

Coronal Plane Partial Articular Fractures of the Distal Humerus: Current Concepts in Management

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J Am Acad Orthop Surg 2008;16:716-728

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Abstract

Partial articular fractures of the distal humerus commonly involve the capitellum and may extend medially to involve the trochlea. As the complex nature of capitellar fractures has become better appreciated, treatment options have evolved from closed reduction and immobilization and fragment excision to a preference for open reduction and internal fixation. The latter is now recommended to achieve stable anatomic reduction, restore articular congruity, and initiate early motion. More complex fracture patterns require extensile surgical exposures. The fractures are characterized by metaphyseal comminution of the lateral column and have associated ipsilateral radial head fracture. With advanced instrumentation, elbow arthroscopy may be used in the management of these articular fractures. Though limited to level IV evidence, clinical series reporting outcomes following open reduction and internal fixation of fractures of the capitellum, with or without associated injuries, have demonstrated good to excellent functional results in most patients when the injury is limited to the radiocapitellar compartment. Clinically significant osteonecrosis and heterotopic ossification are rare, but mild to moderate posttraumatic osteoarthritis may be anticipated at midterm follow-up.

Isolated coronal plane partial articular injuries to the lateral column of the distal humerus involving the capitellum and trochlea are relatively rare.^{1,2} Capitellum and trochlea coronal shear fractures may also be present in more complex distal humeral fractures and elbow fracture-dislocations with concomitant ligamentous injuries.²⁻⁵ Furthermore, the complex nature of isolated capitellum and trochlea fractures has become better appreciated.³⁻⁵ As a result, treatment options have evolved from

closed reduction/immobilization⁶⁻⁸ and fragment excision⁹⁻¹¹ to a preference for open reduction and internal fixation (ORIF)^{1-5,9,12-17} to achieve stable anatomic reduction, restore articular congruity, and initiate early elbow range of motion.

Given the complex nature of these injuries, debate has ensued over the optimal surgical exposure and fixation techniques. In recent studies, surgeons have demonstrated a preference for extensile exposure and articular reconstruction with

hardware countersunk beneath the articular surface.^{1-5,9,12-17} Several extensile exposures and fixation devices to reconstruct the articular surface are available, and a number of series reporting outcomes following ORIF of capitellum and trochlea fractures have been published recently.^{1-5,9,12-17} Sequelae of nonanatomic reduction or failed fixation are significant and include articular incongruity, posttraumatic arthrosis, stiffness, pain, and, if the trochlea-olecranon articulation is involved, potential ulnohumeral instability.

Biomechanics and Mechanism of Action

An intact radiocapitellar articulation is essential to both valgus and longitudinal stability of the elbow and forearm. Tension in the posterolateral ligamentous complex, in conjunction with dynamic compression across the radiocapitellar joint, maintains lateral elbow stability. Similar to Morrey et al,¹⁸ who demonstrated that the radial head is a key secondary stabilizer to valgus stress in the medial collateral ligament-deficient elbow, Dushuttle et al⁶ found that capitellar excision creates coronal plane instability when the medial structures are disrupted. Grantham et al⁹ reported poor clinical results at a mean follow-up of 5.2 years in 7 of 11 patients treated with capitellar resection. Proximal migration of the radius is resisted by axial engagement of the radial head against an intact capitellum, along with the interosseous membrane and the distal radioulnar joint ligaments. Mancini et al¹⁹ reported valgus instability in 4 of 39 patients as well as painful distal radioulnar joint

subluxation at a mean of 12 years following capitellar excision. For these reasons, ORIF of capitellar fractures is strongly preferred over excision of the fracture fragments.

Coronal plane fractures of the distal humerus are often the result of a relatively low-energy fall on an outstretched arm,^{2-4,12,13} and complex fracture patterns (ie, capitellum and trochlea fractures characterized by comminution, medial trochlear extension, or both) are often sustained with the same innocuous mechanism. Dubberley et al³ reported that a fall directly onto the elbow or an outstretched hand was responsible for all 28 capitellum and trochlea fractures in their series, 17 of which were complex fracture patterns. Ring et al⁴ found that 15 of 21 partial articular injuries were sustained during a fall from a standing height.

Direct axial compression transmitted to the capitellum by the radial head with the elbow in a semiflexed position may create a shear capitellum and trochlea fracture. Alternatively, spontaneous reduction after posterolateral elbow subluxation/dislocation²⁰ may be responsible for these partial articular frontal plane fractures. Disruption of the lateral ulnar collateral ligament (LUCL) noted intraoperatively may suggest that the fracture was sustained during an episode of ulnohumeral instability.

Classification

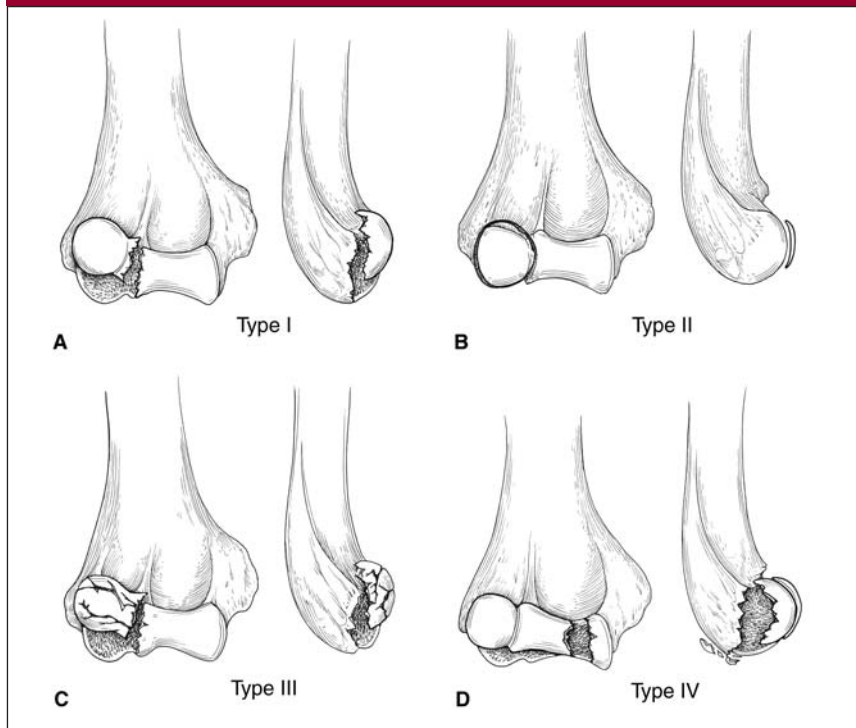
Several classifications for partial articular fractures of the distal humerus have been described.^{1,3,4,9,12,21} The utility of the newly proposed classification schemes^{3,4} lies in their ability to dictate surgical treatment and predict functional and patient-based

