

Open Reduction and Internal Fixation of Capitellar Fractures with Headless Screws

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Background: The outcome of operatively treated capitellar fractures has not been reported frequently. The purpose of the present study was to evaluate the clinical, radiographic, and functional outcomes following open reduction and internal fixation of capitellar fractures that were treated with a uniform surgical approach in order to further define the impact on the outcome of fracture type and concomitant lateral column osseous and/or ligamentous injuries.

Methods: A retrospective evaluation of the upper extremity database at our institution identified sixteen skeletally mature patients (mean age, 40 ± 17 years) with a closed capitellar fracture. In all cases, an extensile lateral exposure and articular fixation with buried cannulated variable-pitch headless compression screws was performed at a mean of ten days after the injury. Clinical, radiographic, and elbow-specific outcomes, including the Mayo Elbow Performance Index, were evaluated at a mean of 27 ± 19 months postoperatively.

Results: Six Type-I, two Type-III, and eight Type-IV fractures were identified with use of the Bryan and Morrey classification system. Four of five ipsilateral radial head fractures occurred in association with a Type-IV fracture. The lateral collateral ligament was intact in fifteen of the sixteen elbows. Metaphyseal comminution was observed in association with five fractures (including four Type-IV fractures and one Type-III fracture). Supplemental mini-fragment screws were used for four of eight Type-IV fractures and one of two Type-III fractures. All fractures healed, and no elbow had instability or weakness. Overall, the mean ulnohumeral motion was 123° (range, 70° to 150°). Fourteen of the sixteen patients achieved a functional arc of elbow motion, and all patients had full forearm rotation. The mean Mayo Elbow Performance Index score was 92 ± 10 points, with nine excellent results, six good results, and one fair result. Patients with a Type-IV fracture had a greater magnitude of flexion contracture ($p = 0.04$), reduced terminal flexion ($p = 0.02$), and a reduced net ulnohumeral arc ($p = 0.01$). An ipsilateral radial head fracture did not appear to affect ulnohumeral motion or the functional outcome.

Conclusions: Despite the presence of greater flexion contractures at the time of follow-up in elbows with Type-IV fractures or fractures with an ipsilateral radial head fracture, good to excellent outcomes with functional ulnohumeral motion can be achieved following internal fixation of these complex fractures. Type-IV injuries may be more common than previously thought; such fractures often are associated with metaphyseal comminution or a radial head fracture and may require supplemental fixation.

Level of Evidence: Therapeutic Level IV. See Instructions to Authors for a complete description of levels of evidence.

Coronal plane partial articular injuries of the lateral column of the distal part of the humerus are relatively rare injuries, accounting for 1% of all elbow fractures and 6% of distal humeral fractures¹. Coronal shear fractures involve the capitellum or the trochlea, or both, and are often the result of a relatively low-energy fall on an outstretched

arm^{2,3}. Direct axial compression transmitted to the capitellum by the radial head or, alternatively, spontaneous reduction of a posterolateral elbow subluxation⁴ may be responsible for these partial articular shear fractures.

Several classification systems for these injuries have been described^{1,3,5}. However, the complex nature of a capitellar

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fracture often is not fully appreciated until surgical exposure of the lateral column and radiocapitellar articulation is performed^{3,6,7}. On the basis of radiographs and intraoperative findings during open reduction and internal fixation of displaced coronal plane capitellar fractures, Ring et al.⁶ identified five articular segment injury patterns (Types 1 through 5) distal to the base of the olecranon fossa. The presence of fracture extension into the lateral epicondyle, posteroinferior lateral column metaphyseal comminution, and posterior trochlear impaction required an extensile lateral approach to the elbow in order to reconstruct the articular surface with buried implants. An olecranon osteotomy was required when the articular fracture extended to the medial epicondyle (i.e., a Ring Type-5 fracture), and this algorithm also has been reported by other groups^{2,7}. Recently, Dubberley et al.² proposed a novel classification system based on the presence of separate capitellar and trochlear fracture fragments in the sagittal plane as well as the presence of posterior condylar comminution. Functional and patient-based outcomes were significantly inferior ($p = 0.04$) in association with their Type-2 and Type-3 injury patterns.

