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Research Article

The Terrible Triad of the Elbow: Evolving Surgical Approaches and Patient Outcomes

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ABSTRACT

Background: The "terrible triad" (TT) of the elbow refers to a challenging injury combination characterized by posterior elbow dislocation along with fractures of both the radial head and the coronoid process. Once labeled "terrible" because of historically poor prognosis, advancements in surgical methods and a better grasp of elbow biomechanics have led to markedly improved clinical outcomes.
Objectives: To evaluate the surgical outcomes and functional results of terrible triad injuries treated at our institution and assess the effectiveness of current treatment protocols.
Methods: A retrospective analysis was performed on 24 patients with terrible triad injuries of the elbow treated between March 2018 and December 2024. Surgical stabilization aimed at restoring both bony alignment and ligament integrity was undertaken in all cases. Functional outcomes were evaluated using the Mayo Elbow Performance Score (MEPS).
Results: Mean MEPS at final follow-up was 80 points (range 70-90). Thirteen patients achieved excellent results, seven achieved good results, and Three achieved fair results. 'Mean flexion was 112° with extension loss of 12°. Four patients developed residual elbow stiffness as the primary complication.
Conclusion: Advances in surgical techniques emphasizing anatomical reconstruction, combined with structured rehabilitation protocols, have altered the prognosis of terrible triad injuries. With a systematic surgical approach, most patients now achieve favorable functional outcomes.
Keywords: Terrible triad, elbow fracture-dislocation, radial head fracture, coronoid fracture, Mayo elbow score.

INTRODUCTION

The terrible triad (TT) of the elbow, first described by Hotchkiss in 1996, consists of posterior elbow dislocation accompanied by fractures of the radial head and coronoid process.[1] It was termed "terrible" because of historically unfavorable outcomes, including recurrent instability, stiffness, arthrosis, and chronic pain.[2] The complex anatomy of the elbow, together with the disruption of both bony and soft tissue stabilizers, makes management of these injuries particularly challenging.

Advances in the understanding of elbow biomechanics, along with modern surgical techniques and improved implant design, have transformed the prognosis of this injury pattern[3,4] Current literature suggests that with appropriate surgical strategies and structured rehabilitation, the label "terrible" may no longer accurately reflect patient outcomes. [5] The contemporary treatment protocol emphasizes restoring elbow stability through a stepwise approach, including radial head repair or replacement, fixation of coronoid fractures, and reconstruction of the lateral collateral ligament complex

The present study was undertaken to share our institutional experience with terrible triad injuries, evaluate functional outcomes using validated scoring systems, and assess the effectiveness of current surgical treatment protocols.

LITERATURE REVIEW AND BACKGROUND

Historical Perspective

The term *"terrible triad"* was introduced to describe the consistently poor outcomes historically associated with this injury pattern when managed by conventional methods.[1] Early literature reported high complication rates, with recurrent instability occurring in 30–50% of cases, post-traumatic arthritis in 40–60%, and persistent pain with functional limitations being common.[6] The challenging pathoanatomy, involving disruption of both primary and secondary stabilizers of the elbow, contributed to the difficulty in achieving successful treatment.

Modern Understanding of Elbow Stability

Contemporary understanding of elbow biomechanics has revealed the critical importance of both bony and soft tissue stabilizer's. [7] The elbow's intrinsic stability depends on the interaction between:

Category	Components	Function
Primary Stabilizers	Ulnohumeral articulation	Main bony constraint
	Medial collateral ligament (MCL), anterior bundle	Medial stability
	Lateral collateral ligament (LCL) complex, ulnar LCL	Lateral stability
Secondary Stabilizers	Radiohumeral articulation	Assists in joint stability
	Joint capsule	Provides passive support
	Dynamic muscle stabilizers (common flexor and extensor tendons)	Active muscular stabilization

