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Management of Radial Head Fractures in Complex Elbow Injuries: An Expanded Comprehensive Review

Muslim Aqeel Abbas
Department of Surgery, College of Medicine, Wasit University, Iraq
Email: muslim.aqeel@uowasit.edu.iq

Abstract: Radial head fractures are a pivotal component of complex elbow instability, particularly within the context of fracture-dislocations and the terrible triad of the elbow. These high-energy injuries involve combined osseous and ligamentous disruption, posing significant challenges in diagnosis, surgical planning, and long-term functional outcomes. The radial head plays a critical biomechanical role in load transmission (40–60%), valgus stability, and proximal radial alignment, rendering its structural integrity essential for normal elbow kinematics and forearm rotation. This expanded comprehensive review synthesizes current evidence on the epidemiology, anatomy, biomechanics, classification systems, imaging modalities, treatment algorithms, surgical techniques, rehabilitation protocols, and complications associated with radial head fractures in complex elbow injuries. Special emphasis is placed on decision-making in polytrauma patients, osteoporotic bone, revision scenarios, and emerging technologies. A systematic literature review was conducted using PubMed, Scopus, Web of Science, and Cochrane Central Register of Controlled Trials (CENTRAL) for studies published between January 2000 and June 2024. Keywords included radial head fracture, elbow instability, terrible triad, ORIF, radial head arthroplasty, LUCL reconstruction, coronoid fracture, and elbow dislocation. Priority was given to randomized controlled trials (RCTs), meta-analyses, prospective cohort studies, clinical guidelines, and biomechanical investigations. The incidence of radial head fractures ranges from 3 to 10 per 100,000 person-years, with a peak in adults aged 30–60 years following a fall on an outstretched hand (FOOSH). In complex injuries, associated lesions include lateral ulnar collateral ligament (LUCL) rupture (up to 85%), coronoid fractures (70%), and medial collateral ligament (MCL) insufficiency (30%). Non-displaced fractures (Mason I) are typically managed conservatively. Displaced but reconstructible fractures (Mason II) benefit from open reduction and internal fixation (ORIF). Comminuted fractures (Mason III/IV), particularly in unstable elbows, require radial head arthroplasty, as isolated excision leads to valgus instability, proximal radial migration, and progressive radiocapitellar arthritis. Modern modular prostheses allow precise anatomical restoration of radial head height, diameter, and neck angle, minimizing complications. Combined bony and soft tissue reconstruction—radial head replacement, LUCL reconstruction, and coronoid fixation—restores stability in over 90% of cases. Emerging techniques include arthroscopic-assisted fixation, 3D-printed patient-specific implants, biologic augmentation with platelet-rich plasma (PRP), and robotic-assisted implant alignment. Successful management of radial head fractures in complex elbow injuries demands a structured, protocol-driven approach integrating accurate imaging, biomechanical understanding, timely surgical intervention, and early controlled rehabilitation. Adherence to established treatment algorithms significantly improves functional outcomes and reduces complication rates. Future directions include enhanced implant longevity, regenerative medicine strategies, and integration of artificial intelligence in preoperative planning.

Keywords: Radial Head Fracture, Terrible Triad of The Elbow, Elbow Fracture-Dislocation, Radial Head Arthroplasty, Open Reduction Internal Fixation (ORIF), LUCL Reconstruction, Coronoid Fracture, Elbow Instability

1. Introduction

Of all elbow fractures, radial head fractures account for approximately one third of cases, and represent one of the most common injuries sustained after adult orthopedic trauma [1]. Many studies suggest that these injuries occur most frequently in patients between the ages of approximately 30 and 60, with a predominance of females being reported in some epidemiologic series. Mechanisms of injury include falls on an outstretched hand (FOOSH) with the elbow extended and forearm pronated [2]. The injury not only is common, but also may incur significant economic burden with an average time off work of 8 – 12 weeks and long-term disability seen in upwards of 15% especially in patients who are manual laborers and physically demanding occupations [3]. This time off work is not solely an economic burden to the worker and employer, but significantly impacts their productivity, longer-term healthcare costs, and overall patient-reported quality of life measures with validated measures like the Disabilities of the Arm, Shoulder and Hand (DASH) and Short Form-36 (SF-36) [4].

Though isolated radial head fractures may be treated non-operatively, the inclusion of a dislocated elbow injury, associated coronoid process fractures, and lateral ligamentous injury indicates a category of high-energy unstable injuries requiring timely and accurate surgical intervention. The terrible triad of the elbow, a term first used by Hotchkiss in 1996, describes the triad of posterior or posterolateral elbow dislocation, fracture of the radial head, and fracture of the coronoid [5]. The injury pattern degenerates into global elbow instability due to the failure of bony and soft tissue stabilizers occurring simultaneously. If the osseoligamentous integrity is not restored appropriately, the chances of redislocation, chronic pain and stiffness, and post-traumatic arthritis are greater than 50% [6].

