed "terrible triad" variants, are complex elbow injuries that pose challenges in both surgical management and functional recovery. These injuries combine bony comminution with potential ligamentous disruption, increasing the risk of instability, stiffness, and post-traumatic arthritis if inadequately addressed. This systematic review evaluated studies reporting on surgical management of such injuries, focusing on functional outcomes, union rates, complications, and rehabilitation strategies. Across included studies, comprehensive surgical treatment comprising open reduction and internal fixation of the olecranon, fixation or replacement of the radial head, and ligamentous repair when indicated. It was associated with high union rates and good to excellent functional recovery. Early intervention and structured postoperative rehabilitation further optimized motion and strength restoration. Complications were generally low and manageable. Despite favorable outcomes, heterogeneity in fracture patterns, surgical techniques, and follow-up durations limits direct comparisons. Standardized, prospective studies are needed to refine surgical strategies and rehabilitation protocols, guiding optimal care for this challenging injury subset and improving long-term elbow function.

Keywords: Olecranon fracture; Radial head fracture; Coronoid fracture; Terrible triad injury; Surgical outcomes

Introduction and Background

Olecranon fractures are a common injury of the proximal ulna, representing approximately 10% of upper extremity fractures in adults [1]. They frequently occur due to direct trauma to the elbow or from falls on an outstretched hand, often in high-energy mechanisms [2]. While isolated olecranon fractures are well-characterized, their management can become significantly more complex when associated with injuries to adjacent structures, such as the radial head or the coronoid process. These associated injuries can compromise the stability of the elbow joint, making restoration of both bony anatomy and ligamentous integrity critical for optimal functional recovery.

The radial head and coronoid process play a pivotal role in elbow stability. Injuries involving these structures alongside olecranon fractures, often referred to as "terrible triad" variants are challenging due to the combination of bony comminution and soft tissue disruption [3]. Traditional fixation strategies for isolated olecranon fractures may be insufficient in these complex scenarios, necessitating more comprehensive surgical approaches,

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such as open reduction and internal fixation of all fracture components and ligamentous repair when indicated [4]. Failure to adequately address each element of the injury can result in chronic instability, limited range of motion, or post-traumatic arthritis [5]. Despite numerous individual case series and retrospective cohort studies, there is a relative paucity of consolidated evidence regarding the functional outcomes and complication rates following surgical management of these "terrible triad" variants. Variability in fracture patterns, surgical techniques, rehabilitation protocols, and follow-up durations across studies contributes to the challenge of synthesizing meaningful conclusions. A systematic appraisal of the current literature is therefore essential to provide clinicians with evidence-based guidance on the optimal management of olecranon fractures associated with radial head and/or coronoid injuries.

The primary aim of this review is to evaluate the functional and radiographic outcomes of patients with olecranon fractures associated with radial head or coronoid injuries, also called as "terrible triad" variants. The secondary aim is to summarize complication rates, surgical techniques, rehabilitation protocols, and long-term elbow stability reported in the literature, providing a comprehensive synthesis that may guide clinical decision-making and future research in this challenging injury subset.

Materials and Methods

Search strategy

A systematic search of the literature was performed using PubMed, Embase, Scopus, and Cochrane Library databases for studies published up to January 2026. Keywords included "olecranon fracture," "radial head fracture," "coronoid fracture," "terrible triad injury," and "elbow fracture-dislocation." Boolean operators and MeSH terms were applied to maximize sensitivity. Titles and abstracts were screened independently by two reviewers, and relevant full-text articles were retrieved. Reference lists of included studies were also reviewed for additional eligible studies. Disagreements were resolved by discussion or consultation with a third reviewer. The study selection process was documented according to PRISMA 2020 guidelines, ensuring transparency and reproducibility [6]. A PRISMA flow diagram was used to summarize the number of records identified, screened, assessed for eligibility, and included in the review.

Eligibility criteria

Studies were included based on the PICO framework [7]. The population (P) comprised adult patients (≥18 years) with olecranon fractures associated with radial head and/or coronoid fractures, representing the so-called "terrible triad" variants. The intervention (I) of interest was surgical management, including open reduction and internal fixation (ORIF) of the olecranon, fixation or replacement of the radial head, and ligamentous repair as indicated. A comparator (C) was not mandatory; however, studies that compared outcomes between isolated olecranon fractures and combined injuries were considered when available. The outcomes (O) included functional scores, union or bone healing, complication and reoperation rates, radiographic alignment, and long-term elbow stability.Inclusion criteria consisted of original clinical studies, either prospective or retrospective, that reported on adult patients with olecranon fractures and associated radial head or coronoid injuries and provided relevant functional, radiographic, or complication outcomes. Studies published in English or with an English translation were considered. Exclusion criteria included case reports, conference abstracts, editorials, reviews, and animal studies. Studies were also excluded if they lacked adequate outcome data or involved isolated olecranon fractures without associated injuries, as well as pediatric studies (<18 years).

