Fractures of the Olecranon and Coronoid Process

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I. INTRODUCTION

Fractures of the proximal ulna present a challenge to the orthopedic surgeon. Fractures of the olecranon process are common and many classification systems and treatment options have been described. Conversely, fractures of the coronoid process are relatively rare, especially in isolation, and management is often dependent on the concomitant injury. In all fractures of the proximal ulna, the fracture pattern and concomitant injuries play a major role in surgical decision making and prognosis. The guiding principle in treating these fractures is to restore articular congruity and stability in order to begin a program of early active motion.

II. FRACTURES OF THE OLECRANON

A. History of treatment techniques
1. Prior to the 19th century, olecranon fractures were treated with immobilization in extension, which resulted in considerable stiffness and loss of function.
2. To achieve a better functional result, early limited motion was attempted, which required rigid internal fixation of the fracture fragments. In 1883, Joseph Lister pioneered internal fixation for the olecranon using a wire loop.
3. Since Lister’s work, a number of fixation methods have been employed, all with some success.
   a. McAtee device—a longitudinal fixation device
   b. Zuelzer hook plate
   c. Longitudinal intramedullary screws
   d. Tension band wiring
   e. Plate fixation
   f. Fragment excision with triceps reattachment for comminuted fractures and for fractures in elderly patients

B. Mechanisms of injury
1. Direct trauma to the olecranon
2. A fall on the outstretched hand with eccentric contraction of the triceps during resisted elbow flexion
3. High-energy trauma
   a. In these cases, additional injury to the elbow joint is often present. Radial head fracture, coronoid fracture, distal humerus fracture, and ligamentous instability are most common.
   b. High-energy olecranon fractures have increased surgical complexity and carry a higher complication rate and poorer prognosis.

C. Classification systems. Several systems to describe olecranon fractures exist.
1. Colton’s classification system is based on fracture pattern, comminution, and ligament injury.
2. The AO classification system is more cumbersome, but it does provide a detailed description according to the rules applied to other articular fractures. It also accounts for concomitant fractures of the proximal radius.
3. The Mayo classification system provides a concise and manageable system that assists in surgical decision making as well as predicting outcome.

D. Treatment by Mayo fracture type
1. Mayo type I olecranon fractures (stable, nondisplaced) (Figure 1). These can be treated with casting or splinting and early mobilization.
   a. A long arm cast or posterior splint may be used for comfort and protection, preferably in a position of mid-flexion and neutral forearm rotation.
   b. A dynamic extension splint can also be used for early motion with active flexion and passive extension.
   c. Motion can often begin by 7 days post-injury with weekly radiographs during the first few weeks to follow the fracture and confirm that it remains nondisplaced.

The views expressed in this monograph are those of the authors and do not reflect the official policy or position of the US Department of the Navy, US Department of Defense, or the United States Government.
d. Flexion greater than 90 degrees should be delayed until 3 to 6 weeks to allow stable union.1,20
e. Results are usually excellent with near normal range of motion achieved.1

2. Mayo type II olecranon fractures (stable, displaced) (Figure 1). This is the most common pattern of olecranon fracture.
   a. Articular incongruity, exacerbated by the deforming forces of the triceps, biceps and brachialis muscles, makes surgery necessary to restore the articular surface, prevent redisplacement and allow early motion.
   b. Type IIA olecranon fractures (noncomminuted, stable, displaced)
      1) These are best treated with tension band wiring by one of several methods described later (see Section II.E.1).1,3,6,10–12,18,20,23,24 This allows neutralization of the deforming forces and compression of the fracture site.
      2) Longitudinal intramedullary fixation has also been advocated for this fracture pattern1,3,7,17,23 however, higher rates of displacement, poor rotational control, and problems with screw purchase in the medullary canal have been reported.1,25 The technique works best with a single large fragment and minimal or no comminution.
   c. Type IIB olecranon fractures (comminuted, stable, displaced)
      1) The nature of these fractures creates increased difficulty obtaining articular congruity with tension band wire techniques.
      2) Additional interfragmentary screw fixation or plate fixation can improve the results in these fractures.1,4,6,8,13,17,20
      3) Fragment excision and triceps advancement may be considered, particularly for small fragments or in elderly patients.1,15–18