Radial head excision was historically considered a treatment option, especially with more comminuted fractures. Unfortunately, long-term follow-up studies have demonstrated that excision alone, particularly with ligamentous injury, had causal relationships to a valgus instability with capitellar erosion, proximal radial migration and progressive degeneration or loss of radiocapitellar joint function [7]. In approximately the last 20 years, we have witnessed a paradigm shift, which now favours anatomical restoration of the elbow with open reduction internal fixation (ORIF), radial head arthroplasty along with ligamentous reconstruction as a form of management. This described evolution of elbow reconstruction and rehabilitation has been facilitated by the continued advancement of our understanding of elbow biomechanics, implant system development and surgical techniques. Improved clinical outcomes can be maintained with the combination of modularity of implants, intraoperative fluoroscopy, and a well-structured rehabilitation protocol. The evolution of classification systems, namely Pugh's treatment-based algorithm, has established a way for the surgeon to make reproducible and predictable decisions in complex cases based on the evidence [8].

More recent literature emphasizes the role of early surgical stabilization and multimodal rehabilitation in limiting stiffness and enhancing function recovery. For example, a recent multicenter cohort study demonstrated significantly different outcomes in Mayo Elbow Performance Scores (MEPS) for reconstruction from elbow fracture-dislocation (89 vs 72, $p < 0.01$) for patients that had reconstruction <7 days from injury compared to patients that had reconstruction based on delayed injury timing [9]. Biologic augmentation (e.g., platelet-rich plasma), 3D printed patient specific implants, and robotic-assisted alignment are examples of interventions beginning to disrupt our established care pathways and offer renewed hope for long-term recovery. This review incorporates a thorough, evidence-based overview of the literature evaluating the management of radial head fractures in the context of complex elbow injury. The emphasis is on classification, surgical decision making, technical aspects, and long-term outcomes. Emerging technologies, regenerative strategies, and applications of artificial intelligence in preoperative planning are also highlighted. The goal of this review is to be the definitive resource for orthopedic surgeons managing this complex area of upper extremity trauma.

2. Anatomy and Biomechanics

2.1. Osseous Anatomy

The radial head is a disc-shaped structure with concave articular surface that articulates with the convex capitellum of the distal humerus, forming the radiocapitellar joint. The radiocapitellar joint is a vital articulation due to the load transmission and forearm rotational capability it provides [6]. The mean diameter of the radial head is approximately 20 to 24 mm, and the neck shaft angle of the radius stains anteriorly in a 15 to 20° angle as compared to the longitudinal axis of the radial shaft [5]. The mean depth of the articular cartilage on the head of the radius is 1.5 to 2.0 mm, important for the shock-absorbing properties and congruency of the joint. Correct screw placement is important to prevent neurovascular injury and to maintain a competent joint when using an open reduction internal fixation (ORIF) method. The anterolateral quadrant of the radial head (between 1 and 3 o'clock when the forearm is supinated) is designated as the safe zone for instrumentation as it avoids the posterior interosseous nerve (PIN), which courses closely along the radial neck in the supinator muscle [5]. The risk of PIN palsy, a well documented complication occurring in 3-7% of cases, is increased if the anterolateral quadrant of the radial head is violated during fixation [9].

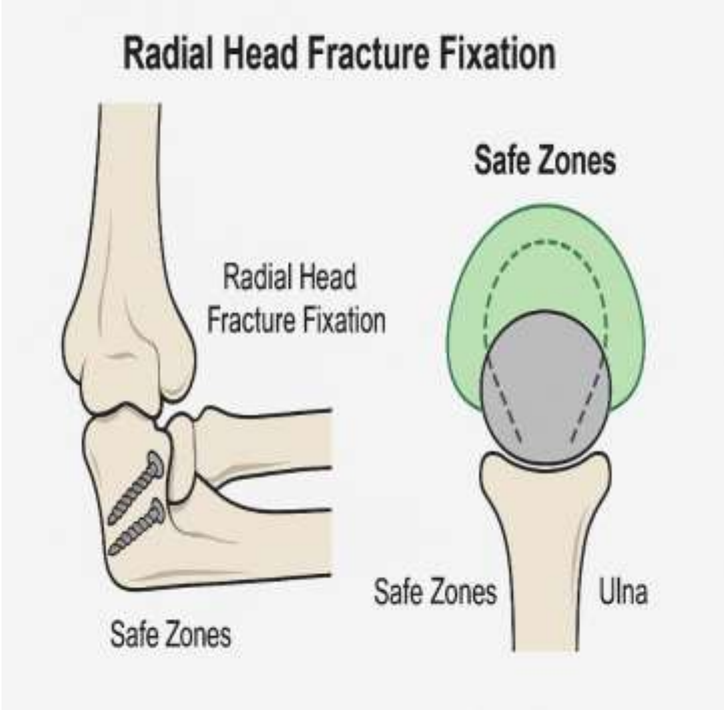

Figure 1. Radial head fracture fixation with screw trajectories and safe zones
Illustration showing optimal screw placement within the anterolateral quadrant (1–3 o'clock position in supination), avoiding the posterior interosseous nerve. Intraoperative fluoroscopic views (AP, lateral, oblique) guide accurate trajectory.