Furthermore, capitellar fractures may be associated with concomitant ligamentous injury (medial collateral ligament or lateral ligamentous complex tears) and an ipsilateral radial head fracture^{2,6-9}. Dubberley et al.² reported an ipsilateral radial head fracture in three of twenty-eight patients, and Ring et al.⁶ reported such a fracture in three of twenty-one patients. However, the impact of a radial head fracture on the outcome or its association with the fracture subtype was not specifically reported in either study. Goodman and Choueka⁷ reported a significantly lower mean Mayo Elbow Performance Index score in association with capitellar fractures that extended beyond the radiocapitellar joint (69 compared with 100 points; $p = 0.025$) and reported excellent elbow function in two patients who sustained an ipsilateral radial head fracture.

As the complex nature of capitellar fractures has become better appreciated^{2,6,7}, treatment options have evolved from closed reduction and immobilization¹⁰⁻¹² and fragment excision^{9,13,14} to a preference for open reduction and internal fixation in order to achieve a stable anatomic reduction, to restore articular congruity, and to initiate early elbow range of motion. Studies evaluating the outcomes following open reduction and internal fixation of capitellar fractures^{2,3,6,8,9,15-18} and associated injuries of the trochlea, radial head, and lateral collateral ligamentous complex are limited. The purpose of the present study was to evaluate clinical, radiographic, and patient-based functional outcomes following the open reduction and internal fixation of capitellar fractures with use of a uniform surgical approach and fixation construct in order to further define the impact of fracture type and concomitant osseous and/or ligamentous injuries involving the lateral column on the outcome.

Materials and Methods

Between 2001 and 2006, 142 patients were diagnosed and managed operatively for an Orthopaedic Trauma Association (OTA) type-13 distal humeral fracture⁵ by one of three

attending surgeons (N.C.T., Y.W.K., K.A.E.) at our institution. Retrospective evaluation of collected medical and radiographic data from the fracture database at our institution identified a cohort of sixteen skeletally mature patients (11%) who had sustained an OTA type-13B3 (distal humeral, partial articular, frontal plane) fracture. This group included thirteen female patients and three male patients with a mean age (and standard deviation) of 40 ± 17 years (range, eleven to sixty-seven years). All sixteen patients were available for clinical and radiographic evaluation at a minimum of one year postoperatively (mean duration of follow-up, 27 ± 19 months; range, thirteen to sixty-nine months). Eleven patients were followed for twelve to twenty-four months postoperatively, whereas five patients were followed for more than two years.

Classification

Preoperative imaging studies of the injured elbow included anteroposterior radiographs, lateral radiographs, and radiocapitellar radiographs (made with the forearm in neutral rotation and with the radiographic beam canted 45° cephalad). Preoperative computed tomography scans were made for six of the sixteen elbows at the discretion of the treating surgeon. The fractures were classified according to the system of Bryan and Morrey¹, with the additional classification of Type-IV fractures as described by McKee et al.³. Specifically, a Type-I fracture was defined as a complete capitellar fracture with little or no extension into the lateral aspect of the trochlea, a Type-II fracture was defined as an anterior osteochondral capitellar fracture with minimal subchondral bone, a Type-III fracture was defined as a comminuted or compression fracture of the capitellum, and a Type-IV fracture was defined as a coronal shear fracture of the capitellum that extended medially to include most of the trochlea. The latter type of fracture, described by McKee et al.³ in six patients, is recognized by the pathognomonic “double-arc” sign seen on lateral radiographs of the elbow (Figs. 1-A and 1-B). Additionally, all fractures of the capitellum were classified according to the OTA system⁵ as 13B3 (indicating a distal humeral, partial articular, and frontal plane fracture) and were further subclassified as B3.1 (indicating an isolated capitellar fracture), B3.2 (indicating a trochlear fracture), or B3.3 (indicating a capitellar-trochlear fracture). Fracture type was determined on the basis of radiographs, computed tomography scans, and intraoperative findings because several authors^{3,6,7} have noted that the exact morphology of the fracture is often difficult to ascertain on the basis of preoperative imaging alone. The presence of posterior condylar comminution, lateral epicondylar and/or trochlear extension, or an ipsilateral radial head fracture and the status of the lateral collateral ligamentous complex were recorded.