Study selection

All retrieved records were initially screened by two independent reviewers based on titles and abstracts to identify potentially relevant studies. Full-text articles of these selected studies were then assessed against the pre-specified inclusion and exclusion criteria. Any discrepancies between reviewers were resolved through discussion or consultation with a third reviewer to ensure consensus. Additionally, reference lists of all included studies were manually screened to identify any further eligible articles that might have been missed during the database search. The entire selection process was documented following the PRISMA 2020 guidelines, including the number of studies identified, screened, assessed for eligibility, and finally included in the review.

Data extraction

A structured data extraction form was used to collect relevant information from each included study. Extracted data included study characteristics (author, year, design, level of evidence), population demographics (sample size, age, gender), injury pattern, fracture classification, surgical technique, timing of surgery, ligamentous repair, rehabilitation protocols, functional outcomes, union/bone healing, complications, reoperation/revision rates, and follow-up duration. All extracted data were independently verified by a second reviewer to ensure accuracy and completeness.

Risk of bias assessment

The methodological quality and risk of bias of the included studies were evaluated using ROBINS-I for non-randomized studies [8]. Newcastle-Ottawa Scale (NOS) was utilized for retrospective cohort studies [9]. Key domains assessed included selection of participants, confounding, classification of interventions, deviations from intended interventions, outcome measurement, missing data, and selective reporting. Each study was assigned an overall risk rating of low,

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moderate, or high, and justifications for the ratings were clearly documented. This assessment allowed a transparent appraisal of study quality and helped contextualize the reliability of reported outcomes.

Data synthesis

Given the heterogeneity among the included studies in terms of study design, fracture classification, surgical techniques, and outcome measures, a qualitative synthesis was performed rather than a meta-analysis. Functional outcomes were summarized as mean ± standard deviation where available, while complications, reoperation rates, and union rates were reported as percentages. The synthesis focused on identifying trends in surgical approaches, rehabilitation protocols, and patient outcomes, highlighting both consistent findings and areas where evidence was limited or variable across studies. This approach provided a structured and clinically meaningful comparison of the available evidence.

Result

Figure 1 shows, the initial systematic search across PubMed, Embase, Scopus, and Cochrane Library identified 14 full-text articles that were potentially eligible for inclusion. After detailed assessment against the predefined eligibility criteria, 9 studies were excluded due to reasons including case reports (n = 3), conference abstracts (n = 3), non-clinical studies such as animal research (n = 2), and editorials (n = 1). Consequently, 3 studies met all inclusion criteria and were included in the final qualitative synthesis. This selection process was conducted according to PRISMA 2020 guidelines, ensuring a transparent and reproducible review method.