2.2. Ligamentous and Soft Tissue Stabilizers

Elbow stability is maintained by a complex network of static and dynamic restraints. On the lateral side, the lateral ulnar collateral ligament (LUCL) is the primary restraint against valgus and posterolateral rotatory instability (PLRI), originating from the lateral epicondyle and inserting onto the supinator crest of the ulna [6]. The annular ligament encircles the radial neck, preventing dislocation, while the quadrate ligament stabilizes the proximal radioulnar joint (PRUJ).

Medially, the anterior bundle of the medial collateral ligament (MCL) resists valgus and external rotation forces, with its origin at the humeral epicondyle and insertion at the sublime tubercle of the ulna. Injury to the MCL is less common in isolated radial head fractures but becomes clinically significant in terrible triad injuries when valgus instability persists after lateral-side reconstruction.

2.3. Biomechanical Roles of the Radial Head

The radial head contributes to 40–60% of axial load transmission across the elbow joint during activities such as pushing, lifting, and weight-bearing [6]. It acts as a mechanical spacer that resists lateral joint gapping, thereby maintaining valgus stability. Biomechanical studies have demonstrated that combined LUCL deficiency and radial head excision result in a 300% increase in valgus laxity compared to the intact state [7].

Furthermore, the radial head prevents proximal migration of the radius; excision leads to upward displacement of 4–6 mm, altering the center of rotation and increasing stress on the ulnohumeral joint [8]. This phenomenon, termed proximal radial migration, represents a classic radiographic sign of ineffective radial head management, and is a powerful predictor of poor outcomes. The radial head also plays an important role in forearm rotation, allowing a congruency of the radiocapitellar and proximal radioulnar joints. The inability of the head to carry out these functions will alter elbow kinematics and hasten degenerative changes, resulting in post-traumatic osteoarthritis.

2.4. The Three-Column Concept of Elbow Stability

A contemporary biomechanical model to explain elbow stability is called the three-column model, which explains the elbow as three osseoligamentous columns: medial, central, and lateral [16]. This model offers an understanding of how failure of one column or columns contributes to progressive instability.

Medial column: Composed of the medial collateral ligament (MCL) and the medial aspect of the distal humerus and ulna. It resists valgus stress.

- Central column: Includes the ulnohumeral joint and the coronoid process. It acts as the keystone of anterior-posterior stability.
- Lateral column: Comprised of the radiocapitellar joint, LUCL, and annular ligament. It resists varus and posterolateral rotatory forces.

In complex elbow injuries such as the terrible triad, at least two columns are disrupted (typically lateral and central), leading to global instability. The radial head, as part of the lateral column, not only contributes to valgus stability but also serves as a secondary restraint to posterior translation of the radial head itself. When both the radial head and coronoid are fractured, the ring concept of the elbow is broken, resulting in a high risk of redislocation unless both bony components are restored [17].

This conceptual model has profound clinical implications: successful treatment must address all unstable columns. For example, in terrible triad injuries, fixation of the coronoid (central column), radial head arthroplasty (lateral column), and LUCL reconstruction (lateral soft tissue) are often required to achieve stability.

2.5. Finite Element Analysis (FEA) in Radial Head Biomechanics

The growth of computational biomechanics has made Finite Element Analysis (FEA) a valuable resource for simulating stress distribution, performance of implants, and stability of fractures in the context of radial head injuries [18]. Finite Element Analysis or FEA generates three-dimensional models that correspond with CT scans; all models are translated into a mesh of elements, creating connectivity, and allowing loads to be applied while simulating the application of each load in varying physiological conditions.

Research involving FEA has found that an anatomical mismatch in size regarding radial head prostheses, even in the context of radial head undersizing by 2mm, will significantly increase the contact pressures on the capitellum and increase stresses at the coronoid region possibly leading to increased cartilage wear and ultimately to nonunion [19].

FEA models have also been researched alongside screw placement in cases where Mason II fractures were present. A study conducted in 2023 noted that two parallel headless screws that were externally 120° apart, shared load distribution among their placement, which mitigated micromotion in both the parallel format over divergent screw position. The overall armature of load distribution and micromotion node retention lessened the risk of consequential delayed or re-displacement events occurring in fast-trauma [21].The computational models mentioned in the studies above will soon serve as a routine utility in the perioperative planning and implant design, providing a personalized approach to complex elbow reconstruction. While not typically available outside of a research setting, the utilization of FEA in conjunction with AI planning systems in the future will be integrated into surgical strategies that will optimize the outcomes through real time analysis.