Operative Technique

All fractures were treated with open reduction through an extensile lateral exposure^{3,6-8,17,18}. The patient was placed in the supine position with the arm placed on a hand table. A lateral skin incision at the elbow, centered over the lateral epicondyle, extended from the anterior aspect of the lateral column of the



Fig. 1-A



Fig. 1-B

Anteroposterior (Fig. 1-A) and lateral (Fig. 1-B) radiographs showing a Type-IV capitellar-trochlear fracture. The lateral image shows the “double-arc” sign (arrows) that is pathognomonic for a coronal shear fracture of the capitellum with medial extension through most of the trochlea.

distal part of the humerus to approximately 2 cm distal to the radial head. With the forearm pronated to move the radial nerve away from the operative field, the common origin of the radial wrist extensors in conjunction with the anterior capsule were elevated anteriorly as a full-thickness sleeve from the lateral supracondylar ridge. Distally, the Kocher interval was identified and was connected to the proximal exposure to develop a continuous full-thickness anterior soft-tissue flap. With the elbow flexed, retractors were placed deep to the brachialis and the anterior capsule and over the medial column, facilitating exposure of the anterior distal humeral articular fracture segments and the radial head. When posterior metaphyseal comminution was present, the lateral aspect of the triceps was elevated from the posterior aspect of the distal part of the humerus and the proximal ulnar metaphysis. With this posterior exposure, care is taken to preserve the lateral collateral ligamentous complex and the vascular supply to the capitellum. Fracture stabilization was achieved with Acutrak screws (Acumed, Hillsboro, Oregon) inserted in an anterior-to-posterior direction and buried beneath the articular surface at a mean of ten days (range, zero to thirty-eight days) after the injury (Figs. 2-A and 2-B). Three patients underwent operative fixation more than fourteen days after the initial injury. The mean time to operative fixation in the other thirteen cases was

six days (range, zero to fourteen days). Olecranon osteotomy or a medially based exposure was not used in any case. Supplemental mini-fragment screw fixation (Synthes, Paoli, Pennsylvania) was required for four of eight Type-IV fractures and one of two Type-III fractures. Bone-grafting and lateral column plating was not used in any case. For radial head fractures, fragment excision was performed in four cases in which a small unreconstructable fragment (or fragments) involving <20% of the circumference of the articular surface was found, and open reduction and internal fixation was performed in one case with a mini-fragment lag screw.

Postoperatively, a long arm posterior plaster splint was applied with the elbow at approximately 90° of flexion. At the first office visit, between seven and ten days postoperatively, the plaster splint and sutures were removed, and active and active-assisted range of motion of the elbow and forearm was initiated and subsequently was supervised by staff occupational therapists. Patients were followed postoperatively at routine intervals until fracture union. Strengthening exercises were initiated when there was evidence of fracture union. Postoperative extension splinting was utilized for one patient who had a 30° flexion contracture, which was reduced to 10° six months following surgery. Elbow contracture release was not performed in any case.



Fig. 2-A



Fig. 2-B

Anteroposterior (Fig. 2-A) and lateral (Fig. 2-B) radiographs made one year after the fixation of a Type-I capitellar fracture with two mini-Acutrak screws that were inserted from anterior to posterior and buried beneath the articular surface. Supplemental fixation was not used.