outcomes. Within the Orthopaedic Trauma Association (OTA)/AO classification system,²¹ capitellar fractures are denoted 13B3—distal humerus, partial articular, and frontal plane—and are further subclassified as B3.1, indicating isolated capitellum fractures; B3.2, trochlea fractures; or B3.3, capitellum and trochlea fractures with a secondary fracture line in the sagittal plane. Capitellum and trochlea fractures may also be components of more complex, multifragmentary intercondylar fractures (ie, 13C3.3).

The most commonly used classification system is that of Bryan and Morrey¹ (type I to type III), with the addendum of type IV fractures by McKee et al¹² (Figure 1). In this system, type I fractures (Hahn-Steinthal) are complete capitellar fractures with little or no extension into the lateral trochlea (Figure 2); type II fractures (Kocher-Lorenz) are anterior osteochondral fractures with minimal subchondral bone; and type III fractures (Broberg-Morrey variant) are comminuted or compression fractures of the capitellum²² (Figure 3). McKee et al¹² described type IV fractures in six patients with coronal shear fractures of the capitellum that extended medially to include most of the trochlea (Figure 4). Although these injuries are often identified by the presence of the pathognomonic “double arc” sign¹² on lateral radiographs of the elbow, this sign may not be radiographically apparent in all type IV fractures because of the presence of an internally rotated capitellum and trochlea fragment.^{2,13} Type IV fractures may be more common than previously thought^{12,13,15} and, in our experience, may account for up to

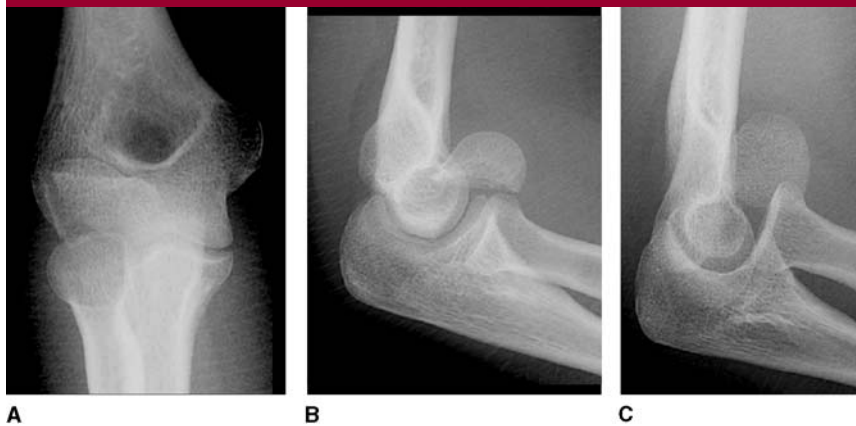
Dr. Tejwani or a member of his immediate family has participated in a speakers bureau or given paid presentations for Biomet, Stryker, and Zimmer and has received research or institutional support from Biomet. Dr. Kwon or a member of his immediate family is a paid consultant to Exactech and Smith & Nephew. Dr. Egol or a member of his immediate family has participated in a speakers bureau or given paid presentations for Biomet; is an unpaid consultant for Exactech; has received research or institutional support from Biomet, Smith & Nephew, Stryker, and Synthes; and holds stock or stock options in Johnson & Johnson. Neither Dr. Ruchelsman nor a member of his immediate family has received anything of value from or owns stock in a commercial company or institution related directly or indirectly to the subject of this article.

Figure 1



Bryan and Morrey¹ classification of capitellar fracture. **A**, Type I (Hahn-Steinthal), complete capitellar fracture with little or no extension into the lateral trochlea. **B**, Type II (Kocher-Lorenz), anterior osteochondral fracture with minimal subchondral bone. **C**, Type III (Broberg-Morrey variant), comminuted/compression fracture of the capitellum. **D**, Type IV¹² extends medially to include most of the trochlea.

Figure 2



Anteroposterior (**A**), lateral (**B**), and radiocapitellar (**C**) views of a displaced Bernard-Morrey type I capitellar fracture.

50% of capitellum fractures.

Based on a retrospective review of 28 patients, Dubberley et al³ recently proposed a novel treatment- and

outcome-oriented classification of capitellum and trochlea fractures. Type I fractures involved the capitellum with or without the lateral

trochlear ridge (ie, Bryan and Morrey type I equivalent); type II injuries involved the capitellum and trochlea as a single piece (ie, McKee type IV); and type III injuries consisted of fractures of both the capitellum and the trochlea as separate fragments. Each fracture type was additionally subclassified as A or B based on the presence of posterior condylar comminution, which was found to influence surgeon selection of fixation method as well as outcome.