3. Injury Patterns and Classification Systems

3.1. Mason Classification (1954)

The Mason classification represents the most common classification system for radial head fractures:

• Type I: undisplaced or minimally displaced fracture (<2 mm);

• Type II: displaced fracture, with less than 50% of the articular surface;

• Type III: Comminuted fracture with greater than 50% of the articular surface involved;

• Type IV: radial head fracture with an elbow dislocation;

Despite widespread usage, the Mason classification demonstrates significant interobserver variability (kappa values ranging from 0.2 to 0.4) and disregards concomitant ligamentous injuries, constraining its use to influence treatment of complex injuries [8]. Additionally, it does not take into account the extent of soft tissue disruption or the amount of coronoid involvement, both significant contributors to elbow stability.

3.2. Broberg and Morrey Classification (1986)

This radiographic classification quantifies long-term outcomes:

• Grade I: normal joint architecture;

• Grade II: mild joint incongruity;

• Grade III: severe deformity;

• Grade IV: post-traumatic osteoarthritis;

This classification is mainly meant for measuring outcomes, rather than for acute management. It provides a way to quantify degenerative change, following radial head injury [9].

3.3. Regan and Morrey Classification of Coronoid Fractures

Coronoid involvement plays a key role in determining stability.

• Type I: avulsion fracture of the tip;

• Type II: less than 50% - of the coronoid height;

• Type III: more than 50% - including the anteromedial

Fractures involving the anteromedial facet are particularly significant, as this region serves as the primary insertion site for the anterior bundle of the MCL. These injuries are often underestimated on plain radiographs and require computed tomography (CT) for accurate diagnosis [10].

3.4. Schenck Classification of Elbow Dislocations

Categorizes dislocations based on associated injuries:

- LE: Simple lateral dislocation.
- PE: Posterolateral dislocation.
- PE + RH: With radial head fracture.
- PE + RH + CF: With coronoid fracture (terrible triad).
- DRUJ: Additional distal radioulnar joint injury.

3.5. Pugh's Treatment-Based Classification (2004)

Pugh et al. proposed a clinical algorithm integrating fracture morphology and instability:

- Isolated Mason I/II: Conservative or ORIF.
- Radial head fracture with dislocation: ORIF or arthroplasty with LUCL repair.
- Terrible triad: Radial head arthroplasty, coronoid fixation, LUCL reconstruction [11].

This classification has become a cornerstone in modern treatment protocols, bridging the gap between radiographic findings and clinical decision-making.

3.6. Critical Appraisal of Current Classification Systems

While the Mason, Regan-Morrey, and Pugh systems have served as foundational tools, they exhibit significant limitations in clinical applicability and reproducibility.

The Mason classification is overly simplistic and fails to guide treatment in the presence of concomitant soft tissue injuries. A Mason Type III fracture with intact ligaments may be stable and amenable to ORIF, whereas an identical fracture with LUCL rupture constitutes a terrible triad requiring arthroplasty and ligamentous reconstruction.

To address these shortcomings, more comprehensive systems have been developed. The AO/OTA Classification for Elbow Fractures (2018) classifies radial head fractures under Type 21-C (intra-articular, multifragmentary), with subtypes based on comminution and displacement [12].

More recently, the Rozell Classification (2021) integrates osseous injury, ligamentous disruption, and instability pattern into a numerical score (1–4), demonstrating substantial interobserver agreement ($\kappa = 0.72$) and strong correlation with surgical complexity [13].

Despite these advances, no single system is universally adopted. Future classifications must be dynamic, treatment-oriented, and prospectively validated.