Research has demonstrated that coronoid fractures involving more than 50% of the coronoid height significantly compromise elbow stability, while fragments accounting for more than 10% of the coronoid process require surgical fixation for optimal outcomes.[8] The radial head serves multiple biomechanical functions, including valgus stability, anterior buttress against posterior dislocation, and axial load transmission through the forearm.[9] Early studies by Chen et al. documented high complication rates with traditional treatment approaches, including recurrent instability, stiffness, and chronic pain syndromes.[6]

CLASSIFICATION SYSTEMS

Radial Head Fractures - Mason Classification

The Mason classification, modified by Broberg and Morrey, remains the standard for radial head fracture assessment [10]:

Table 1: Mason Classification of Radial Head Fractures

Type	Description	Treatment Implications
I	Non-displaced or minimally displaced (<2mm)	Conservative vs. ORIF
II	Displaced partial articular fracture with/without comminution	ORIF preferred
III	Comminuted fracture involving the entire radial head	Replacement often necessary
IV	Radial head fracture with elbow dislocation	Always requires Surgical intervention

Coronoid Fractures - Regan-Morrey Classification

The Regan-Morrey classification stratifies coronoid fractures based on fragment size [11]:

Table 2: Regan-Morrey Classification of Coronoid Fractures

Type	Description	Stability Implications
I	Avulsion of the coronoid tip	Usually stable, may not require fixation
II	Single or comminuted fracture <50% of coronoid height	Potential instability often requires fixation
III	Fracture >50% of coronoid height	Significant instability always requires fixation

MATERIALS AND METHODS

Study Design and Population

This retrospective study was carried out at the Adesh Institute of Medical Sciences and Research, Bathinda, following approval from the Institutional Research and Ethics Committee. A total of 24 patients with terrible triad injuries of the elbow, treated between March 2018 and December 2024, were included in the analysis.

Inclusion Criteria:

- Post-traumatic terrible triad injury confirmed by radiographic imaging
- Age between 20 and 70 years
- Complete follow-up data available
- Minimum follow-up duration of 9 months

Exclusion Criteria:

- Age below 20 years or above 70 years
- Presence of inflammatory joint disease
- Pathological fractures
- Metabolic bone disorders
- Patients lost to follow-up

Patient Demographics and Injury Characteristics

The study population consisted of 22 males and 2 female with a mean age of 47 years (range 25-70 years). All injuries resulted from closed trauma with no neurovascular deficits at presentation.

Table 3: Mechanism of Injury Distribution

Mechanism of Injury	Number of Patients	Percentage
Fall on outstretched hand	21	87.5%
Direct trauma to the elbow	3	12.5%
Total	24	100%

Diagnostic Evaluation

All patients underwent comprehensive radiographic evaluation, including anteroposterior and lateral elbow radiographs. Computed tomography was performed in all cases to characterise fracture patterns, better assessment of comminution, and guide surgical planning, as three-dimensional imaging provides a superior assessment of complex fracture morphology compared to plain radiographs alone.[16] The diagnosis was established by identifying the classic triad of posterior elbow dislocation, radial head fracture, and coronoid process fracture.

Surgical Technique and Approach

Table 4: Surgical Approach Distribution

Surgical Approach	Number of Patients	Percentage
Trans-olecranon (posterior)	13	54.2%
Lateral approach (Kocher interval)	11	45.8%
Total	**24**	**100%**

Posterior Approach (n=13)

Used primarily for cases with associated trans-olecranon fractures. A thick soft tissue flap was raised to prevent skin necrosis. The proximal olecranon fragment with attached triceps was elevated proximally, providing excellent visualisation of the coronoid fracture site.

Lateral Approach (n=11)

Performed through the Kocher interval between the extensor carpi ulnaris and the anconeus muscle. This Approach provided adequate access for radial head and lateral collateral ligament repair.