Often the complex nature of capitellum and trochlea fractures is not fully appreciated on plain radiographs alone.^{4,5,12} Based on radiographs and intraoperative findings during ORIF of displaced coronal plane capitellum fractures, Ring et al⁴ identified five articular segment injury patterns (types I to V) distal to the base of the olecranon fossa, representing progression of the severity of the articular injury beyond an isolated capitellum fracture (type I). The presence of fracture extension into the lateral epicondyle (type II), posteroinferior lateral column metaphyseal comminution (type III), and posterior trochlea impaction (type IV) required an extensile lateral approach to the elbow to reduce and reconstruct the articular surface with buried implants. An olecranon osteotomy was required when the articular fracture extended to the medial epicondyle (type V). This algorithm has also been reported by other groups.^{3,5}

Clinical and Radiographic Evaluation

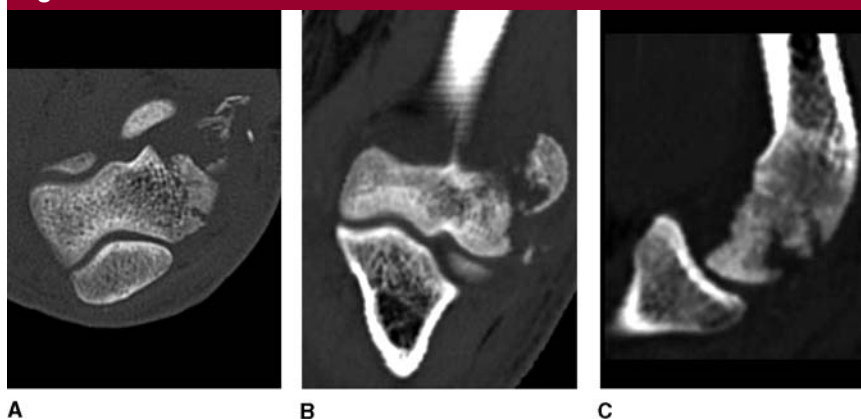
Circumferential inspection of the skin should be performed to identify open fracture and traumatic arthrotomy of the elbow joint. A mechanical block to elbow flexion may be present with an anteriorly displaced capitellum fracture. Assessment of elbow stability is limited in the emergency department or office setting because of pain and guarding,

and should be repeated under anesthesia at the time of surgical intervention. The interosseous membrane is palpated and the distal radioulnar joint stressed to assess for the presence of a concomitant Essex-Lopresti lesion. A thorough neurovascular examination of the upper extremity should be performed, and the status of the forearm compartments should be documented. A secondary musculoskeletal survey should be performed to rule out additional contiguous or noncontiguous musculoskeletal injuries.

Requisite radiographic images should be taken of the ipsilateral elbow, forearm, and wrist. An elbow trauma series comprising anteroposterior, lateral, and radiocapitellar views should be obtained. Several authors^{2,4,5,12} have reported that the exact morphology of the fracture is often difficult to ascertain from preoperative plain radiographs alone; they recommend preoperative computed tomography (CT) scanning with sagittal and coronal plane reconstructions. Doornberg et al²³ recently demonstrated that the use of three-dimensional CT scans improves both intra- and interobserver reliability of distal humeral fracture classification and characterization. We also have found preoperative three-dimensional reconstructions to be helpful. CT scans help to define the medial extent of the fracture, articular impaction, and metaphyseal and condylar comminution and thus aid in preoperative planning with regard to the surgical exposure and choice of internal fixation implants (Figure 3).

Ipsilateral musculoskeletal trauma in the upper extremity may be observed in up to 50% of patients.³ Several authors have reported on the presence of additional ipsilateral periarticular elbow injuries coincident with capitellum and trochlea fractures. Goodman and Choueka⁵ termed these “complex” coronal shear fractures. Concomitant fractures of the radial head,^{2-5,9,13} olec-

Figure 3



Axial (A), coronal (B), and sagittal (C) computed tomography scans of a displaced, comminuted Bernard-Morrey type III capitellar fracture. Note the involvement of the posterolateral column and the sparing of the trochlear segment.

Figure 4



Anteroposterior (A) and lateral (B) radiographs of a type IV capitellum and trochlea fracture. The lateral image shows the “double arc”¹² sign that is pathognomonic for a coronal shear fracture of the capitellum with medial extension through most of the trochlea.

ranon,^{4,5} lateral condyle⁵ and epicondyle,^{2,3,15} and medial column^{4,5} may occur. Additionally, associated closed ulnohumeral dislocation, both posteromedial⁴ and posterolateral,² have been reported.

Additional lateral column injuries should be suspected with coronal shear fractures, but variable inci-

dences for concomitant fracture of the radial head and disruption of the LUCL complex have been reported. Dubberley et al³ (n = 28) and Ring et al⁴ (n = 21) independently reported ipsilateral radial head fractures in three patients in their respective series. Concomitant radial head fracture was seen in two of eight pa-

Figure 5

Lateral radiograph demonstrating a double arc¹² sign consistent with a type IV capitellum and trochlea fracture. An ipsilateral Mason type II radial head fracture is identified.

tients studied by Goodman and Choueka.⁵ In a series of 16 patients from our center, fracture involving the ipsilateral radial head was seen in 5 (31%) patients (2 Mason type I, 3 Mason type II); 4 of these 5 cases (80%) were associated with type IV capitellum and trochlea fractures² (Figure 5). When a lateral extensile exposure is selected, the Kocher interval is used distally to address radial head pathology with fragment excision,^{2,3} ORIF,^{2,3} or radial head arthroplasty,³ based on the fracture pattern. The co-occurrence of higher-grade radial head fractures (Mason types III and IV) and their impact on outcomes following fixation of capitellum fractures is not currently known.