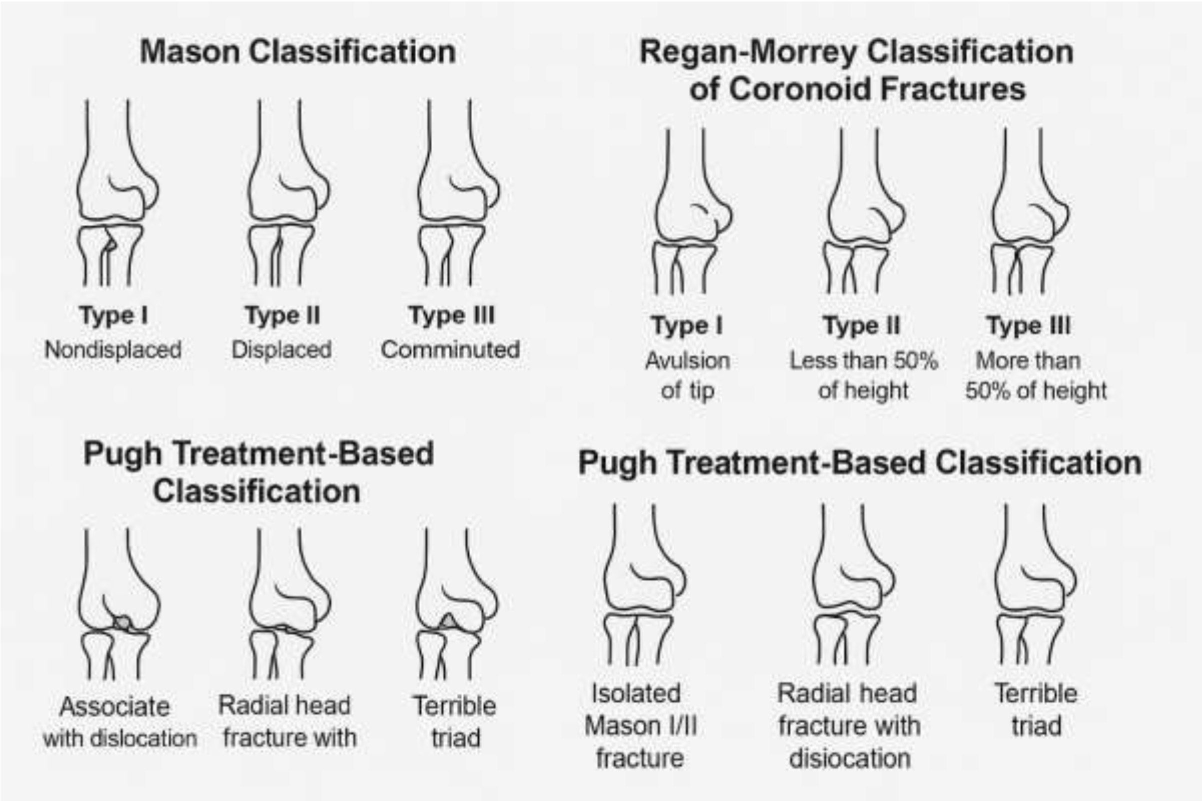

Figure 2. Classification systems (Mason, Regan-Morrey, Pugh, etc.)
Comparative diagram illustrating Mason types I–IV, Regan-Morrey coronoid fracture types, Schenck dislocation patterns, and Pugh's treatment algorithm.

4. Diagnostic Workup

4.1. Clinical Evaluation

Patients present with pain, swelling, tenderness over the radial head, and limited range of motion, especially in pronation and supination. Neurovascular assessment is essential, focusing on the posterior interosseous nerve (PIN) and ulnar nerve.

4.2. Imaging Evaluation

Standard radiographs include AP, lateral, and 45° pronated oblique views. CT scanning is indicated in all displaced or suspected comminuted fractures to assess fragment size, comminution, and coronoid involvement. Three-dimensional reconstructions enhance preoperative planning.

MRI is not routinely used acutely but may identify occult ligament injuries.

Key radiographic signs:

- Block sign: Interposed fragment preventing reduction.
- Terry Thomas sign: Increased radio-capitellar distance due to LUCL rupture.
- Frag sign: Fragmented coronoid morphology on CT, indicating instability [12].

5. Treatment Algorithms

5.1. General Management Pathway

Management is guided by fracture displacement, comminution, bone quality, and associated instability:

- Mason I: Non-operative, early motion.
- Mason II: ORIF if reconstructible.
- Mason III/IV: Arthroplasty in unstable elbows.

Concomitant LUCL repair/reconstruction is mandatory in gross instability. Coronoid fixation is indicated for Type II/III fractures.

Table 1. Decision-Making Factors Between Open Reduction Internal Fixation (ORIF) and Radial Head Arthroplasty in Complex Elbow Injuries.

Comminution	**Limited**	**Severely comminuted**
Bone Quality	Good	Osteoporotic
Fragment Size	≥2 large reconstructible fragments	No repairable fragments
Instability	None/mild	Severe (e.g., terrible triad)
Patient Age	<50 years	>60 years
Functional Demand	High	Low
Coronoid Fracture	Type I	Type II/III

5.2. Decision Between ORIF and Arthroplasty

See Table 1. Key factors include comminution, bone quality, instability, and patient profile.

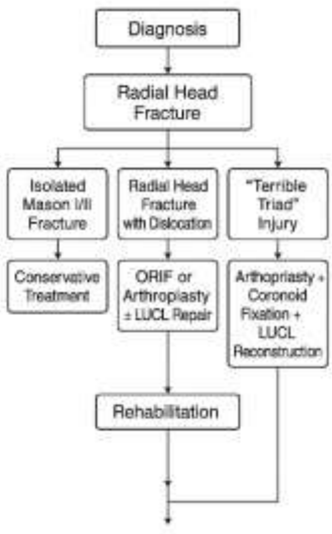

Figure 3. Surgical algorithm flowchart.

Decision tree based on Pugh's classification, guiding management from diagnosis to rehabilitation.

6. Surgical Techniques

6.1. Open Reduction and Internal Fixation (ORIF)

Open reduction and internal fixation (ORIF) is the treatment of choice for displaced but reconstructible radial head fractures, primarily Mason Type II and select Mason Type III fractures with ≥2 large, viable fragments. The primary goal is anatomical reduction and stable fixation to preserve native joint biomechanics and minimize the risk of post-traumatic osteoarthritis [13].

