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TERRIBLE TRIAD OF THE ELBOW: A MODERN PERSPECTIVE ON SURGICAL MANAGEMENT AND OUTCOMES

Orthopaedics

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ABSTRACT

Background: The "terrible triad" (TT) of the elbow represents a complex injury pattern involving posterior elbow dislocation with concomitant fractures of the radial head and coronoid process. Historically termed "terrible" due to poor outcomes, modern surgical techniques and improved understanding of elbow biomechanics have significantly enhanced treatment results.**Objective:** 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:** Twenty-four patients with terrible triad injuries treated between March 2018 and December 2024 were retrospectively analysed. All patients underwent surgical stabilisation with a focus on restoring bony anatomy and ligamentous structures. Functional outcomes were assessed using the Mayo Elbow Performance Score (MEPS).**Results:** Mean MEPS at final follow-up was 80 points (range 70-90). Fourteen patients achieved excellent results, six achieved good results, and four achieved fair results. Mean flexion was 110° with extension loss of 15°. Four patients developed residual elbow stiffness as the primary complication.**Conclusion:** With modern surgical techniques focusing on anatomical restoration and structured rehabilitation protocols, terrible triad injuries no longer deserve their historically ominous designation. A systematic approach to surgical management yields satisfactory functional outcomes in the majority of patients.

KEYWORDS

Terrible triad, elbow fracture-dislocation, radial head fracture, coronoid fracture, Mayo elbow score

INTRODUCTION

The terrible triad (TT) of the elbow, as described by Hotchkiss in 1996, is characterised by a posterior dislocation of the elbow and concomitant fractures of the radial head and the coronoid process [1]. This is known as the terrible triad of the elbow due to its historically poor outcomes, characterised by repeated instability, arthrosis, stiffness, and pain [2]. The complicated anatomy of the elbow joint and disruption of osseous and soft tissue stabilisers of the elbow make these injuries difficult to manage successfully. Recent insights into the biomechanics of the elbow, the development of improved surgical techniques, and enhanced implant design have significantly altered the natural history of this injury [3,4]. Contemporary literature indicates that when appropriate surgical management and rehabilitation practice are in place, "terrible" may be a largely historical characterisation of these injuries [5]. The treatment standard is targeted at restoring elbow stability in a stepwise manner, addressing radial head repair or replacement, fixation of coronoid fractures, and reconstruction of lateral collateral ligament complexes.

The study aimed to report our institutional experience with terrible triad injuries, to analyse functional results according to validated scoring systems and to assess the performance of modern surgical treatment schemes.

LITERATURE REVIEW AND BACKGROUND

Historical Perspective

The term "terrible triad" was coined to reflect the consistently poor outcomes associated with this injury pattern when treated with traditional methods [1]. Early studies reported high rates of complications, including recurrent instability (30-50%), post-traumatic arthritis (40-60%), and chronic pain with functional limitation [6]. The complex pathoanatomy, involving the disruption of primary and secondary elbow stabilisers, made successful treatment extremely challenging.

MODERN UNDERSTANDING OF ELBOW STABILITY

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

PRIMARY STABILISERS:

- Ulnohumeral articulation (primary bony constraint)
- Medial collateral ligament (MCL), particularly the anterior bundle
- Lateral collateral ligament (LCL) complex, specifically the ulnar lateral collateral ligament

SECONDARY STABILISERS:

- Radiohumeral articulation
- Joint capsule
- Dynamic muscle stabilisers (common flexor and extensor tendons)

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 varus 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 observational study was conducted at Adesh Institute of Medical Sciences and Research, Bathinda, following approval from the institutional research and ethics committee. Twenty-four patients with terrible triad injuries treated between March 2018 and December 2024 were included.