Concomitant LUCL disruption (partial and complete) or its functional equivalent (ie, fracture of the lateral epicondyle) with capitellum and trochlea fractures must be recognized, as LUCL repair helps restore elbow stability. Dubberley et al³ identified four lateral ligament disruptions and seven avulsion fractures of the lateral epicondyle in 28 patients, corresponding to a 39% rate of lateral ligamentous injury. Ring et al⁴ reported lateral epicondylar fracture in 11 of 21 patients (52%), but no cases of intrasubstance

ligament injury. In contrast, Mighell et al¹⁷ reported only two cases of comminuted type III fracture with lateral epicondylar extension in 16 patients (12.5%). Similarly, a recent series reported that the lateral ligamentous complex was intact in 15 of 16 elbows (94%).² These data suggest that functional disruption of the LUCL secondary to capitellar comminution with lateral epicondylar fragmentation or avulsion is more common than is an intrasubstance tear of the ligament.

Surgical Approaches

Lateral Extensile

A lateral extensile approach^{2,4,5,12,13,16,17} is preferred for exposure and surgical fixation of coronal shear capitellum and trochlea fractures. This exposure provides sufficient visualization to address medial trochlear extension, impaction, and comminution in type IV fractures as well as concomitant radial head pathology. The patient is positioned supine on the operating table with the arm placed on a hand table. A well-padded pneumatic tourniquet is applied. Following general or regional anesthesia, the injured elbow is assessed for stability. A lateral skin incision (Figure 6) at the elbow is centered over the lateral epicondyle and extended from the anterior aspect of the lateral column of the distal humerus to approximately 2 cm distal to the radial head. Should the need for medial exposure be anticipated (ie, concomitant medial epicondyle fracture, Ring et al⁴ type V fracture), a midline posterior skin incision with subsequent elevation of a full-thickness lateral skin flap is recommended (Figure 6).

Following dissection through the subcutaneous tissue layers, the lateral column is palpated. With the forearm pronated to move the radial nerve away from the surgical field, the common origin of the radial wrist extensors in conjunction with the anterior capsule is elevated ante-

riorly as a full-thickness sleeve from the lateral supracondylar ridge. Distally, the Kocher interval is identified and connected to the proximal exposure to develop a continuous full-thickness anterior soft-tissue flap. With the elbow flexed, retractors are placed deep to the brachialis and the anterior capsule and over the medial column, facilitating exposure of the anterior articular fracture segments (Figure 7). Retractor placement anterior to the radial neck is avoided to prevent iatrogenic injury to the posterior interosseous nerve.

When posterior metaphyseal comminution is present, exposure may require elevation of the lateral aspect of the triceps from the posterior distal humerus and proximal ulna. With this posterior exposure, care is taken to preserve the LUCL and the vascular supply to the capitellum.²⁴ Release of the LUCL^{2,4,12,17} is not always necessary even when there is trochlear extension of the coronal shear capitellar fracture. In cases with a lateral epicondylar fracture fragment (ie, Bryan and Morrey type III fracture,¹ Ring types II to IV⁴), the epicondylar fragment with the lateral collateral ligamentous complex origin can be reflected distally to enhance exposure.^{2,4,17} Using the lateral extensile exposure does not seem to increase the risk of osteonecrosis of the capitellum or trochlea.^{2,4,12,16,17}

Olecranon Osteotomy and Medial-based Approaches

When the trochlea cannot be visualized from a lateral approach, a supplemental medial incision followed by a flexor-pronator split/elevation or a posterior approach with olecranon osteotomy may be needed.³⁻⁵ Recently, Dubberley et al³ presented a novel treatment-oriented classification of capitellum and trochlea fractures in which surgical exposure and fixation constructs were dictated by increasing fracture complexity characterized by the presence of capitellum and trochlea fragmentation and posterior

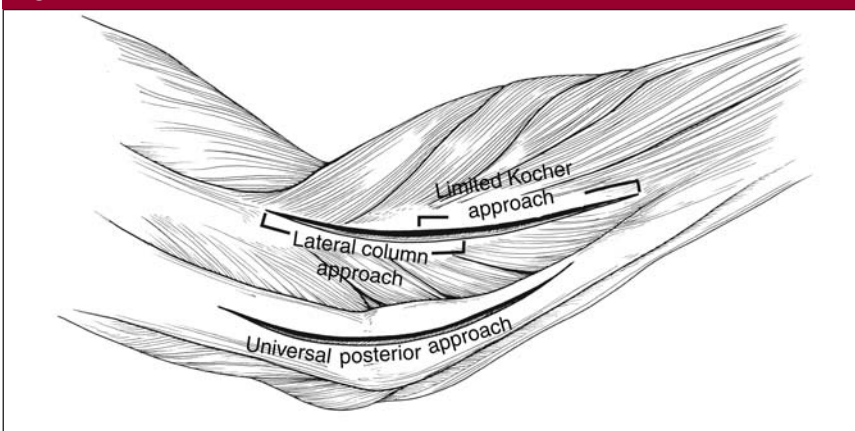
condylar comminution. Although all 11 type I injuries were managed with a lateral interval approach (ie, Kocher,²⁵ Kaplan,²⁶ or Boyd²⁷ intervals), the 17 type II and III fracture patterns required a medial flexor-pronator split (2 patients), flexor-pronator elevation (1 patient), or olecranon osteotomy (14 patients). These surgeons recommended that all coronal plane partial articular fractures of the lateral column be approached through a posterior longitudinal skin incision to afford simultaneous bicolunar and olecranon access if needed via a single skin incision.