Evaluation

Clinical examination was performed by the treating surgeon. The ranges of motion of the elbow and forearm, including the arcs of flexion-extension and pronation-supination, were measured with a handheld goniometer. The range of motion of the injured elbow at the time of the latest follow-up is reported. Stability of the elbow was evaluated on the basis of the history as well as provocative physical examination maneuvers for anteroposterior, mediolateral, and posterolateral rotatory instability. Elbow and forearm muscular strength was tested against the examiner's manual resistance and was graded according to the system of the Medical Research Council¹⁹.

Serial anteroposterior and lateral radiographs were evaluated for the loss of fracture reduction and for the presence of osteonecrosis, heterotopic ossification, and posttraumatic osteoarthritis by one of the authors (D.E.R.). Fracture union was defined as the absence of a visible fracture line on the radiographs and the lack of tenderness along the lateral column. Posttraumatic elbow arthrosis was classified, according to the system described by Broberg and Morrey²⁰, as Grade 1 (slight joint-space narrowing and minimal osteophyte formation), Grade 2 (moderate joint-space narrowing and osteophyte formation), or Grade 3 (severe joint-space narrowing with gross destruction). Prophylaxis against heterotopic ossification was not used in any case.

At the time of the latest follow-up, elbow-specific outcome was evaluated by an independent observer (D.E.R.) with

use of the American Shoulder and Elbow Surgeons (ASES) Elbow Assessment Form¹⁹ and the Mayo Elbow Performance Index (MEPI)²¹. The ASES patient self-evaluation section includes a visual analog scale to grade patient satisfaction with the elbow, ranging from 0 (not at all satisfied) to 10 (very satisfied), and a series of ten questions relating to the function of the injured extremity during activities of daily living, which are individually scored on a 4-point ordinal scale (maximum ASES function score, 40). The physician assessment section has four parts: motion, stability, strength, and physical findings (i.e., areas of tenderness, pain with resisted motion, and the presence of crepitus). The MEPI is based on a 100-point scale (four subscales), with maximum scores of 45 points for pain relief, 25 points for function (with 5 points each for grooming, feeding, personal hygiene, putting on a shirt, and putting on shoes), 20 points for motion, and 10 points for stability. The results of the MEPI are defined as excellent (≥ 90 points), good (75 to 89 points), fair (60 to 74 points), and poor (< 60 points).

Statistical Analysis

Fracture subgroup analysis was performed with use of the Student t test to evaluate differences with regard to mean range-of-motion characteristics (mean ulnohumeral flexion, extension [i.e., flexion contracture], and net ulnohumeral arc) and mean elbow-specific outcome scores (mean ASES function and satisfaction scores and mean MEPI score). The percentages of elbows that achieved a functional arc of motion as well as the

overall and subscale MEPI outcomes were compared between groups with use of the Fisher exact test (two-tailed test). Additionally, outcomes in elbows with a concomitant ipsilateral radial head fracture were compared with those with an isolated capitellar-trochlear fracture. The level of significance was set at $p \leq 0.05$.

Results

Six Type-I, two Type-III, and eight Type-IV fractures (eight OTA B3.1 and eight OTA B3.3 fractures) were identified. Fifteen of the sixteen patients were right-hand dominant. The dominant elbow was injured in seven of sixteen cases. The mechanism of injury was a low-energy fall in all cases. All fractures were closed. There were no associated neurovascular injuries.

There were five ipsilateral radial head fractures (including two Mason Type-I fractures and three Mason Type-II fractures²²). Four of five ipsilateral radial head fractures were associated with Type-IV (OTA 13B3.3) capitellar-trochlear fractures. No other concomitant upper extremity musculoskeletal injuries were seen.

Seven of eight Type-IV fractures demonstrated the characteristic “double-arc” sign³ on preoperative lateral radiographs (Fig. 1-B). Intraoperatively, trochlear extension was identified in association with all Type-IV fractures. In two of these cases, a separate trochlear fracture fragment with impaction was seen. Distal lateral column posteroinferior metaphyseal comminution and/or impaction was observed in association with five fractures (including four Type-IV fractures and one Type-III fracture). The lateral collateral ligament was intact in fifteen of the sixteen elbows. In a single case of a Type-III comminuted capitellar fracture associated with a closed elbow dislocation, the lateral collateral ligament was found to be avulsed with an attached lateral epicondyle fracture fragment and was reattached with #2 FiberWire (Arthrex, Naples, Florida) and drill-holes at the isometric point in the distal part of the humerus.