The Kocher approach (between the extensor carpi ulnaris and anconeus) is the most commonly used surgical exposure, providing excellent visualization of the lateral elbow and radial head while minimizing disruption to the extensor mechanism. The Kaplan interval (between the extensor digitorum and extensor carpi radialis longus) may be used as an alternative to reduce the risk of extensor tendon injury, particularly in revision cases.

Surgical steps:

1. Exposure: Incise the capsule over the radial neck.
2. Hematoma evacuation and debridement: Remove interposed soft tissue and bone fragments that cannot be salvaged.
3. Reduction: Use Kirschner wires (K-wires) to provisionally stabilize the main fragments.
4. Fixation: Employ 2.0–2.7 mm cannulated headless screws. Headless screws are preferred as they minimize soft tissue irritation and avoid joint penetration.
5. Intraoperative imaging: Use fluoroscopy in AP, lateral, and oblique views to confirm anatomical reduction, proper screw length, and absence of joint penetration.
6. Final check: Ensure full range of motion without impingement.

Critical technical points:

- Avoid over-compression, which can lead to articular collapse.
- Screws must not extend into the radiocapitellar joint.
- Use of a guide sleeve to direct screws along the safe zone (1–3 o'clock in supination).

Studies report good to excellent functional outcomes (MEPS >80) in 70–85% of appropriately selected cases [13]. However, failure rates increase significantly with poor bone quality, severe comminution, or inadequate fixation.

6.2. Radial Head Arthroplasty

Radial head arthroplasty is the standard of care for Mason Type III and IV fractures that are not amenable to stable fixation, especially in the context of complex elbow instability (e.g., terrible triad). The primary objectives are restoration of load transmission, prevention of proximal radial migration, and stabilization of the lateral column.

Prosthesis types:

Type	Description	Advantages	Disadvantages
Monoblock	Single-piece implant (head and stem as one unit)	Simple, low cost	Limited sizing options, less anatomical fit
Modular	Separate head and stem components	Independent adjustment of head diameter,	Higher cost, potential for mechanical failure

		neck length, and version	at junction
Bipolar	Dual-bearing surface (head articulates with capitellum and within a polyethylene liner)	Reduced capitellar wear	Complex, higher risk of loosening

Surgical steps:

1. Approach: Kocher or Kaplan.
2. Radial head excision: Remove all non-reconstructible fragments.
3. Stem sizing and reaming: Use trial stems to determine optimal diameter and length. The reamer should be aligned at 15° of anterior inclination to match native anatomy.
4. Head selection: Choose head diameter and thickness using trial heads. The ideal fit prevents gapping (undersizing) or impingement (oversizing).
5. Implantation: Insert the final stem and head.
6. Stability check: Assess range of motion and valgus stability under fluoroscopy.

Key considerations:

- Undersizing by ≥2 mm increases valgus laxity and capitellar wear [19].
- Oversizing causes pain, impingement, and accelerated cartilage damage.
- Modular prostheses allow precise anatomical restoration, leading to better long-term outcomes [14].

Long-term studies show high implant survivorship (90% at 10 years) and mean Mayo Elbow Performance Scores (MEPS) of 85–90 [24].

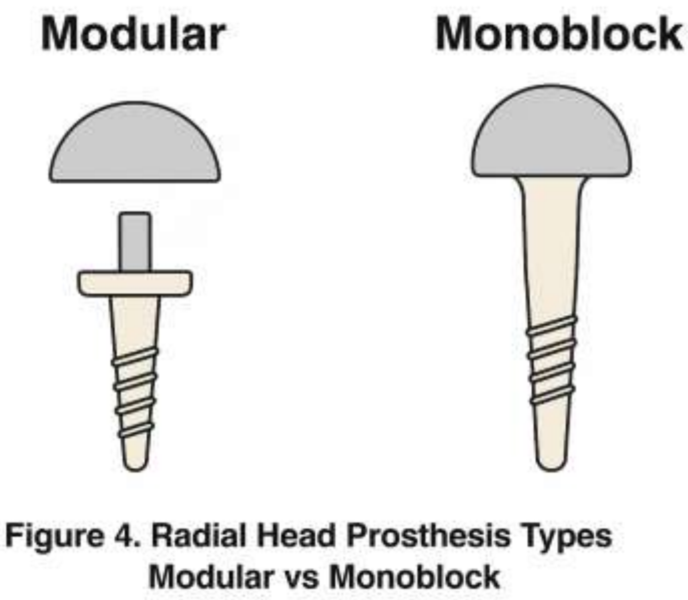

Figure 4. Radial head prosthesis types: modular vs monoblock
Side-by-side comparison illustrating the adjustability of modular implants (independent head and stem) versus the fixed geometry of monoblock prostheses.