Olecranon osteotomy is indicated when exposure is inadequate through one of the lateral intermuscular intervals. Alternatively, this approach may be selected primarily when trochlear comminution or extension of the articular fracture beyond the radiocapitellar compartment is identified preoperatively (ie, Ring type V fracture with medial epicondyle extension).^{3-5,14} We prefer the apex-distal chevron osteotomy after which, the proximal fragment with the triceps is mobilized cephalad. Although our preference for fixation of the osteotomy is a tension band and Kirschner wire (K-wire) construct, a variety of constructs, including a reconstruction plate or tension band and screw, may be used.²⁸

Anterolateral

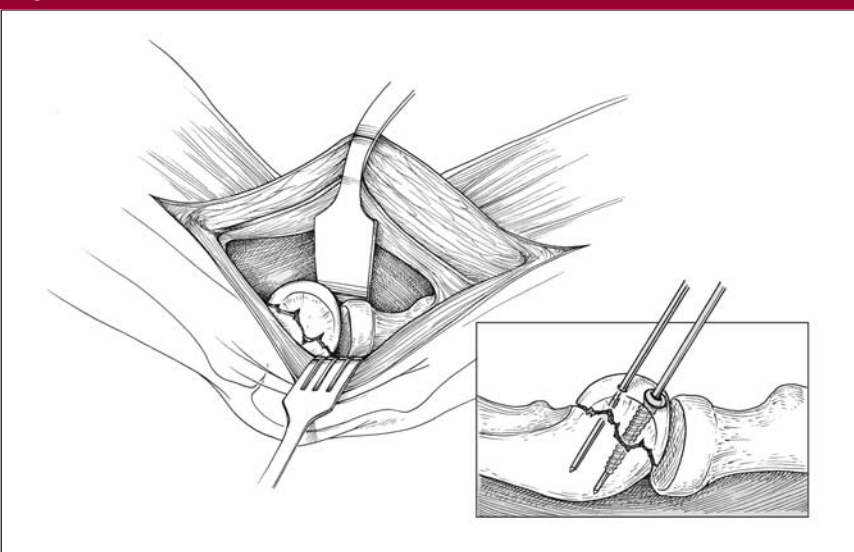
The treating surgeon should also be familiar with alternative surgical exposures for these fracture types. Imatani et al¹⁵ advocated the anterolateral approach for fixation of these fractures. The skin incision is centered over the antecubital fossa and extends approximately 7 cm proximal and distal to the elbow flexion crease. Proximally, the interval between the brachioradialis and biceps muscles is developed, and the radial nerve is identified between them. The brachioradialis and radial nerve are retracted laterally and the biceps medially. The brachialis is divided,

Figure 6



Two available skin incisions for capitellum and trochlea fracture. A lateral skin incision is centered over the lateral column of the distal humerus, the lateral epicondyle, and the Kocher interval distally. A midline posterior skin incision is selected if the need for medial exposure is anticipated. Lateral and medial muscular intervals are identified following elevation of skin flaps.

Figure 7

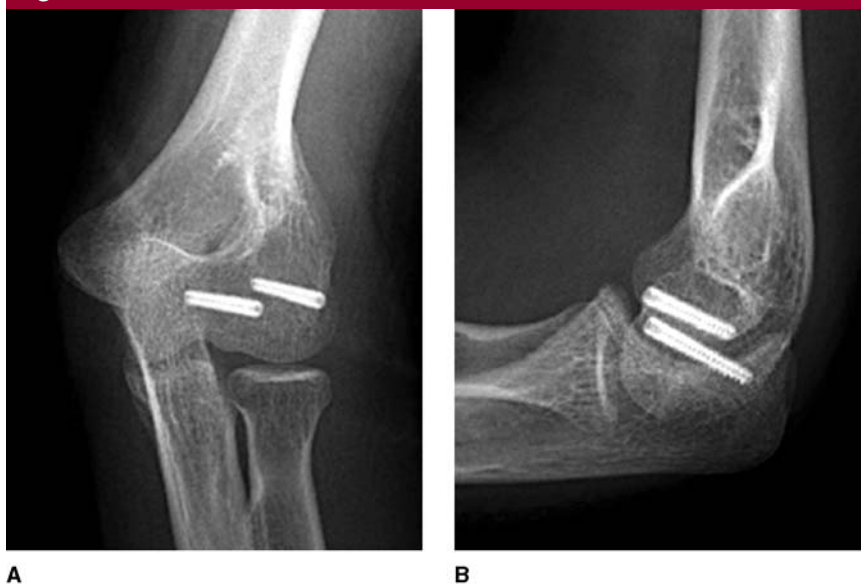


Lateral column approach to manage capitellum and trochlea fracture. The common origin of the radial wrist extensors and the anterior capsule are elevated from the lateral supracondylar ridge and connected distally to the Kocher interval to develop a continuous full-thickness anterior soft-tissue flap. Retractors are placed deep to the brachialis and the anterior capsule and over the medial column to expose the anterior articular fracture segments. Inset, Articular reduction and reconstruction with buried cannulated screws inserted over guidewires in an anterior-to-posterior direction.

and an anterior capsulotomy is performed.

Malki et al²⁹ used a limited antero-

lateral approach to achieve articular reduction and provisional K-wire fixation in three patients with a type I

Figure 8

Postoperative anteroposterior (**A**) and lateral (**B**) radiographs following fixation of a type I capitellum fracture with two mini-Acutrak (Acumed, Hillsboro, OR) screws inserted from anterior to posterior and buried beneath the articular surface. Supplemental fixation was not required.

fracture of the capitellum. Definitive fixation was then obtained by percutaneously placing 3.5-mm cannulated screws from a posterior-to-anterior direction over K-wires in parallel with the provisional, anteriorly placed K-wires. At 6-month follow-up, there was no evidence of elbow instability, and only one patient had a 10° flexion contracture.