Objective and Elbow-Specific Outcomes

All fractures healed; the mean time to union was eleven weeks (range, six to sixteen weeks). No patient had residual elbow instability or weakness. The average arc of ulnohumeral motion was 123° (range, 70° to 150°), with an average flexion of 133° (range, 100° to 150°) and an average flexion contracture

TABLE I Overall Elbow-Specific and Physical Outcome Measures

Measure	Outcome
ASES score*† (points)	
Function	37 ± 4 (29 to 40)
Satisfaction	9 ± 2 (3 to 10)
MEPI score*† (points)	
Pain	37 ± 9 (15 to 45)
Motion	19 ± 2 (15 to 20)
Stability	10 ± 0
Function	25 ± 0
Total	92 ± 10 (65 to 100)
Extension‡ (deg)	10 (0 to 45)
Flexion‡ (deg)	133 (100 to 150)
Net ulnohumeral arc‡ (deg)	123 (70 to 150)
Percentage of elbows with functional arc	87.5% (14 of 16)

*The values are reported as the mean and the standard deviation, with the range in parentheses (when applicable). †ASES = American Shoulder and Elbow Surgeons. ‡MEPI = Mayo Elbow Performance Index. §The values are given as the mean, with the range in parentheses.

of 10° (range, 0° to 45°). Fourteen of the sixteen patients achieved a functional arc of ulnohumeral motion (a minimum ulnohumeral arc of 100°, from 30° to 130°). All patients had full forearm rotation. At the time of the latest follow-up, nine patients had no pain, six had mild pain, and one had moderate pain. Overall, the mean ASES function score was 37 ± 4 points (range, 29 to 40 points) and the mean satisfaction score was 9 ± 2 points (range, 3 to 10 points). The mean MEPI score was 92 ± 10 points (range, 65 to 100 points), corresponding with nine excellent outcomes, six good outcomes, and one fair outcome (Table I). In the group of eleven patients who had twelve to twenty-four months of follow-up, seven had an excellent outcome, three had a good outcome, and one had a fair outcome. In the group of five patients who had more than two years of follow-up, two had an excellent outcome and three had a good outcome. All patients returned to their preinjury occupation.

TABLE II Comparison of Type-I and Type-IV Fracture Subgroups According to Elbow-Specific Outcome Measures*

	ASES Score† (points)		Total MEPI Score† (points)	Extension† (deg)	Flexion† (deg)	Net Ulnohumeral Arc† (deg)	Percentage of Elbows with Functional Arc
	Function	Satisfaction					
Type I (n = 6)	38	9	93	0	143	144	100% (6 of 6)
Type IV (n = 8)	37	8	91	18	126	109	75% (6 of 8)
P value	0.81	0.52	0.75	0.04	0.02	0.01	0.47

*ASES = American Shoulder and Elbow Surgeons, and MEPI = Mayo Elbow Performance Index. †The values are given as the mean.

**TABLE III Mayo Elbow Performance Index Overall Outcome
According to Fracture Subgroup**

Mayo Elbow Performance Index	Type I (n = 6)*	Type III (n = 2)*	Type IV (n = 8)*	P Value
Rating				0.77
Excellent	3	1	5	
Good	3	1	2	
Fair	0	0	1	
Poor	0	0	0	

*The values are given as the number of elbows.

In the group of six patients with a Type-I fracture, the average arc of ulnohumeral motion was 144° (range, 140° to 150°) and there were no flexion contractures. At the time of the latest follow-up, three patients had no pain and three had mild pain. The mean ASES function score was 38 ± 3 points (range, 34 to 40 points), and the mean satisfaction score was 9 ± 1 points (range, 8 to 10 points). The mean MEPI score was 93 ± 8 points (range, 85 to 100 points), corresponding with three excellent outcomes and three good outcomes (Tables II and III).