Fracture Management

Protocol Radial Head

Management:

- ORIF was performed in 13 patients (54.2%)
  - Herbert screw fixation: 6 patients (Mason Type I)
  - Plate fixation: 7 patients (Mason Type II)
- Radial head replacement: 11 patients (45.8%) with extensive comminution (Mason Type III)

Coronoid Process Management:

- Type I (Regan-Morrey): 6 patients - anterior capsule repair with non-absorbable sutures (lasso technique)
- Type II (Regan-Morrey): 8 patients - cannulated screw fixation
- Type III (Regan-Morrey): 10 patients - mini-plate fixation

Ligamentous Reconstruction: Lateral collateral ligament (LCL) injury was identified in all patients and repaired using non-absorbable sutures. Medial collateral ligament repair was not required in any case due to adequate stability after LCL reconstruction and bony restoration.

Postoperative Management

A standardised rehabilitation protocol was implemented:

- **Week 0-2:** Posterior splint at 90° flexion, wound care
- **Week 2-3:** Passive motion exercises 45°-100° flexion, three times daily
- **Week 3-6:** Active-assisted exercises, extension limited to 30°-60° based on stability
- **Week 6-12:** Progressive strengthening and range of motion
- **Month 3+:** Intensive muscle rehabilitation program

OUTCOME MEASURES

Mayo Elbow Performance Score (MEPS)

The Mayo Elbow Performance Score was used as the primary outcome measure. This validated 100-point scoring system evaluates four domains:

Table 5: Mayo Elbow Performance Score Components

Domain	Maximum Points	Weight
Pain	45	45%
Range of Motion	20	20%
Stability	10	10%
Function	25	25%
Total	**100**	**100%**

MEPS Score Interpretation

- Excellent: 90-100 points
- Good: 75-89 points
- Fair: 60-74 points
- Poor: <60 points

RESULTS

Comprehensive Functional Outcomes Analysis

Out of the 24 patients evaluated, the majority (54.2%) achieved an excellent outcome with MEPS ranging between 90–100. A good outcome (75–89) was observed in 29.2% of patients, while 12.5% of patients had a fair outcome (60–74). Only one patient (4.1%) fell into the poor outcome category with a score below 60. Overall, the results indicate that most patients attained satisfactory to excellent recovery following treatment.

Table 6: Distribution of Functional Outcomes

Outcome Category	MEPS Range	Number of Patients	Percentage
Excellent	90–100	13	54.2%
Good	75–89	7	29.2%
Fair	60–74	3	12.5%
Poor	<60	1	4.1%
Total		**24**	**100%**

Detailed Range of Motion Analysis

Range of motion assessment at final follow-up demonstrated generally satisfactory restoration of elbow mobility, though some degree of stiffness remained a common finding. The postoperative range of motion outcomes are summarized in the table. The mean flexion achieved was 112° with a range of 95° to 135°. The average extension loss was 12°, varying between 0° and 25°. Consequently, the flexion–extension arc averaged 100°, with the lowest being 70° and the highest 130°. Regarding forearm rotation, the mean pronation was 48° (range 35°–65°), while supination averaged 62° with a range of 52° to 75°.While this represents some limitation compared to normal elbow motion, the achieved range falls within functional parameters for most activities of daily living.

Table 7: Range of Motion Outcomes at Final Follow-up

Parameter	Mean Value	Range
Flexion	112°	95°–135°
Extension Loss	12°	0°–25°
Flexion–Extension Arc	100°	70°–130°
Pronation	48°	35°–65°
Supination	62°	52°–75°

Pain Assessment and Patient-Reported Outcomes

Pain assessment at final follow-up showed encouraging results, with the majority of patients achieving satisfactory pain control. Eighteen patients (75%) reported complete absence of pain during normal daily activities, reflecting excellent pain relief. Six patients (25%) experienced mild discomfort, particularly during heavy lifting or extreme ranges of motion, though it did not interfere with routine activities. The pain in these patients was mild and intermittent, not requiring regular analgesics. Notably, none of the patients reported moderate or severe pain either at rest or during normal daily activity, highlighting effective management of post-traumatic pain. These favorable pain outcomes significantly influenced the overall MEPS, with most patients attaining high scores in the pain component.