At a mean follow-up of 40 months following ORIF performed through the anterolateral approach, Imatani et al¹⁵ reported good and excellent outcomes in five of six patients and a mean flexion contracture of 14.5°. Similar functional outcomes and degree of flexion contracture have been reported by several groups following ORIF using the lateral extensile approach or alternative exposures.^{2,12,17}

Arthroscopic-assisted Fracture Reduction

Hardy et al³⁰ described arthroscopic-assisted reduction and fixation of a type I fracture using three lateral portals (one viewing portal

and two instrumentation portals) and a buried cannulated screw. Although arthroscopic excision may be useful for type II anterior osteochondral fractures,³¹ the indications for arthroscopic fixation of more complex capitellum and trochlea fracture patterns remain unclear. Further studies are needed to assess whether the arthroscopic technique is superior to formal ORIF.

Articular Reconstruction

Following surgical exposure, the fracture hematoma is evacuated. The posteroinferior aspects of the distal lateral column and trochlea are evaluated for impaction and comminution. Impacted segments are carefully elevated and may require supplemental bone grafting to fill the metaphyseal defect.³⁻⁵ Anatomic reduction is directly visualized as cortical keys along the proximal metaphyseal margin and trochlea are reduced. After provisional fixation with a minimum of two 0.045- or 0.062-inch K-wires, anatomic reduction is again con-

firmed with orthogonal fluoroscopy or direct visualization. When there is sufficient subchondral bone on the articular segment, buried headless cannulated screws inserted over guidewires in an anterior-to-posterior direction is our preferred method of internal fixation (Figures 7 and 8). Terminally threaded Herbert screws^{3,4,12-16,32,33} (Zimmer, Warsaw, IN) and fully threaded mini-Acutrak^{2,5} headless screws (Acumed, Hillsboro, OR) provide fracture site compression through variable thread pitch designs. Biomechanical data have demonstrated that Acutrak screw fixation of capitellum fractures is superior to posteroanterior 4.0-mm cancellous lag screws³⁴ and Herbert screws.³⁵

Two screws placed in a divergent fashion are recommended to ensure rotational control, and sufficient screw spread is necessary to avoid iatrogenic fracture of the capitellum. Although two screws are sufficient to maintain stable fixation of type I fractures, supplemental fixation is often required to reconstruct more complex fracture patterns with posteroinferior/lateral metaphyseal comminution and/or trochlear extension (ie, type III and IV fractures)^{2-4,17} (Figure 9). Supplemental fixation options include minifragment Synthes screws (West Chester, PA) threaded K-wires, and bioabsorbable pins for small (ie, <5 mm) osteochondral capitellum and trochlea fragments. When extensive posterolateral comminution is present, plating of the lateral column with pelvic reconstruction, precontoured, or locking (ie, fixed-angle) plates may be required to buttress the lateral column.^{3,4,17} When LUCL avulsion is identified or the lateral epicondyle fragment is too small to accept screw fixation, the LUCL may be repaired primarily to its origin using transosseous sutures passed through drill holes^{2,3,13,17} or suture anchors,¹³ or the fragment may be secured with a figure-of-8 tension-band wire technique.⁴ Medial collateral ligament disruption may require primary re-

pair or treatment in a hinged elbow brace.³ When stable reconstruction of the articular surface cannot be achieved, total elbow arthroplasty may be considered in a select group of patients (ie, elderly, osteoporotic).

Postoperative Care

When rigid fixation is achieved, a long arm posterior plaster splint or compressive dressing is worn by the patient until the first office visit, typically between 7 and 10 days postoperatively. Active and active-assisted range of motion of the elbow and forearm is then initiated. When fixation is suboptimal, the patient may be placed into a functional brace. In the presence of concomitant ligamentous or functionally equivalent osseous injuries, a ligament-specific protocol is instituted, with mobilization in pronation (lateral-sided injury)³⁶ or supination (medial-sided injury).³⁷ Strengthening exercises are initiated when there is clinical and radiographic evidence of fracture union.

Delayed or protected mobilization with a hinged elbow brace may be necessary when there is concern about the stability of fixation. A hinged brace with gradual reduction of the extension block helps to maintain radial head congruity with the reduced capitellum. Extension thermoplastic splinting is used when flexion contracture occurs in the early postoperative period. Turnbuckle splinting has also been shown to be effective in regaining ulnohumeral motion.^{4,38} When poor ulnohumeral motion is present and the flexion contracture is recalcitrant to these measures, contracture release is considered.

Outcomes

Published retrospective cohort series^{2-5,12-17} (level IV evidence) suggest that overall, most patients undergoing ORIF of capitellum and trochlea fractures achieve good to

excellent outcomes.^{9,39,40} Satisfactory clinical and functional results following ORIF of type IV¹² fractures have also been reported by several authors.^{2,5,12,13,15} A functional arc of ulnohumeral motion is achieved in most of these patients at latest follow-up,^{2,5,12,13,15} despite a mean postoperative flexion contracture of 14.5° to 17.5°.^{2,12,15}

A number of series have reported on patient outcomes following ORIF of capitellum and trochlea fractures (Table 1).^{2-5,12-17} Only two series^{2,3} have attempted to correlate clinical and functional outcome with fracture subtype. In a cohort of 28 patients, Dubberley et al³ reported significantly inferior functional ($P = 0.005$ [American Shoulder and Elbow Surgeons function score]; $P = 0.04$ [Mayo Elbow Performance Index]) and patient-rated ($P = 0.04$) elbow evaluation scores when there was medial trochlear extension and/or capitellum-trochlea comminution (ie, Dubberley type II and type III fracture patterns, respectively). Fracture subtypes differed significantly with respect to grip strength and flexion-extension power, but not with respect to elbow or forearm motion.² At 2 years postoperatively, our group² has found that patients with type IV fractures have significantly reduced terminal flexion ($P = 0.02$) and net ulnohumeral arc ($P = 0.01$) and greater loss of terminal extension (ie, larger flexion contracture) ($P = 0.04$) compared with patients with type I fractures. The increased flexion contracture in these patients may be due to the increased severity of the injury and to the extended surgical dissection needed to facilitate exposure of the anterior articular segments. Lower scores on elbow-specific functional outcome measures were also seen in type IV patients at the latest follow-up, but these differences did not reach statistical significance.