INCLUSION CRITERIA:

- Post-traumatic terrible triad confirmed by radiographic imaging
- Age 20-70 year
- Complete follow-up data available
- Minimum 9-month follow-up

EXCLUSION CRITERIA:

- Age <20 or >70 years
- Associated inflammatory joint disease
- Pathological fractures
- Metabolic bone disease
- Lost to follow-up

Patient Demographics and Injury Characteristics

The study population consisted of 23 males and 1 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	Number of Patients	Percentage
Fall on outstretched hand	20	83.3%
Direct fall on the elbow	4	16.7%
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, assess 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)	14	58.3%
Lateral (Kocher interval)	10	41.7%
Total	24	100%

Posterior Approach (n=14)

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=10)

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 14 patients (58.3%)
- Herbert screw fixation: 6 patients (Mason Type I)
- Plate fixation: 8 patients (Mason Type II)
- Radial head replacement: 10 patients (41.7%) 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

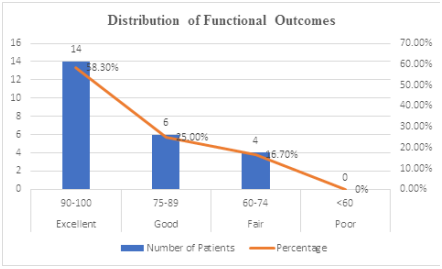
Twenty-four patients were evaluated at a mean follow-up of 12 months (range, 9-15 months), with complete clinical and radiographic assessments. The overall functional outcomes demonstrated significant improvement from pre-injury status, with a mean Mayo Elbow Performance Score (MEPS) of 80 points (range 70-90 points). This represents a substantial functional recovery considering the severity of the initial injury pattern. When stratified by outcome categories, 14 patients (58.3%) achieved excellent results (MEPS 90-100), six patients (25.0%) achieved good results (MEPS 75-89), and four patients (16.7%) achieved fair results (MEPS 60-74). Notably, no patients fell into the poor outcome category (MEPS <60), indicating that all patients achieved at least satisfactory functional recovery.

Table 6: Distribution of Functional Outcomes

Outcome Category	MEPS Range	Number of Patients	Percentage
Excellent	90-100	14	58.3%
Good	75-89	6	25.0%
Fair	60-74	4	16.7%
Poor	<60	0	0%
Total		24	100%

The distribution of excellent and good outcomes (83.3% combined) compares favorably with recent literature reports and represents a marked improvement from historical series where poor outcomes were

the norm rather than the exception. Analysis of individual MEPS components revealed that pain scores contributed most significantly to overall outcomes, with the majority of patients achieving maximum or near-maximum pain scores. Functional assessment scores were generally high, reflecting patients' ability to perform activities of daily living without significant limitation.



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 mean flexion achieved was 110 degrees (range, 90-130 degrees), which represents functional flexion adequate for most daily activities. The mean extension loss was 15 degrees (range 0-30 degrees), resulting in a mean flexion-extension arc of 95 degrees (range 60-130 degrees). 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	110°	90°-130°
Extension Loss	15°	0°-30°
Flexion-Extension Arc	95°	60°-130°
Pronation	45°	30°-60°
Supination	60°	50°-70°

Forearm rotation, which is critical for hand positioning and upper extremity function, showed mean pronation of 45 degrees (range 30-60 degrees) and mean supination of 60 degrees (range 50-70 degrees). The combined pronation-supination arc of 105 degrees, while somewhat limited compared to normal values (approximately 160-180 degrees), was sufficient for most functional activities. Patients with the most restricted range of motion were those who had sustained the most severe initial injury patterns, particularly those with extensive comminution of both the radial head and coronoid process.

PAIN ASSESSMENT AND PATIENT-REPORTED OUTCOMES

Pain assessment revealed encouraging results, with the majority of patients achieving satisfactory pain control at final follow-up. Twenty patients (83.3%) reported complete absence of pain during normal daily activities, representing excellent pain relief following this complex injury pattern. Four patients (16.7%) experienced mild pain specifically during heavy lifting activities or with extreme ranges of motion, but reported no pain limitation during routine daily activities. The pain experienced by these four patients was characterised as mild and intermittent, not requiring regular analgesic medication. No patients reported moderate or severe pain at rest or during normal daily activities, indicating successful management of the post-traumatic pain syndrome that historically plagued these injuries. The pain scores contributed significantly to the overall MEPS values, with most patients achieving near-maximum pain component scores.