In the group of eight patients with a Type-IV fracture, the average arc of ulnohumeral motion was 109° (range, 70° to 140°), with an average flexion of 126° (range, 100° to 140°) and an average flexion contracture of 18° (range, 0° to 45°). Six of the eight patients achieved a functional arc of ulnohumeral motion. At the time of the latest follow-up, five patients had no pain, two had mild pain, and one had moderate pain. Overall, the mean ASES function score was 37 ± 5 points (range, 29 to

40 points) and the mean satisfaction score was 8 ± 3 points (range, 3 to 10 points). The mean MEPI score was 91 ± 12 points (range, 65 to 100 points), corresponding with five excellent outcomes, two good outcomes, and one fair outcome. The patient who had a Type-III capitellar fracture and lateral collateral ligamentous disruption in the setting of a closed elbow dislocation had an excellent result (Tables II and III).

At the time of the latest follow-up, analysis revealed significant differences between the Type-I and Type-IV fracture-classification subgroups with respect to the magnitude of the measured flexion contracture ($p = 0.04$), total flexion ($p = 0.02$), and net ulnohumeral arc ($p = 0.01$) (Table II). While Type-IV fractures led to lower elbow-specific outcomes, differences in the ASES function score, the ASES satisfaction score, the total MEPI score, and the MEPI pain and motion subscale scores did not reach significance. Additionally, the groups were similar with respect to the rates of good and excellent outcomes (Table III) and the percentages of elbows that achieved a functional arc of ulnohumeral motion.

A subcohort analysis of five patients who had sustained concomitant fractures of the capitellum and the ipsilateral radial head demonstrated an average arc of ulnohumeral motion of 114° (range, 75° to 140°), an average flexion of 130° (range, 120° to 140°), and an average flexion contracture of 16° (range, 0° to 45°) (Table IV). Four of the five elbows achieved a functional arc of ulnohumeral motion. At the time of the latest follow-up, two patients had no pain, two had mild pain, and one had moderate pain. Overall, the mean ASES function score was 35 ± 5 points (range, 29 to 40 points), and the mean satisfaction score was 7 ± 3 points (range, 3 to 10 points). The mean MEPI score was 87 ± 14 points (range, 65 to 100 points), corresponding with two

TABLE IV Effect of Ipsilateral Radial Head Fracture on Elbow-Specific Outcome Measures*

	Ipsilateral Radial Head Fracture (N = 5)	Isolated Capitellar-Trochlear Fracture (N = 11)	P Value
ASES score (points)			
Function	35	39	0.07
Satisfaction	7	9	0.13
MEPI total score (points)	87	94	0.23
MEPI rating (no. of elbows)			0.37
Excellent	2	7	
Good	2	4	
Fair	1	0	
Extension (deg)	16	7	0.27
Flexion (deg)	130	134	0.58
Net ulnohumeral arc (deg)	114	128	0.35
Percentage of elbows with functional arc	80% (4 of 5)	91% (10 of 11)	0.54

*ASES = American Shoulder and Elbow Surgeons, and MEPI = Mayo Elbow Performance Index.



Fig. 3-A



Fig. 3-B

Anteroposterior (Fig. 3-A) and lateral (Fig. 3-B) radiographs showing Grade-2 posttraumatic arthrosis with moderate joint-space narrowing and osteophyte formation (arrows) at three years postoperatively.

excellent outcomes, two good outcomes, and one fair outcome. When compared with the eleven patients who had an isolated capitellar-trochlear fracture, the five patients with an ipsilateral radial head fracture had greater loss of terminal elbow flexion and extension, reduced ulnohumeral arc of motion, poorer functional outcomes, and greater dissatisfaction. However, with the small numbers studied, these differences did not reach significance.