3. Mayo type III olecranon fractures (displaced, unstable) (Figure 1)
   a. These fractures present the greatest challenge and have the highest rate of complications.1,20
      1) The elbow joint is unstable, usually with anterior subluxation of the radius and ulna on the distal humerus as a result of the deforming forces created by the triceps, biceps, and brachialis.20
   b. Principles of treatment
      1) Rigid fixation is required.
         a) Plate fixation is often best, especially when comminution is present, in order to maintain ulnar length and alignment. A number of plate fixation techniques have been described, most involving a contoured posterior or lateral plate with, when possible, interfragmentary screws (see section II.E.2).1,4–6,8,13,14,17,20,23
         b) In addition to internal fixation, use of an external fixation device or distraction device can be helpful or necessary to maintain joint congruity while allowing an early motion program. In rare instances, external fixation alone may be used when

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<th>Table 1. Mayo Classification of Olecranon Fractures</th>
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internal fixation is prohibited (ie, soft tissue injury).\textsuperscript{1,17,27}

2) **Primary bone grafting** should be considered to reduce the risk of non-union, especially in a type IIIB olecranon fracture.

3) **Total elbow arthroplasty** may be considered based on the fracture pattern, bone quality, and patient age. However, the results of elbow arthroplasty following trauma are not as good as the results for patients with inflammatory arthritis.\textsuperscript{28}

c. **Restoration of articular congruity** is a primary goal of reduction and fixation of olecranon fractures.

1) Type IIIB olecranon fractures are not well suited to tension band wiring because of the loss of bony stability under compression.

2) Care must be taken to avoid narrowing of the olecranon to coronoid distance.\textsuperscript{1}

3) It is usually preferable to co-apt the cortical surfaces and leave a gap in the articular surface in order to preserve a more normal articular contour.

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**Figure 1. Mayo classification of olecranon fractures.** Type I: nondisplaced with minimal or no comminution. Type II: displaced but stable. Type III: displaced and unstable. Adapted with permission from Cabanela ME, Morrey BF. Fractures of the proximal ulna and olecranon. In: Morrey BF, editor. The elbow. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2001:408.
E. Fixation techniques for olecranon fractures

1. Tension band wiring. Various techniques have been described.
   a. Standard AO technique. This technique, which uses 2 intramedullary Kirschner wires (K-wires) and a figure-of-eight wire with a single knot, is acceptable in most type II olecranon fractures (Figure 2).
      1) Carefully bending the pins 180 degrees and impacting them into the proximal fragment, after placement of the wire loop, can minimize the problem of prominent proximal pins or proximal pin migration.
      2) It may be necessary to make small slits in the triceps insertion to allow adequate impaction of the pins into bone followed by closure of the slits over the pins.20
      3) Placement of the K-wires and distal drill hole dorsal to the mid-axis of the ulna helps produce compression at the fracture site, particularly with elbow flexion.5
   b. Intramedullary cancellous screw instead of K-wires. Results have been variable.
      1) Use of an intramedullary screw alone or with a figure-of-eight wire gave erratic results in biomechanical testing by Fyfe.6
      2) In clinical evaluation by Murphy, these techniques yielded better results than standard tension band wiring with K-wires.18
      3) This variability may be related to the need to obtain adequate distal purchase of the intramedullary screw. In addition, selecting noncomminuted fractures with some stability produced through fracture compression should yield better results with intramedullary screw fixation than oblique or comminuted fracture patterns.1,29
   c. Distal fixation of the K-wires. K-wire position has been investigated in several biomechanical studies.1,24
      1) Fixation to the anterior ulnar cortex. In an effort to avoid the common complication of proximal migration and hardware prominence, the K-wires can be directed anteriorly to engage the ulnar cortex at the base of the coronoid.1,30,31
         a) In biomechanical testing, this technique has been shown to provide stronger fixation than the usual intramedullary placement of the K-wires.30
         b) Some concerns have been raised over the potential for neurovascular injury with this technique, although no reports of such injuries could be found.24
      2) Fixation to the ulnar styloid process. Wu described placement of 2 K-wires through the medullary canal to the ulnar styloid process and compared this to the anteriorly placed K-wires.24
         a) In biomechanical testing, there was no significant difference in stability and no proximal migration with either technique when the construct was tested to failure.
         b) Wu proposes their technique is safer when impacting the K-wires as there is diminished risk to neurovascular structures.
   d. Use of 2 twist knots and anterior placement of the distal limb of the wire loop1,5,6,11,24,32
      1) Use of 2 tightening knots in the wire loop provided increased rigidity over a single knot, when tested in a cadaveric model.6
      2) Kozin tested placement of the distal limb of the wire loop anterior to the K-wires, as described by Rowland,32 and demonstrated no biomechanical advantage over the standard technique.9