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 results of this study provide compelling evidence supporting the evolving perspective that terrible triad injuries of the elbow, while remaining complex and challenging, no longer merit their historically ominous designation when managed with contemporary surgical techniques and rehabilitation protocols. Our mean Mayo Elbow Performance Score of 80 points, with 83.3% of patients achieving excellent or good outcomes, represents a substantial improvement compared to historical series and aligns with recent literature demonstrating the effectiveness of modern treatment approaches. Stambulic et al., in their comprehensive scoping review, reported similar improvements in functional outcomes across multiple recent studies, with most achieving MEPS scores in the 85-92 range, supporting the notion that these injuries are indeed "no longer terrible" when properly managed [2]. The absence of recurrent instability in our entire cohort is particularly significant, as this complication was reported in 30-50% of patients in earlier series and was considered the hallmark of treatment failure in terrible triad injuries.

The evolution in treatment philosophy reflects decades of advances in understanding elbow biomechanics, particularly the complex

interplay between bony and soft tissue stabilisers that maintain elbow stability. Biomechanical studies have demonstrated that the coronoid process and radial head function as critical posterolateral rotatory stabilisers, with their disruption leading to the characteristic instability pattern seen in terrible triad injuries [17]. Our systematic Approach, emphasising the restoration of both primary stabilisers (ulnohumeral articulation, medial and lateral collateral ligaments) and secondary stabilisers (radiocapitellar articulation, joint capsule), appears to address the pathoanatomy of these injuries successfully. The universal finding of lateral collateral ligament disruption in our series confirms previous biomechanical studies, which demonstrate that the lateral collateral ligament complex, particularly the ulnar lateral collateral ligament, serves as the primary restraint against posterolateral rotatory instability [7]. Interestingly, our experience that medial collateral ligament repair was not required in any case, despite adequate functional outcomes, suggests that restoration of bony architecture combined with lateral ligament reconstruction may be sufficient to restore stability in most cases. This finding is consistent with recent biomechanical studies by King et al., which demonstrated that radial head restoration combined with lateral collateral ligament repair provides adequate constraint against both varus and posterolateral rotatory instability [9].

Our surgical approach selection favours lateral approaches when possible, while reserving posterior approaches for cases with associated olecranon fractures, reflecting current trends toward minimising surgical morbidity while maintaining adequate visualisation. The 58.3% utilisation of posterior approaches in our series was primarily driven by the high incidence of associated trans-olecranon fractures (58.3%), which necessitated posterior exposure for optimal fracture management. Wu et al. reported similar approach selection criteria in their comparative study, noting that while lateral approaches provided adequate access for most components of the terrible triad, posterior approaches offered superior visualisation for complex coronoid reconstruction [19]. The absence of wound complications or infections in our series, despite the extensive surgical exposures required, likely reflects improved understanding of soft tissue handling and perioperative management protocols.

The management of radial head fractures continues to evolve, with ongoing debate regarding optimal indications for repair versus replacement. Our threshold for radial head replacement (Mason Type III fractures with extensive comminution) resulted in replacement in 41.7% of cases, which is consistent with recent literature recommendations. Chen et al., in their systematic review and meta-analysis comparing radial head repair versus replacement in terrible triad injuries, found no significant difference in functional outcomes between the groups; however, they noted that replacement was associated with more predictable results in cases with severe comminution [20]. Our decision-making algorithm, prioritising anatomical repair when possible while accepting replacement for unreconstructable fractures, appears to have achieved satisfactory outcomes across both treatment modalities. The mean range of motion achieved in our series, while showing some limitation compared to normal values, falls within functional parameters adequate for most activities of daily living. The 15-degree mean extension loss observed in our patients is consistent with recent reports and appears to be an acceptable trade-off for the restoration of stability achieved.