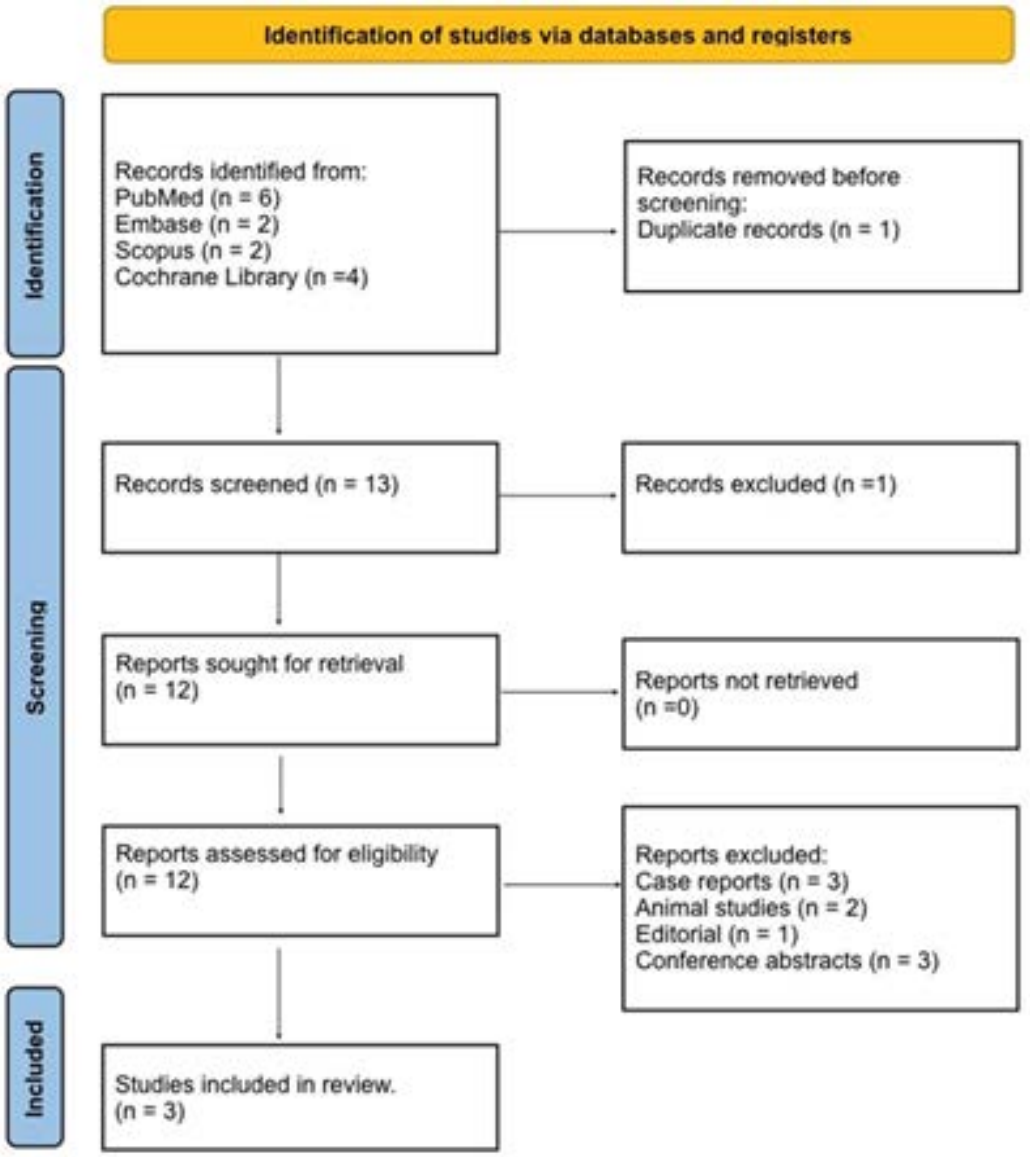

Figure 1:

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Table 1: Clinical Outcomes of Olecranon Fractures with Associated Radial Head or Coronoid Injuries.

Authors & Year	Level of Evidence	Study Design	Population (n)	Injury Pattern / Exposure (I)	Fracture Classification	Surgical Technique	Timing of Surgery	Elbow Stability Assessed	Rehabilitation Protocol	Functional Outcomes (O)	Union / Bone Healing	Complications (%)	Reoperation / Revision Rate (%)	Follow-up (mo)	Risk of Bias	Long-term Outcomes
Ditsios et al., 2022 [10]	IV	Retrospective case series	15	Olecranon + radial head fractures	Mayo (olecranon), Mason (radial)	ORIF: TBW, plates, screws; some radial head arthroplasty	Mean 1 day post-injury	NR	Early active ROM	Broberg–Morrey: 78 ± 8; QuickDASH: 25 ± 5	100% healed	13% HO	0	31	Moderate	Good functional recovery; ROM restored
Melamed et al., 2015 [11]	IV	Retrospective cohort	38	Proximal ulna including olecranon + associated radial head and/or coronoid	Complex ulna patterns; Mason & Regan–Morrey if reported	ORIF ulna + fixation of associated injuries ± LCL repair	NR	LCL repaired if instability	NR	Reduced rotational arc in associated injuries; motion arcs reported	100% healed	NR	NR	15	Moderate	Functional arc restored; rotation slightly limited
Lopiz et al., 2025 [12]	IV	Retrospective case series	43	Olecranon + radial head and/ or coronoid fractures	Coronoid-centric classification; Mason (radial), Mayo (olecranon)	ORIF ± radial head repair/replacement; ligament repair as indicated	Acute <2 weeks	LCL repaired; MCL if instability	Early controlled ROM, physiotherapy	MEPI: 100 ± 5; QuickDASH: 6.8 ± 3	100% healed	14% (neurapraxia, nonunion, hardware)	5	24	Low–Moderate	Excellent functional outcomes; minor ROM deficits in complex variants