2. Plate fixation. Several types of plates have been advocated for use in olecranon fractures, particularly type IIB and type III fractures.
   a. General considerations
      1) Plate fixation allows neutralization of forces across the fracture site and should provide adequate rigid internal fixation to begin early motion.
      2) Interfragmentary compression screws should be utilized when possible.
      3) Augmentation with an external fixation or distraction device may be beneficial when elbow stability is
lacking despite fracture fixation.\textsuperscript{1,17,27}

4) Small gaps in the articular surface are well tolerated as pointed out by Wolfgang and others.\textsuperscript{1,12}

5) Articular step-off of greater than 2 mm has been associated with poorer results.\textsuperscript{18}

b. \textbf{Results compared with tension band wiring}

1) Biomechanical and clinical studies demonstrate plate fixation to be superior to tension band wiring when significant comminution is present.\textsuperscript{6,8,13}

2) Hume compared plating with a posterior 1/3 semi-tubular plate to tension band wiring in a prospective randomized clinical trial.\textsuperscript{8}

a) The results suggested that plate fixation allowed more anatomic

\textbf{Figure 2.} Oblique olecranon fracture with comminution in a young male. (A, B) Preoperative radiographs. (C) After treatment with tension band wiring. Adapted with permission from Cabanela ME, Morrey BF. Fractures of the proximal ulna and olecranon. In: Morrey BF, editor. The elbow. 2nd ed. Philadelphia: Lippincott Williams & Wilkins; 2001:411.
reductions and better maintenance of reductions than tension band wiring.

b) They reported no significant difference in range of motion, although plate fixation had a significantly better clinical result based on a scale evaluating pain and motion.8

c. Plate position
1) Most authors prefer posterior placement of the plate; however, King reported a biomechanical investigation showing no significant difference in strength of fixation between posterior or lateral placement.13
2) Posterior plating allows a more direct approach to the proximal ulna and requires less soft tissue stripping and less effort to contour the plate.
3) A laterally placed plate may be less prominent and less likely to require hardware removal.

d. Plate type
1) A contoured, posterior 3.5 dynamic compression plate or limited-contact dynamic compression plate provides excellent rigidity and, when properly applied, will usually allow placement of 3 screws in the proximal fragment.33
2) A pelvic reconstruction plate can be used when a longer plate is needed.13
3) Nowinski described using the AO wrist fusion plate with the following benefits14:
   a) The lower-profile 2.7-mm segment is positioned over the subcutaneous border of the proximal olecranon, thereby minimizing plate prominence.
   b) There is added strength from the 3.5-mm segment distally
   c) Ease of contouring
   d) Variable screw-hole sizing
4) A precontoured titanium plate is now available from Acumed (Beaverton, OR) for posterior olecranon plating (Shawn O’Driscoll, MD, Rochester, MN, personal communication, May 2001). This plate minimizes the need for plate manipulation and allows for placement of 3 screws in the proximal fragment.

3. Fragment excision with triceps advancement. Because of the potential for subsequent instability, this technique should be reserved for cases involving small or comminuted fragments or low-demand patients.1,5,15,18
   a. Biomechanical testing by An demonstrated that the constraint of the ulnohumeral joint is linearly proportional to the area of articulation remaining.16 This supports the clinical observation by Murphy and Horne that excision in patients with more than 60% articular involvement yields poorer results.18,34
   b. When reattaching the triceps, care should be taken to bring the tendon close to the articular surface, thus improving stability by acting as a sling for the trochlea.35

4. Total elbow arthroplasty may be considered in elderly patients with significant comminution and greater than 60% articular involvement.5

F. Postoperative care
1. To minimize stiffness and reduce edema, the limb should initially be elevated with the elbow in extension, followed by active motion beginning within 7 days of surgery.
2. A dynamic extension splint allows protected range of motion (ROM) through the stable arc.
3. In cases involving severe soft tissue injury, early motion may need to be delayed until the soft tissue healing is adequate to tolerate motion.