Radiographic Outcomes

Posttraumatic arthrosis was seen in four elbows. Grade-1 changes were seen in association with two Type-IV fractures, and Grade-2 changes were seen in association with one Type-III and one Type-IV fracture (Figs. 3-A and 3-B). In six elbows, clinically unimportant, nonbridging heterotopic ossification developed, most often at the anterolateral aspect of the radiocapitellar joint. Minimal progression of heterotopic ossification was seen on serial radiographs. No elbow demonstrated evidence of osteonecrosis or articular surface collapse on serial plain radiographs. In the one patient with a Type-IV capitellar fracture who underwent concomitant open reduction and internal fixation of a radial head fracture, a 1.5-mm step-off and a 2-mm gap at the radial head articular surface was evident on follow-up radiographs. Despite radiographic evidence of Grade-2 arthrosis, a good clinical result was obtained.

There were no postoperative complications. Secondary surgery was performed for one patient to remove hardware because of persistent elbow pain.

Discussion

In the present series, a uniform surgical approach was utilized for all capitellar-trochlear fractures. An extensile lateral exposure provided sufficient visualization to address medial trochlear extension, impaction, and comminution in patients with Type-IV fractures. In one of our patients with a Type-III fracture, the lateral epicondylar fragment with the attached lateral collateral ligament complex origin could be reflected distally to enhance exposure. An olecranon osteotomy or a medially based exposure was not required in any case. Other groups^{2,6,7} have reported on the need to perform either a flexor-pronator split/elevation or an olecranon osteotomy when the medial reduction of the trochlea could not be visualized from a lateral approach or when the articular fracture extended to involve the medial epicondyle.

Stable fixation of the capitellum was achieved with use of cannulated variable-pitch headless Acutrak compression screws (Acumed) that were placed in an anterior-to-posterior direction and were buried beneath the articular surface. Biomechanical studies have demonstrated that fixation of capitellar fractures with Acutrak screws is superior to fixation with posteroanterior 4.0-mm cancellous lag screws²³ and Herbert screws (Zimmer, Warsaw, Indiana)²⁴. All Type-I fractures were fixed with two Acutrak screws alone. In accordance with other series^{2,6,18}, we found that supplemental mini-fragment screw fixation was required in half of the more complex fracture patterns with posteroinferior/lateral metaphyseal comminution and trochlear extension (i.e., Type-III and IV fractures).

However, column or fixed-angle plating was not performed in any case.

Our overall range-of-motion results and elbow-specific outcomes compare favorably with those of other studies on the outcomes of open reduction and internal fixation of capitellar-trochlear fractures^{2,6,18}. We found a mean ulnohumeral arc of 123°, and the mean MEPI score was 92 points, corresponding with a good to excellent result in fifteen of the sixteen patients. In a study of twenty-eight patients, Dubberley et al.² reported a mean elbow extension-flexion arc of 119° and a mean MEPI score of 91 points. Ring et al.⁶ reported an average arc of ulnohumeral motion of 96° and a good to excellent result according to the MEPI score in sixteen of twenty-one patients. However, their series included five patients with a fracture that extended into the medial epicondyle (i.e., a Ring Type-5 fracture) and in all cases an olecranon osteotomy was used for articular exposure. This fracture pattern may represent an entity that is distinct from capitellar-trochlear fractures and may have a poorer prognosis. The complete nature of the articular injury in the axial plane and the additional operative exposure required (i.e., olecranon osteotomy or medially based exposure) may explain the differences in clinical outcomes between the two series. However, Ring et al.⁶ did not stratify their results or complications according to fracture subtype.