Although Dubberley et al³ and Ring et al⁴ independently reported three cases of ipsilateral radial head

Figure 9



Supplemental fixation construct in a type IV capitellum and trochlea fracture. Two mini-Acutrak screws with a supplemental minifragment screw were placed from the inferolateral articular surface into the lateral column and countersunk beneath the articular surface. The radial head fracture was fixed with two minifragment screws.

and capitellum fractures in their respective series, the impact of radial head fracture on outcome or its association with fracture subtype was not specifically evaluated in either study. Goodman and Choueka⁵ reported excellent elbow function in two patients who each sustained an ipsilateral radial head fracture, and a significantly lower mean Mayo Elbow Performance Index ($P = 0.025$) in patients with capitellum fractures extending beyond the radiocapitellar joint (ie, complex capitellum fracture). Subcohort analysis in a series of 16 patients revealed that patients ($n = 5$) who sustained concomitant fractures of the capitellum and radial head (Mason type I and type II) achieved an average ulnohumeral motion of 114°, with a mean flexion contracture of 16°.² Four of five ipsilateral radial head fractures occurred in association with type IV capitellum and trochlea fractures. At latest follow-up, two patients had no pain, two had mild pain, and one had

Table 1**Outcomes Following ORIF of Capitellum and Trochlea Fractures**

Study	No. of Patients (fracture type)	Mean Follow-up (mos)	Mean Age (yrs)	Surgical Approach	Fixation Method	Mean Ulnohumeral Arc (degrees)
Ruchelsman et al ²	16 (6 type I, 2 type III, 8 type IV) [*]	25	40	Lateral Kocher	Acutrak screws (Acumed, Hillsboro, OR) (plus minifragment screws in 5)	123
Dubberly et al ³	28 (11 type I, 4 type II, 13 type III) [†]	56	43	Boyd (7), lateral Kocher (5), Kaplan (14), olecranon osteotomy (14), flexor pronator split (2) or elevation (1)	Cancellous screws (7), Herbert screws (3), biodegradable pins (1), type II and III supplemental screw fixation (NR), K-wires (4), pelvic reconstruction plate (2)	119
Ring et al ⁴	21 (3 type I, 2 type II, 5 type III, 4 type IV, 7 type V) [‡]	40	50	Lateral Kocher (14), olecranon osteotomy (7)	Herbert screws (all), lateral plate/screws (8), tension band (4)	96
McKee et al ¹²	6 (type IV) [§]	22	38	Lateral Kocher	Herbert screws (4), 4.0-mm partially threaded cancellous AO screw (2), posterolateral plate (2)	126
Goodman and Choueka ⁵	8 (all type IV) [§]	14	56	Lateral Kocher (4), posterior (4)	Acutrak screws	NR
Imatani et al ¹⁵	6 (all type IV) [§]	40	47	Anterolateral	Herbert screws	114
Stamatis and Paxinos ¹³	5 (all type IV) [§]	Range, 39-50	Range, 27-53	Lateral Kocher	Herbert screws (5), plus 2.7-mm AO screw (1)	Full ^{††}
Mahirogullari et al ¹⁶	11 (type I) [*]	23.4	27.5	Lateral Kocher	Herbert screws	117
Sano et al ¹⁴	6 (2 type IIA, 1 type IIB, 1 type IIC, 2 type IIIA) [¶]	67	51	Lateral Kocher (4), olecranon osteotomy (2)	Herbert screws	132
Mighell et al ¹⁷	16 (8 type I; 2 type III; 6 type IV) [*]	13	NR	Lateral Kocher	Acutrak screws	124

ASES = American Shoulder and Elbow Surgeons Standardized Elbow Assessment Form, K-wires = Kirschner wires, LCL = lateral collateral ligament, MCL = medial collateral ligament, MEPI = Mayo Elbow Performance Index (E = excellent, G = good, F = Fair, P = poor), NR = not recorded, OA = osteoarthritis, ON = osteonecrosis, ORIF = open reduction and internal fixation, ROH = removal of hardware, TEA = total elbow arthroplasty

^{*} Bryan and Morrey¹ classification

[†] Dubberly et al³ classification

[‡] Ring et al⁴ classification

[§] McKee et al¹² classification

[¶] Grantham et al⁹ classification

[#] Functional outcome per Broberg and Morrey⁴⁰ elbow-rating scale

^{**} Functional outcome per Grantham et al⁹ scale

^{††} 10° flexion contracture in one patient

^{‡‡} 45° flexion contracture in one patient with grade 1 heterotopic ossification

Table 1 (continued)**Outcomes Following ORIF of Capitellum and Trochlea Fractures**

Mean MEPI (no.)	Mean ASES Function Score	Additional Elbow Injuries	ON	OA	Complications	Additional Surgery (no. of patients)
91.6 (9 E, 6 G, 1 F)	37.4	Radial head (5); lateral epicondyle (1)	0	4	0	ROH (1)
91	29	Lateral epicondyle (7), LCL (4), radial head (3), MCL (1)	3 (1 type 3A; 2 type 3B)	9	2	ROH (6), capsulectomy and ROH (7), external fixation with grafting (1), TEA (2)
NR (4 E, 12 G, 5 F)	NR	Radial head (3), olecranon (1)	0	0	10	Contracture release (6), ulnar neuropathy (2), ROH (1), revision ORIF (1)
NR (3 E; 3 G) [#]	NR	None	0	1	0	0
84.4 (5 E, 1 G, 1 F, 1 P)	NR	Radial head (2), olecranon (2), lateral condyle (2), medial column fracture (1)	NR	NR	Ulnar nerve paresthesias (2)	TEA (1), ROH (1)
NR (1 E, 4 G, 1 F) ^{**}	NR	Lateral epicondyle (1)	0	NR	0	0
Range, 98-100 (5 E)	NR	0	1	1	0	0
93.6 (8 E, 3 G)	NR	0	0	0	0	0
NR (3 E, 3 G) ^{**}	NR	0	0	0	0	0
NR (11 E, 5 G) [#]	NR	0	0	2	1 ^{††}	0