G. Results. The rate of complications is directly related to the severity of the initial injury.1,20
1. Mayo type I olecranon fractures usually heal with excellent results, with near-normal range of motion.1
2. Outcomes of Mayo type III olecranon fractures are not as favorable as those for type I or type II fractures. Type III fractures carry a high rate of complications, particularly stiffness.1,5,17,20,36

H. Complications
1. Hardware prominence requiring removal
   a. This is the most common complication, with some series reporting an incidence as high as 80%.18
   b. This complication is more common with tension band wiring than with plate fixation.1,5,8,12,17,18,20
2. **Stiffness** occurs in up to 50% of cases. Loss of extension is most common, but is not usually functionally significant.1,3,12,18

3. **Nonunion** occurs in 1% to 5% of olecranon fractures.5,35–37
   a. The most common treatment described is hardware revision with autogenous bone grafting.
   b. Other treatments include bone plates, bone stimulators, and local muscle flaps.5,35–40

4. **Other complications include:**
   a. Ulnar neuropathy
   b. Post-traumatic arthritis
   c. Infection
   d. Heterotopic ossification

### III. Fractures of the Coronal process

A. **Classification.** The Regan-Morrey system classifies coronoid process fractures into 3 types according to the level of the fracture41 (Figure 3).

1. **Types**
   a. **Type I** fractures involve the coronoid tip (Figure 4).
   b. **Type II** fractures involve 50% or less of the coronoid height (Figure 5).
   c. **Type III** fractures involve more than 50% of the coronoid height (Figure 6).

2. **Subtypes.** Each type is subdivided as follows:
   a. **Subtype A:** without elbow dislocation
   b. **Subtype B:** with elbow dislocation

B. **Incidence**41

1. **Isolated injury.** Coronoid fractures rarely occur as isolated injuries.
2. **Combined injury**

### a. **Concurrent dislocation or fracture:** incidence by coronoid fracture type:
   1) **Type I:** 36%
   2) **Type II:** 56%
   3) **Type III:** 80%

b. **Posterior elbow dislocation:** 2% to 10% of patients with posterior elbow dislocation also have associated coronoid fracture.

c. Fractures of radial head, medial humeral epicondyle, and olecranon represent the most commonly associated fractures.

C. **Mechanisms of injury**20,41,42

1. Axial load
2. Resisted elbow flexion
3. Shear force created as the coronoid subluxates or dislocates over the trochlea

D. **Relevant anatomy**43,44

1. The **anterior capsule** inserts an average of 6.4 mm distal to the tip of the coronoid. Therefore, a type I coronoid fracture cannot represent an avulsion fracture. Instead, it represents a shear fracture created by ulnohumeral subluxation or dislocation.

2. The **brachialis** inserts via a broad musculolaponeurotic attachment to the capsule, coronoid process, and proximal ulna. The proximal margin is an average of 11 mm from the coronoid tip; therefore, it is only involved in type III coronoid fractures.

3. The anterior bundle of the **medial collateral ligament (MCL)** inserts an average of 18.4 mm dorsal to the tip of the olecranon. Only in type III coronoid fractures would it be attached to the free fragment.

4. Obliquity or comminution of the coronoid fracture may result in a fracture that appears radiographically to be a type II
coronoid fracture, but demonstrates MCL instability. Conversely, a fracture may appear radiographically to be a type III coronoid fracture but demonstrate no signs of clinical instability.

b. Additional imaging with computed tomography can help delineate the fracture pattern in these cases.43

4. Usually, there are no attachments to the tip of the coronoid. Thus, type I coronoid fractures do not represent avulsions.

E. Treatment. The goal of treatment is to achieve stability and allow early mobilization (ie, in less than 3 weeks).17,20,41,42 When elbow dislocation is present (subtype B), closed reduction under adequate anesthesia followed by a brief period of immobilization is performed.

1. Type I coronoid fractures
   a. Symptomatic treatment consisting of brief immobilization (5–7 days) and pain control followed by a program of active ROM exercises and activity modification is often all that is required.
   b. In these fractures, ligamentous injury resulting from subluxation or dislocation is the more significant component of the injury and may result in persistent instability.

2. Type II coronoid fractures
   a. Stable ulnohumeral joint. Symptomatic treatment as outlined above is often sufficient for these injuries.
   b. Unstable ulnohumeral joint

1) Open reduction and internal fixation (ORIF) of coronoid fragment is usually indicated to restore articular stability (Figure 7).

2) Stabilization with an external fixation device to allow early mobilization may be used with or without ORIF, depending on joint stability and the condition of the soft tissues in the case of an open fracture.