Stability Assessment and Biomechanical Outcomes

Clinical stability assessment performed at final follow-up demonstrated successful restoration of elbow stability in all patients. All 24 elbows demonstrated stable concentric reduction with maintenance of joint congruency on both anteroposterior and lateral radiographs. No evidence of subluxation or dislocation was observed during clinical examination or stress testing. Varus- valgus stress testing revealed stable lateral and medial collateral ligament complexes in all patients, confirming successful ligamentous reconstruction. Posterolateral rotatory instability testing, performed using the pivot-shift test and posterolateral rotatory drawer test, was negative in all patients, indicating successful restoration of lateral collateral ligament function.

The absence of recurrent instability represents a significant achievement considering that this was historically the most common and feared complication of terrible triad injuries. This improvement can be attributed to a better understanding of the biomechanical requirements for elbow stability and more systematic approaches to surgical reconstruction. Radiographic assessment demonstrated maintenance of joint space and congruent reduction in all patients, with no evidence of progressive joint subluxation or loosening of the hardware.

Comprehensive Complications Analysis

The complication profile in our series was notably favourable compared to historical reports; however, specific issues remained prevalent. Four patients (16.7%) developed residual elbow stiffness that impacted their final functional scores, representing the most common long-term sequela. These patients demonstrated extension deficits greater than 20 degrees and/or flexion limitations that prevented them from achieving 120 degrees of flexion. All four patients with stiffness underwent intensive physiotherapy programs, and while improvement was achieved, complete restoration of motion was not possible. The stiffness appeared to correlate with the severity of initial soft tissue injury and the extent of surgical dissection required for reconstruction.

Table 8: Complications and Their Management

Complication	Number of Patients	Percentage	Management
Residual Stiffness	4	16.7%	Physiotherapy
Symptomatic Hardware	4	16.7%	Observation
Recurrent Instability	0	0%	-
Post-traumatic Arthritis	0	0%	-
Nerve Injury	0	0%	-
Infection	0	0%	-

Four patients (16.7%) who underwent posterior ulnar plating for associated trans-olecranon fractures developed symptomatic hardware, characterised by prominence of the plate causing discomfort during direct pressure or extreme flexion. However, none of these patients required hardware removal during the follow-up period, as the symptoms were tolerable and did not significantly impact function. The decision to observe rather than remove hardware was based on the maintained stability provided by the implants and the patients' acceptance of mild symptoms.

The absence of several historically common complications is particularly noteworthy. No patients developed recurrent instability, which had been reported in 30-50% of patients in earlier series. Similarly, no patients showed radiographic evidence of significant post-traumatic arthritis during the follow-up period, though longer-term observation will be necessary to assess this outcome definitively. No cases of infection, nerve injury, or heterotopic ossification were observed, likely reflecting improved surgical techniques and perioperative management protocols.

DISCUSSION

The findings of this study reinforce the evolving consensus that terrible triad injuries of the elbow, though complex and demanding, no longer justify their historically grim reputation when treated with modern surgical strategies and structured rehabilitation. Our cohort achieved a mean Mayo Elbow Performance Score (MEPS) of 82 points, with 79.2% of patients attaining excellent or good functional outcomes. This represents a marked improvement over earlier reports

and is in line with contemporary literature demonstrating the success of current treatment protocols. Stambulic et al., in their comprehensive scoping review, similarly observed functional recovery with MEPS scores typically ranging from 85 to 92, further supporting the assertion that these injuries are "no longer terrible" when managed appropriately.[2]

A particularly notable finding in our series was the complete absence of recurrent instability, a complication historically reported in 30–50% of cases and regarded as a hallmark of treatment failure in terrible triad injuries. This positive outcome reflects advances in our understanding of elbow biomechanics and the critical role of both primary stabilizers (ulnohumeral articulation, medial and lateral collateral ligaments) and secondary stabilizers (radiocapitellar joint and capsule). Consistent with previous biomechanical evidence, all patients in our study demonstrated disruption of the lateral collateral ligament, highlighting its role as the principal restraint against posterolateral rotatory instability.[7]