ASES = American Shoulder and Elbow Surgeons Standardized Elbow Assessment Form, K-wires = Kirschner wires, LCL = lateral collateral ligament, MCL = medial collateral ligament, MEPI = Mayo Elbow Performance Index (E = excellent, G = good, F = Fair, P = poor), NR = not recorded, OA = osteoarthritis, ON = osteonecrosis, ORIF = open reduction and internal fixation, ROH = removal of hardware, TEA = total elbow arthroplasty

* Bryan and Morrey¹ classification

† Dubberly et al³ classification

‡ Ring et al⁴ classification

§ McKee et al¹² classification

¶ Grantham et al⁹ classification

Functional outcome per Broberg and Morrey⁴⁰ elbow-rating scale

** Functional outcome per Grantham et al⁹ scale

†† 10° flexion contracture in one patient

‡‡ 45° flexion contracture in one patient with grade 1 heterotopic ossification

Figure 10

Anteroposterior (A) and lateral (B) radiographs, demonstrating moderate posttraumatic arthrosis 3 years after ORIF for a capitellum fracture.

moderate pain. The mean Mayo Elbow Performance Index was 87.0 and corresponded to two excellent and two good outcomes and one fair outcome. Compared with the 11 patients with an isolated capitellum and trochlea fractures, these patients with ipsilateral radial head fractures had greater loss of terminal flexion and extension, reduced ulnohumeral arc of motion, lower functional outcome scores, and greater dissatisfaction. However, with this small sample size, these differences did not reach statistical significance. Analysis of a larger cohort may reveal significantly inferior clinical and functional outcomes in this patient subgroup. The degree to which concomitant Mason type III and IV radial head fractures affect functional outcome is currently unknown.

Complications

Several complications following ORIF of capitellum and trochlea fractures have been reported. Loss of fixation, pain, instability, stiffness,

and neurologic complications may occur in the early postoperative period. When a functional range of ulnohumeral motion is not achieved despite extension splinting and therapy, elbow contracture release should be considered. Dubberley et al³ reported that 7 of 17 patients with type II or III fractures underwent capsulectomy and hardware removal for residual elbow contracture with less than functional ulnohumeral arc of motion (ie, <30° to 130°). Contracture release was indicated in 8 of 21 patients in the series by Ring et al,⁴ and a mean increase of 42° in ulnohumeral motion was achieved. These authors also reported ulnar neuropathy in two patients following ORIF performed through an extended lateral approach that ultimately required decompression and transposition. Hardware complications have been reported after olecranon osteotomies and were related to the subcutaneous position of the hardware. Impingement of the hardware in the radiocapitellar joint may also necessitate screw removal.

Mild to moderate degenerative changes have been reported in patients with partial articular fractures of the lateral column of the distal humerus.^{2,3} (Figure 10). The longest mean duration of follow-up in published clinical series is approximately 5 years; thus, additional studies are needed to more fully evaluate the incidence and severity of posttraumatic arthrosis following these fractures. Despite capitellar displacement and rotation, posterior metaphyseal comminution, separation from soft-tissue attachments, and in some cases a delay prior to ORIF, osteonecrosis of the capitellum and/or trochlea or late articular collapse have been rarely reported.^{2-4,9,12-17} Articular nonunions may require delayed bone grafting. Total elbow arthroplasty represents a salvage option for severe symptomatic posttraumatic arthrosis, articular osteonecrosis, nonunion/malunion, and elbow instability. Clinically significant heterotopic ossification has not been reported, and thus, there is no evidence to support a recommendation for prophylactic treatment.

Summary

Coronal shear fractures involving the capitellum and trochlea represent significant articular injuries that may occur in isolation or as part of complex ipsilateral periarticular elbow trauma. Such trauma includes osseous or ligamentous injuries extending beyond the lateral column. Fracture classification, surgical exposure, and selection of internal fixation techniques are based on the fracture pattern and articular involvement. Headless cannulated screws placed in an anterior-to-posterior direction and buried beneath the articular surface achieve fracture site compression through variable thread pitch designs. These have become the implants of choice for simple fracture types. More complex patterns often require extensile

exposures and supplemental fixation with minifragment screws, bioabsorbable implants, or column plating. Concomitant osseous and ligamentous injuries are addressed simultaneously and may influence the postoperative mobilization and rehabilitation protocol selected.

Familiarity with available exposures and implant options is essential to achieve satisfactory clinical outcomes. Patients with more complex fractures should be counseled appropriately about potential outcomes and sequelae, including postoperative flexion contracture. Multiple perioperative factors, in addition to the surgical exposure selected, affect the degree of postoperative flexion contracture. These include concomitant osseous and ligamentous injuries, iatrogenic disruption of the brachialis, hemarthrosis, and compliance with postoperative rehabilitation. Although osteonecrosis and clinically significant heterotopic ossification are rare complications, longer-term data are needed to evaluate more fully the incidence and severity of posttraumatic arthrosis following partial articular fractures of the lateral column of the distal humerus.

References

Evidence-based Medicine: Reference 23 is a level II randomized control study. Most of the other references presented are level IV case-control studies or case reports, level V expert opinion series, or cadaveric, biomechanical, and anatomic studies.

Citation numbers printed in **bold type** indicate references published within the past 5 years.

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