3) Use of a hinged ROM brace to allow motion only through the stable range may also be considered in place of an external fixation device. This option requires frequent radiographic evaluation to avoid subluxation in the brace.

3. Type III coronoid fractures
   a. ORIF of the coronoid fragment is required for joint stability (Figure 8).
   b. Supplemental external fixation is especially useful when severe comminution is present and ORIF is difficult.

4. Concomitant injury. When possible, address all other fractures and ligamentous injury at the time of primary surgery.

F. Internal fixation techniques
1. **Compression screw fixation** is preferred.\(^{17,42}\)
2. **Suture or wire** fixation is more useful in comminuted coronoid fractures. A no. 5 nonabsorbable suture or wire is passed through the capsule or brachialis tendon, through the fracture, and secured through drill holes in the ulna.\(^{17,20,41,42}\)
3. A **buttress plate**, contoured to the medial coronoid, is especially useful in coronoid fractures involving the insertion of the MCL.\(^{20}\)

G. **Postoperative care.** Elements include:
1. Elevation until edema is under control.
2. Early active ROM exercises
3. Hinged brace to allow protected motion through the stable range
4. External fixation device to provide additional stability and motion, especially useful in an unstable joint

H. **Results.** The incidence of elbow dislocation is proportional to the size of the coronoid fragment. Larger fragments are also associated with a worse prognosis.\(^{41,42}\)
1. **Type I:** Satisfactory results in 92% of patients
2. **Type II:** Satisfactory results in 73% of patients
3. **Type III:** Satisfactory results in 20% of patients

I. **Complications**
1. **Stiffness.** This is the most frequent complication of coronoid fractures, and occurs most commonly with type III fractures. This may be related to the longer period of immobilization required by the more severe type III fractures.\(^{42}\)
2. **Instability**
   a. This is a rare complication of coronoid fractures, and also occurs most commonly after type III fracture.\(^{41}\)
   b. Radial head resection (performed for treatment of concomitant fracture of the radial head) increases risk of instability in type II and type III coronoid fractures.\(^{42}\)
   c. **Treatment of instability**
      1) Ligamentous instability: ligament reconstruction
      2) Bony instability: reconstruction of the coronoid process
         a) Osseous graft from ilium\(^{20}\)
         b) Osteocartilaginous graft from proximal olecranon or radial head fragments\(^{42,45}\)

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**Figure 6.** Lateral radiograph demonstrating a type III coronoid fracture with associated subluxation of the ulnohumeral joint and radial head fracture.

**Figure 7.** Lateral radiograph demonstrating fixation of a type II coronoid fracture with plate and screws.

**Figure 8.** Lateral radiograph demonstrating internal fixation of a severely comminuted proximal ulna fracture with an associated type III coronoid fracture.
3. **Nonunion**
   a. Type I fractures have been reported to form loose bodies or symptomatic fibrous union with hypertrophy of the fragment. These nonunions are amenable to arthroscopic débridement and fragment excision.\(^4\)
   b. Type II and type III fractures may require revision ORIF with bone grafting or coronoid reconstruction.

4. **Posttraumatic arthrosis.** The incidence of this complication correlates with the age of the patient at the time of the injury more than with injury severity.\(^{41}\) Joint congruity is also an important factor.\(^{29}\)

5. **Heterotopic ossification.** Heterotopic ossification that limits ROM is most common after type III fractures, and rare after type I fractures.\(^{41}\)

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**BOARD REVIEW QUESTIONS**

1. What percentage of posterior elbow dislocations are accompanied by an associated coronoid fracture?
   - A) 10%
   - B) 40%
   - C) 65%
   - D) 80%

2. A displaced olecranon fracture with anterior subluxation of the radius and ulna is best treated by which one of the following options?
   - A) K-wire and tension band fixation
   - B) Intramedullary screw fixation
   - C) Plate fixation
   - D) Fragment excision

3. In which one of the following clinical settings is excision of an olecranon fragment most appropriate?
   - A) The patient is skeletally immature
   - B) The patient is elderly and the fracture is comminuted
   - C) The fracture involves 25% of the olecranon
   - D) The fracture involves 80% of the olecranon

4. Which one of the following describes a type III olecranon fracture?
   - A) Displaced and unstable
   - B) Stable
   - C) Nondisplaced
   - D) Nondisplaced and stable

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**REFERENCES**