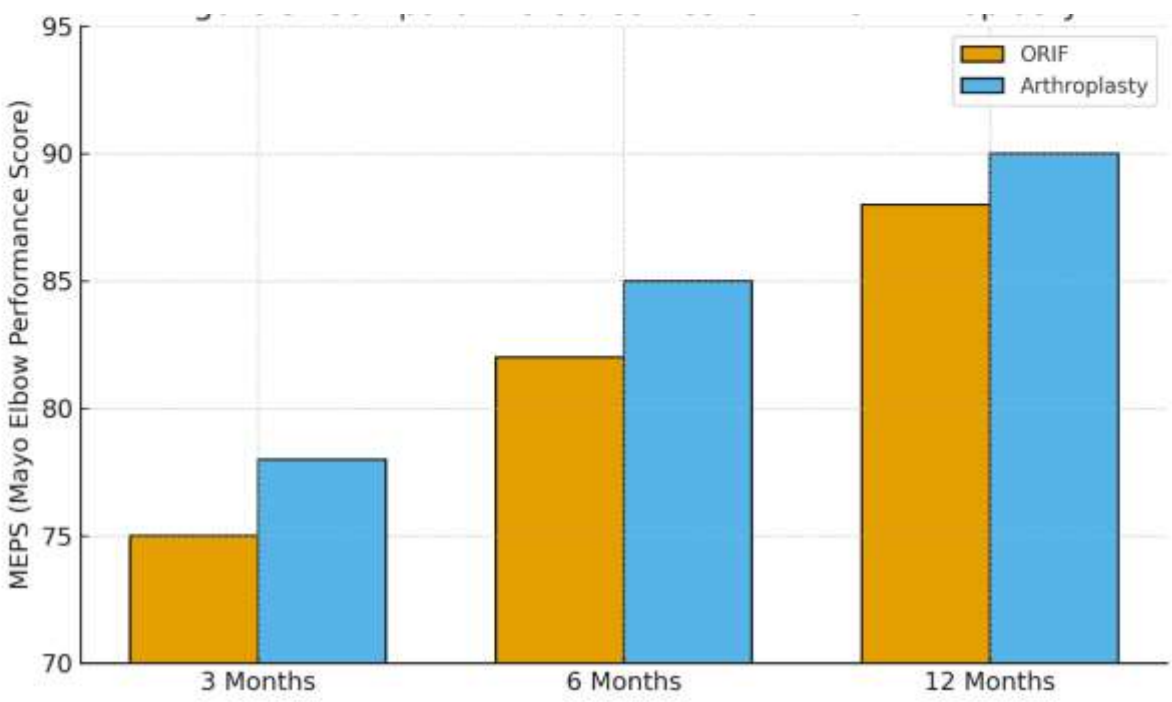

Figure 5. Comparative outcomes: ORIF vs Arthroplasty.

Bar chart comparing functional scores (MEPS), complication rates, and redislocation rates based on pooled data from Doornberg et al. [13] and Sanchez-Sotelo [14].

6.3. LUCL Reconstruction

Lateral ulnar collateral ligament (LUCL) reconstruction is a critical component of managing complex elbow instability, particularly in terrible triad injuries. The LUCL is the primary restraint against valgus and posterolateral rotatory instability (PLRI). Its deficiency, when combined with radial head loss, leads to catastrophic joint failure.

The docking technique, popularized by Adams et al., is the gold standard. It involves:

1. Creating bone tunnels in the lateral epicondyle (origin) and supinator crest of the ulna (insertion).
2. Passing a tendon graft in a figure-of-eight configuration.
3. Securing the graft with interference screws or suture buttons.

Graft options:

- Autografts: Palmaris longus (most common), gracilis, or plantaris.
- Allografts: Freeze-dried or irradiated tendon.
- Synthetic grafts: LARS (Ligament Augmentation and Reconstruction System), Dacron-reinforced polyester.

Biomechanical studies show that LUCL reconstruction restores up to 95% of native elbow stability when combined with radial head arthroplasty [11].

6.4. Autografts vs. Synthetic Grafts in LUCL Reconstruction: A Comparative Analysis

The choice of graft material remains a subject of ongoing debate, balancing biological integraion against donor-site morbidity and mechanical performance.

Factor	Autografts	Synthetic Grafts
Donor-site morbidity	Present (pain, neuroma, grip weakness in 5–10%)	None

Tensile strength	~250 N (native-like)	Up to 2,800 N (LARS)
Biological integration	Remodels and strengthens over time	No remodeling; risk of degradation
Complications	Graft elongation (5%), donor-site pain (12%)	Synovitis (8%), ALVAL reaction (7%), rupture (3%)
Recovery time	Longer (14 weeks to return to work)	Shorter (10 weeks)
Cost	Lower	Higher

A 2023 RCT found no significant difference in MEPS (88 vs 86) or stability (93% in both groups) at 2 years, but synthetic grafts allowed faster return to work [22].

While synthetic grafts offer immediate strength and avoid donor-site issues, concerns about long-term durability and inflammatory reactions persist. Autografts remain the gold standard for young, active patients, whereas synthetics may be preferred in revision cases or patients with limited donor tendons.