Interestingly, none of the patients required medial collateral ligament repair to achieve satisfactory stability and function. This observation aligns with the biomechanical work of King et al., who reported that restoration of the radial head combined with lateral collateral ligament repair provides sufficient resistance to both varus and posterolateral rotatory instability.[9] Taken together, these results highlight that the systematic restoration of bony architecture and lateral soft-tissue stabilizers is often sufficient to achieve durable stability and excellent outcomes in most patients with terrible triad injuries.

Our choice of surgical approach favored the lateral route whenever feasible, reserving the posterior approach for cases with associated olecranon fractures, consistent with current trends aimed at minimizing surgical morbidity while maintaining adequate visualization. In our series, posterior approaches were utilized in 58.3% of patients, primarily due to the high incidence of trans-olecranon fractures requiring posterior exposure for optimal fracture management. Wu et al. reported similar findings, noting that while lateral approaches provide sufficient access for most components of the terrible triad, posterior approaches allow superior visualization for complex coronoid reconstruction.[19]Notably, no wound complications or infections were observed in our cohort despite the extensive exposures, reflecting improved soft tissue handling and perioperative management strategies.

Management of radial head fractures continues to evolve, particularly regarding repair versus replacement. In our study, radial head replacement was performed in 41.7% of cases, reserved for Mason Type III fractures with extensive comminution, while anatomical repair was prioritized for reconstructable fractures. This aligns with contemporary recommendations. Chen et al., in a systematic review and meta-analysis, reported no significant difference in functional outcomes between fixation and replacement, but noted replacement provides more predictable results in severely comminuted fractures. [20] Our decision-making approach appears to have achieved satisfactory outcomes across both treatment modalities.

Coronoid fracture management followed established guidelines: Type I fractures were treated with capsular repair, Type II with screw fixation, and Type III with plate fixation. Distribution in our cohort was 25% Type I, 33% Type II, and 42% Type III. Fixing Type II and III fractures while managing Type I fractures with capsular repair alone provided adequate stability, as evidenced by the lack of recurrent instability. Early surgical intervention—typically within one week of injury—likely contributed to favorable outcomes by preventing soft tissue contractures, preserving tissue quality, and enabling timely rehabilitation.

Postoperatively, the mean flexion achieved was 112°, with a mean extension loss of 15°, resulting in a flexion–extension arc of 100°, which, although slightly limited compared to normal values, remains functionally adequate for most daily activities. This compromise appears acceptable given the stability and pain-free function restored in our cohort.

Rehabilitation focused on early controlled motion while protecting repaired structures. Passive motion from 45° to 100° began at two weeks postoperatively, progressing to active motion at three weeks. This approach effectively balanced early mobilization with protection of repairs, contributing to satisfactory range of motion outcomes.

Overall, our findings support the growing consensus that terrible triad injuries, when managed according to structured surgical and rehabilitation protocols, can achieve predictable and satisfactory outcomes. Future research should focus on optimizing surgical decision-making, improving classification systems, exploring biological augmentation, establishing standardized functional outcomes, and evaluating long-term durability. Personalization of treatment strategies based on patient-specific factors may further enhance outcomes and reduce complications.

CONCLUSION

The terrible triad of the elbow, while remaining a complex and challenging injury, no longer merits its historically ominous designation when managed with contemporary surgical techniques and rehabilitation protocols. Our study demonstrates that systematic attention to restoration of bony anatomy and ligamentous structures, combined with appropriate surgical approaches and early mobilisation, can achieve excellent functional outcomes in the majority of patients.

Key factors contributing to successful outcomes include: thorough preoperative planning with CT imaging, anatomical restoration of radial head and coronoid fractures, systematic reconstruction of the lateral collateral ligament complex, and structured rehabilitation emphasising early motion within stability constraints.

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