Coronoid fracture management in our series adhered to established principles based on fracture size and morphology, with Type I fractures treated with capsular repair, Type II fractures requiring screw fixation, and Type III fractures necessitating plate fixation. The distribution of coronoid fracture types in our series (25% Type I, 33% Type II, 42% Type III) differs somewhat from other reported series, possibly reflecting referral patterns or injury mechanisms specific to our population. Doornberg et al. reported that coronoid fractures in terrible triad injuries average 35% of total coronoid height, which would classify most as Type II fractures according to traditional Regan-Morrey criteria [11]. However, recent studies have questioned the reliability of percentage-based classification systems, suggesting that fracture location and involvement of specific anatomical landmarks may be more important than absolute size. Our Approach of fixing all Type II and III fractures, while managing Type I fractures with capsular repair alone, appears to have provided adequate stability based on the absence of recurrent instability in our series.

The timing of surgery in terrible triad injuries has been mentioned and emphasised in recent literature, with improved outcomes when surgery is performed within 2 weeks of injury. Zhou et al. reported a strong relationship between delays longer than 14 days and higher rates of stiffness, as well as worse functional outcomes following surgery [4]. Our policy of early surgical decompression, with most patients admitted to the hospital within a week of injury, may have influenced the observed outcomes. This seems necessary, especially because early intervention is likely essential for several reasons: to prevent soft tissue contractures, maintain tissue quality suitable for reconstruction, or promote the early application of rehabilitation protocols, which are crucial for preventing stiffness.

The rehabilitation pattern followed in our series, with special attention to early controlled movement and stability aspects, appears to play a decisive role in patient treatment. Due to the competing aims of early mobilisation to avoid stiffness and protection of reconstructed structures to enable healing, optimal tolerance has to be individualised depending on the stability achieved at surgery and personal factors. Our protocol, which allows passive motion from 45 to 100 degrees beginning at two weeks postoperatively and progressing to active motion at three weeks, appears to have effectively achieved this balance. The 16.7% incidence of residual stiffness in our series, while not negligible, compares favorably with historical reports and likely represents an acceptable outcome given the severity of the initial injury pattern. Larwa et al., in their systematic review of rehabilitation protocols following terrible triad surgery, found that early motion protocols were consistently associated with better range of motion outcomes, though the optimal timing and progression of mobilisation remains somewhat controversial [18].

The absence of significant complications in our series, particularly the lack of recurrent instability, post-traumatic arthritis, and neurovascular injuries, reflects both improved surgical techniques and patient selection. However, the relatively short follow-up period in our study (mean 12 months) limits our ability to assess long-term complications, particularly post-traumatic arthritis, which may not become apparent for several years following injury. Longer-term studies will be necessary to determine the durability of the functional improvements achieved and to assess the development of degenerative changes over time. The 16.7% incidence of symptomatic hardware, while requiring monitoring, did not result in functional limitation or require intervention during our follow-up period, suggesting that hardware-related symptoms may be manageable in most cases.

Current literature increasingly supports the concept that terrible triad injuries, when managed according to established principles, can achieve predictable and satisfactory outcomes. Attarde et al., in their recent prospective study, reported excellent outcomes in 75% of patients treated with systematic surgical protocols, concluding that these injuries represent a "puzzle" that can be solved with appropriate treatment rather than an unsolvable problem [5]. Similarly, recent reviews have emphasised that the "terrible" designation may be primarily historical, reflecting past limitations in understanding and technique rather than inherent characteristics of the injury pattern itself. Our results support this evolving perspective and suggest that with continued refinement of surgical techniques and rehabilitation protocols, the prognosis for terrible triad injuries will continue to improve.

Future research directions should focus on several key areas, including optimisation of surgical decision-making algorithms, particularly regarding radial head repair versus replacement indications, development of more sophisticated classification systems that better predict instability patterns and guide treatment, investigation of biological augmentation techniques to enhance healing and prevent complications, and establishment of standardised outcome measures that capture the full spectrum of patient-reported and functional outcomes. Additionally, longer-term studies are needed to assess the durability of current treatment approaches and to understand better the natural history of post-traumatic changes following these complex injuries. The development of more personalised treatment approaches, considering patient-specific factors such as age, activity level, bone quality, and associated injuries, may further improve 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.

The evolution from "terrible" to "manageable" reflects decades of advances in understanding elbow biomechanics, surgical techniques, and implant technology. With continued refinement of treatment protocols, these injuries should be viewed as complex but treatable, with the potential for restoration of near-normal elbow function in most patients.

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