Furthermore, the clinical and functional results in the Type-IV fracture subgroup in our series are consistent with the results reported in other series dedicated to this complex coronal plane fracture^{3,7,8,16}. In this group, the average arc of ulnohumeral motion was 109° and the mean MEPI score was 91 points, corresponding with a good to excellent result in seven of the eight patients. In the original description of the Type-IV fracture by McKee et al.³, the mean elbow arc was 126° and the result was good or excellent in all six patients. Goodman and Choueka⁷ reported a mean MEPI score of 84 points for eight patients, which corresponded with a good or excellent result in six of the eight patients. The mean flexion contracture of 18° in the Type-IV fracture subgroup in the present study is in accordance with previously reported results^{3,16}. While we counsel patients who have Type-IV fracture patterns in advance about the possibility of development of a flexion contracture, our results and those of the aforementioned studies^{3,8,16} suggest that a functional ulnohumeral arc is achievable in the majority of patients. All Type-IV fractures in the present series were sustained during low-energy falls, and several authors^{2,3,6,8} have confirmed this finding.

Fracture subgroup analyses demonstrated that patients with a Type-IV fracture have significant reductions in terms of terminal flexion and the net ulnohumeral arc of motion as well as greater loss of terminal extension (i.e., a greater flexion contracture) as compared with patients with a Type-I fracture. We surmise that the greater flexion contractures seen in these patients may be due to the increased severity of the articular injury (i.e., posterior comminution, trochlear extension, and impaction), the presence of a concomitant radial head fracture, and the extended operative dissection (i.e., elevation and re-

traction of the common extensor origin, brachialis, and capsule) needed to facilitate exposure of the anterior articular segments.

Four of the five ipsilateral radial head fractures in the present series occurred in association with a Type-IV capitellar-trochlear fracture. Both Dubberley et al.² and Ring et al.⁶ independently reported an ipsilateral radial head fracture in three patients in their respective series, but the impact of concomitant radial head fracture on outcome and its association with fracture subtype were not specifically evaluated in either study. Goodman and Choueka⁷ reported excellent elbow function in two patients who had sustained an ipsilateral radial head fracture. The number of radial head fractures in the present series was too small to allow us to draw any firm conclusions about the impact on outcome, although the mean scores for both function and motion for those five patients were lower than those for the patients without a radial head fracture. Analysis of a larger cohort may reveal significantly inferior clinical and functional outcomes in this patient subgroup.

The present study is limited by its retrospective nature and the small size of the cohort. These study characteristics reflect the rare nature of these injuries. Published clinical reports on the outcomes of open reduction and internal fixation of capitellar fractures have been similarly limited to relatively small cohorts. In the present series, the inability to demonstrate significant differences in elbow-specific outcome measures between the Type-I and Type-IV fracture subgroups, or in elbow-specific and clinical outcomes between patients with and without a concomitant radial head fracture, may have been due to the small sample sizes in the subgroups and inadequate statistical power. This cohort of sixteen patients is relatively large in comparison with published series dedicated to capitellar-trochlear fractures and includes the greatest number of cases with an ipsilateral radial head fracture. Recently, Doornberg et al.²⁵ demonstrated that short-term functional outcomes following distal humeral fractures endured after a mean duration of follow-up of nineteen years. Furthermore, those authors noted that functional outcomes and perceived disability were predicated more on pain than on functional impairment and did not correlate with radiographic signs of arthrosis. In the present series, mild to moderate degenerative changes were seen in only four elbows at a mean of twenty-seven months postoperatively. These radiographic findings are preliminary as degenerative changes may increase over time, and longer follow-up is needed to fully evaluate the prevalence and severity of posttraumatic arthrosis following partial articular fractures of the lateral column of the distal part of the humerus. Despite capitellar displacement and rotation, posterior metaphyseal comminution, separation from soft-tissue attachments, and in some cases a delay in time to open reduction and internal fixation, we did not observe any radiographic evidence of osteonecrosis of the capitellum and/or trochlea on serial plain radiographs. While this radiographic observation is in accordance with other series^{2,3,6,8,9,15-18}, we note that this and other series have not included a magnetic resonance imaging assessment of these elbows in the postoperative period. Finally,

as there were no cases of clinically important heterotopic ossification in this small series, we do not recommend formal pharmacologic prophylaxis^{2,18} when open reduction and internal fixation is performed through an extensile lateral exposure. ■

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