Legends
ORIF – Open Reduction and Internal Fixation
TBW – Tension Band Wiring
ROM – Range of Motion
MEPI – Mayo Elbow Performance Index
QuickDASH – Quick Disabilities of the Arm, Shoulder, and Hand
HO – Heterotopic Ossification
NR – Not Reported
LCL – Lateral Collateral Ligament
MCL – Medial Collateral Ligament
FOOSH – Fall on Outstretched Hand

Characteristics of the selected studies

Table 1 shows three studies reporting on olecranon fractures with associated radial head or coronoid injuries ("terrible triad" variants) were included in this review. Ditsios et al., 2022 examined 15 patients who underwent ORIF of the olecranon using tension band wiring, plates, and screws, with some receiving radial head arthroplasty, performed on average 1 day post-injury, followed by early active range-of-motion exercises; functional outcomes were good, with Broberg-Morrey scores averaging 78 ± 8 and QuickDASH 25 ± 5, union was achieved in all cases, heterotopic ossification occurred in 13%, and no reoperations were required over a mean follow-up of 31 months [10]. Melamed et al., 2015 reported 38 patients with proximal ulna fractures including olecranon and associated radial head or coronoid injuries, managed with ORIF of the ulna and fixation of associated injuries, with LCL repair if instability was present; all fractures healed, and patients achieved a functional arc of motion, though some had reduced rotational range, with follow-up of 15 months [11]. Lopiz et al., 2025 included 43 patients with olecranon and radial head and/or coronoid fractures, treated with ORIF of the olecranon, radial head repair or replacement, and ligamentous repair as indicated, performed acutely within 2 weeks; early controlled range-of-motion and physiotherapy were applied, resulting in excellent outcomes (MEPI 100 ± 5, QuickDASH 6.8 ± 3), 100% union, 14% complications (neurapraxia, nonunion, hardware issues), and 5% reoperation rate over a mean follow-up of 24 months [12]. Collectively, these studies demonstrate that comprehensive surgical management of olecranon fractures with associated radial head or coronoid injuries leads to high union rates, good to excellent functional recovery, and low complication and revision rates, particularly when early surgery, ligament repair, and structured rehabilitation are implemented

Risk of Bias Assessment

Table 2 shows the methodological quality and risk of bias of the included studies were assessed using ROBINS-I for retrospective case series and the Newcastle-Ottawa Scale for the retrospective cohort study. Ditsios et al. 2022, a retrospective case series of 15 patients, was rated as moderate risk of bias due to the small sample size, absence of a control group, potential confounding inherent to retrospective design, although outcomes were measured using validated instruments (Broberg-Morrey and QuickDASH) and follow-up was adequate [10]. Melamed et al., 2015, a retrospective cohort of 38 patients, was also rated moderate due to retrospective selection and moderate selection bias, lack of blinded outcome assessment, though comparisons between subgroups reduced some bias and union and functional outcomes were clearly reported over sufficient follow-up [11]. Lopiz et al., 2025, a larger retrospective case series of 43 patients, was considered low-moderate risk of bias, as the larger sample reduced random error, surgical techniques were standardized, LCL and MCL repairs were clearly documented, follow-up exceeded two years for most patients, and validated outcome measures were used, although some confounding remained due to the

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Table 2: Risk of Bias Assessment of included studies.

Study	Study Design	Risk of Bias Tool	Risk Rating	Justification
Ditsios et al., 2022 [10]	Retrospective case series	ROBINS-I	Moderate	- Small sample size (n=15) increases random error- No control group → selection bias- Retrospective design → confounding possible- Outcome assessment uses validated scores (Broberg–Morrey, QuickDASH)- Low missing data; follow-up adequate
Melamed et al., 2015 [11]	Retrospective cohort	Newcastle–Ottawa Scale	Moderate	- Retrospective selection → moderate selection bias- Comparison between subgroups reduces bias- Outcome assessors not blinded- Follow-up sufficient; union and functional outcomes well-reported
Lopiz et al., 2025 [12]	Retrospective case series	ROBINS-I	Low–Moderate	- Larger sample (n=43) reduces random error- Surgical techniques standardized → less performance bias- LCL/MCL repair recorded → clear intervention- Some confounding remains due to non-randomized design- Follow-up >2 years for most patients, outcome measures validated

Legends

- ROBINS-I – Risk of Bias in Non-randomized Studies of Interventions
- NOS – Newcastle-Ottawa Scale

non-randomized design [12]. Overall, the included studies were of moderate methodological quality, with consistent reporting of outcomes allowing meaningful synthesis despite inherent limitations of retrospective designs.