7. Combined Reconstruction in Terrible Triad Injuries

The terrible triad (posterior dislocation, radial head fracture, coronoid fracture) requires a structured, sequential approach to restore stability:

Surgical sequence:

1. Coronoid fixation (central column):
    - Type I: Suture repair.
    - Type II/III: Mini-plate or suture anchor fixation via anteromedial approach.
2. Radial head arthroplasty (lateral column):
    - Restores load transmission and prevents radial migration.
3. LUCL reconstruction (lateral soft tissue):
    - Docking technique with autograft or synthetic graft.
4. Intraoperative stability check:
    - Assess under fluoroscopy with valgus and rotational stress.
5. MCL repair (if indicated):
    - Only if valgus instability persists after lateral-side reconstruction.

Approach options:

- Single-stage: All procedures in one setting (preferred in stable patients).
- Staged: Soft tissue reconstruction delayed in polytrauma or severe swelling.

Success rates of 85–90% stable elbows at 2-year follow-up have been reported [13].

8. Postoperative Rehabilitation

A structured, phase-based protocol is essential to balance healing and motion:

Phase	Duration	Goals	Interventions
I	0–2 weeks	Protect repair, control swelling	Hinged brace locked at 30–90°; ice; elevation
II	2–6 weeks	Restore ROM	Passive and active-assisted motion; brace adjustments
III	6–12	Strengthening	Isometric exercises;

	weeks		progressive resistance
IV	3–6 months	Return to function	Sport/work-specific training

Pharmacological prophylaxis:

- Indomethacin 25 mg TID × 6 weeks reduces heterotopic ossification risk by 50% [15].
- Alternative: Single-dose radiation (700 cGy) in high-risk cases.

Early motion (within 1 week) improves outcomes, but must be balanced against the risk of redislocation [26].

9. Complications

Table 2. Common Postoperative Complications Following Radial Head Fracture Management and Their Treatments.

Complication	Incidence (%)	Management
Stiffness	20–30%	Physical therapy, manipulation under anesthesia (MUA), arthrolysis
Heterotopic Ossification	15–25%	Indomethacin, radiation prophylaxis
Implant Loosening	5–10%	Revision arthroplasty
PIN Palsy	3–7%	Observation; most resolve within 3–6 months
Redislocation	<5%	LUCL reconstruction ± coronoid revision or arthroplasty
Capitellar Erosion	5–8%	Prosthesis revision, pyrocarbon implants

10. Emerging Technologies and Future Directions

- 3D-printed implants: Patient-specific designs improve fit in revision or severe comminution [23].
- Arthroscopic-assisted fixation: Minimally invasive option for select Mason II fractures [25].
- Biologic augmentation: PRP, mesenchymal stem cells under investigation [21].
- Robotic-assisted surgery: Potential for improved precision in reaming and alignment [27].
- Next-gen prostheses: Pyrocarbon heads, hydroxyapatite-coated stems to reduce wear and enhance osseointegration [24].

10.1. Critical Discussion: Challenges and Controversies

This review is based on a comprehensive literature search; however, the heterogeneity of study designs and outcome measures across publications represents a limitation in drawing definitive conclusions for some treatment modalities

Despite advances, key controversies remain:

1. Order of stabilization: Biomechanical evidence favors osseous stability first (coronoid → radial head) before soft tissue repair to prevent graft failure [29], [30].
2. MCL repair: Only indicated if valgus instability persists after lateral reconstruction [23].
3. Long-term prosthetic wear: Modular implants show promise, but capitellar erosion remains a concern in young, active patients [24].
4. Access to innovation: 3D printing and AI planning are limited to specialized centers; cost and validation are barriers to widespread adoption.

11. Conclusion

Radial head fractures in complex elbow injuries demand a multidisciplinary, algorithm-driven approach. Anatomical restoration of the bony and soft tissue stabilizers—radial head, coronoid, and LUCL—is paramount. ORIF is suitable for reconstructible fractures, while radial head arthroplasty is the standard for comminuted injuries. Combined reconstruction in terrible triad injuries achieves stability in over 85% of cases.

Early, controlled rehabilitation and pharmacological prophylaxis reduce complications. Future innovations in implant design, biologics, and surgical technology hold promise for improving outcomes in this challenging subset of upper extremity trauma.

Clinical Pearls:

- Start with osseous stability: Address the radial head and coronoid fractures before soft tissue reconstruction to provide a stable foundation for ligament repair.
- Use modular prostheses: They allow independent adjustment of head diameter, neck length, and version, minimizing the risk of malreduction, impingement, or joint gapping.
- Respect the "safe zone": Instrumentation of the radial head should be confined to the anterolateral quadrant (1–3 o'clock in supination) to avoid injury to the posterior interosseous nerve (PIN).

Early surgical intervention: Reconstruction within 7 days of injury is associated with significantly better functional outcomes (e.g., MEPS >85) and lower stiffness rates compared to delayed surgery.

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