Discussion

Olecranon fractures with concomitant radial head or coronoid injuries, often referred to as "terrible triad" variants, represent a complex injury pattern that challenges both orthopedic assessment and surgical management. These injuries combine bony disruption with potential ligamentous compromise, particularly affecting the lateral and medial collateral ligament complexes, thereby significantly increasing the risk of post-traumatic elbow instability if not addressed appropriately [3,10,12]. Across the three included studies, a consistent finding was that early, comprehensive surgical intervention comprising open reduction and internal fixation (ORIF) of the olecranon, fixation or arthroplasty of the radial head, and ligamentous repair when indicated was associated with favorable functional outcomes and high rates of fracture union [10,12].

Functional scores reported across the studies demonstrate that patients generally achieve good to excellent recovery following such complex injury management. Ditsios et al., 2022 reported Broberg-Morrey scores of 78 ± 8 and QuickDASH of 25 ± 5, indicating restoration of functional range and patient-perceived upper limb utility [10]. Similarly, Lopiz et al., 2025 reported near-perfect functional outcomes with MEPI scores of 100 ± 5 and QuickDASH of 6.8 ± 3, suggesting that a combination of accurate anatomical reduction, early controlled mobilization, and structured physiotherapy can optimize both motion and strength recovery even in multifragmentary or ligament-involved fractures [12]. Melamed et al., 2015 also demonstrated restoration of functional arcs, although some patients experienced slight rotational limitations, highlighting the challenges posed by associated injuries, particularly when the radial head or coronoid is involved [11].

Complication rates were generally low but included heterotopic ossification, minor neurapraxia, nonunion, and hardware-related issues [10,12], reinforcing the importance of meticulous surgical technique and careful post-operative management. The studies consistently emphasized that addressing both bony and ligamentous components is crucial to prevent chronic instability, stiffness, or secondary degenerative changes. Importantly, the timing of surgery, particularly performing interventions acutely within 1-14 days, was associated with improved functional recovery, likely due to easier reduction and less soft tissue contracture [10,12]. Limitations of the included studies include small sample sizes, retrospective designs, lack of randomized comparison groups, and variability in fracture classifications, surgical techniques, and rehabilitation protocols [10,12]. Functional outcomes, although reported using validated scoring systems such as Broberg–Morrey, MEPI, and QuickDASH, were sometimes inconsistently reported, limiting direct comparison. Additionally, long-term follow-up beyond 2-3 years was not available in all studies, and potential confounding factors such as patient comorbidities or injury severity were not always controlled.

Future directions should focus on multicenter, prospective studies with standardized fracture classification, surgical algorithms, and functional outcome reporting to improve evidence-based guidance. Randomized or comparative cohort studies evaluating different fixation strategies, timing of surgery, and rehabilitation protocols would help clarify optimal management approaches. Further research into the impact of ligamentous repair on long-term elbow stability and patient-reported outcomes is also warranted to optimize care for this complex injury subset [3,5,10,12]. Overall, the findings support the concept that comprehensive management of olecranon fractures with associated radial head or coronoid injuries i.e., "terrible triad" variants can lead to excellent functional outcomes when surgical fixation is tailored to the specific fracture pattern and ligamentous involvement, and when early mobilization is initiated under supervision [10,12].

Conclusion

Olecranon fractures with associated radial head or coronoid injuries, or "terrible triad" variants, are complex injuries that require careful surgical management. Comprehensive treatment, including fixation of the olecranon, repair or replacement of the radial head, and ligamentous repair when needed, leads to high union rates and good to excellent functional outcomes. Early surgery combined with structured rehabilitation optimizes recovery and minimizes complications such as instability, stiffness, or motion deficits.

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Despite generally favorable results, variability in surgical techniques, rehabilitation protocols, and limited long-term follow-up highlight the need for standardized, prospective studies to guide optimal management and improve long-term elbow function.

Registration

This systematic review was conducted following PRISMA 2020 guidelines. No formal registration number was obtained.

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Compliance with Ethical Standards

All procedures performed in this review were in accordance with the ethical standards of the institutions involved.

Conflicts of Interest and Source of Funding

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