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OUTCOME AFTER OPEN REDUCTION AND INTERNAL FIXATION OF CAPITELLAR AND TROCHLEAR FRACTURES

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Background: Capitellar and trochlear fractures are uncommon fractures of the distal aspect of the humerus. There is limited information about the functional outcome of patients managed with open reduction and internal fixation.

Methods: The functional outcome of twenty-eight patients, with a mean age (and standard deviation) of 43 ± 13 years, who were treated with open reduction and internal fixation for capitellar and trochlear fractures was evaluated at a mean duration of follow-up of 56 ± 33 months. Patient outcomes were assessed with physical and radiographic examination, range-of-motion measurements, strength testing, and self-reported questionnaires (Short Form-36, Mayo Elbow Performance Index, American Shoulder and Elbow Surgeons Elbow Assessment Form, and Patient-Rated Elbow Evaluation scales).

Results: Eleven fractures involved the capitellum with or without fracture of the lateral ridge of the trochlea, four involved the capitellum and trochlea as one piece, and thirteen involved the capitellum and trochlea as separate fragments. These fractures were further characterized by the presence or absence of posterior comminution. Fourteen patients had isolated fractures, and fourteen had other elbow, forearm, or wrist injuries. Patients with more complex fractures required more extensive surgery, had more complications resulting in secondary procedures, and had poorer outcomes compared with those with simple fractures. The average score on the Mayo Elbow Performance Index (91 ± 11), the average quality-of-life scores (46 on the physical component and 50 on the mental component of the Short Form-36), and the average range of motion (19° to 138°) suggest favorable patient outcomes overall. Two comminuted fractures did not unite and required conversion to a total elbow arthroplasty.

Conclusions: Patients with isolated noncomminuted capitellar and/or trochlear fractures have better results than those with more complex fractures. A classification system based on the radiographic patterns of these fractures is recommended.

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

Coronal fractures of the distal aspect of the humerus involve the capitellum, the trochlea, or a combination of both. Capitellar fractures are uncommon¹, and isolated trochlear fractures are even more rare². Capitellar fractures may be associated with soft-tissue injuries (e.g., medial collateral ligament tears or lateral ligamentous complex tears) and/or other fractures (e.g., a radial head fracture)³⁻⁸. Current classification systems of capitellar and trochlear fractures^{1,9-11} are descriptive and do not direct treatment. Bryan and Morrey¹ classified capitellar fractures as Type 1, 2, and 3. Type 1 is a shear fracture in the coronal plane involving most of the capitellum and little or none of the trochlea. Type 2 involves a variable amount of articular cartilage of the capitellum with minimal attached subchondral bone. Type 3 is a comminuted or compression fracture of

the capitellum. McKee et al.⁹ described a fourth type, a shear fracture of the distal aspect of the humerus in the coronal plane including the capitellum and most of the trochlea. According to the AO classification¹⁰, these fractures would be grouped as B3 (distal aspect of the humerus, partial articular, and frontal), with B3.1 indicating capitellar fractures; B3.2, trochlear fractures; and B3.3, capitellar and trochlear fractures. Ring et al.¹¹ recently reported another descriptive classification for distal humeral articular fractures, which describes five anatomic components: (1) the capitellum and the lateral aspect of the trochlea, (2) the lateral epicondyle, (3) the posterior aspect of the lateral column, (4) the posterior aspect of the trochlea, and (5) the medial epicondyle.

Treatment has included closed reduction^{8,12-14}, excision^{3,15,16},

open reduction with or without internal fixation^{1,4,9,11,17-24}, and prosthetic replacement²⁵. The purposes of the present study were to perform a comprehensive objective and subjective evaluation of the outcome of patients with capitellar and trochlear fractures that were treated with open reduction and internal fixation and to propose a new classification system that reflects our current treatment and is correlated with the clinical outcome.

Materials and Methods

During a ten-year period at a single hospital, four surgeons treated thirty-eight fractures involving the capitellum and/or the trochlea with open reduction and internal fixation within two weeks after the injury. Eight patients were lost to

follow-up, and two died of unrelated illnesses. Approval from the institutional review board was obtained, and twenty-eight patients consented to participate in the study. Patients were interviewed and examined in person for a detailed objective and subjective review by an independent observer. Twenty-four patients were female, and four were male. The mean age (and standard deviation) was 43 ± 13 years (range, twenty to seventy-one years) (see Appendix). The mean duration of follow-up was 56 ± 33 months (range, fourteen to 121 months). The mechanism of injury in all patients was a fall directly onto the elbow or onto an outstretched hand.

Fractures were retrospectively classified (Fig. 1) into those involving primarily the capitellum with or without the lateral trochlear ridge (Type 1), those involving the capitellum

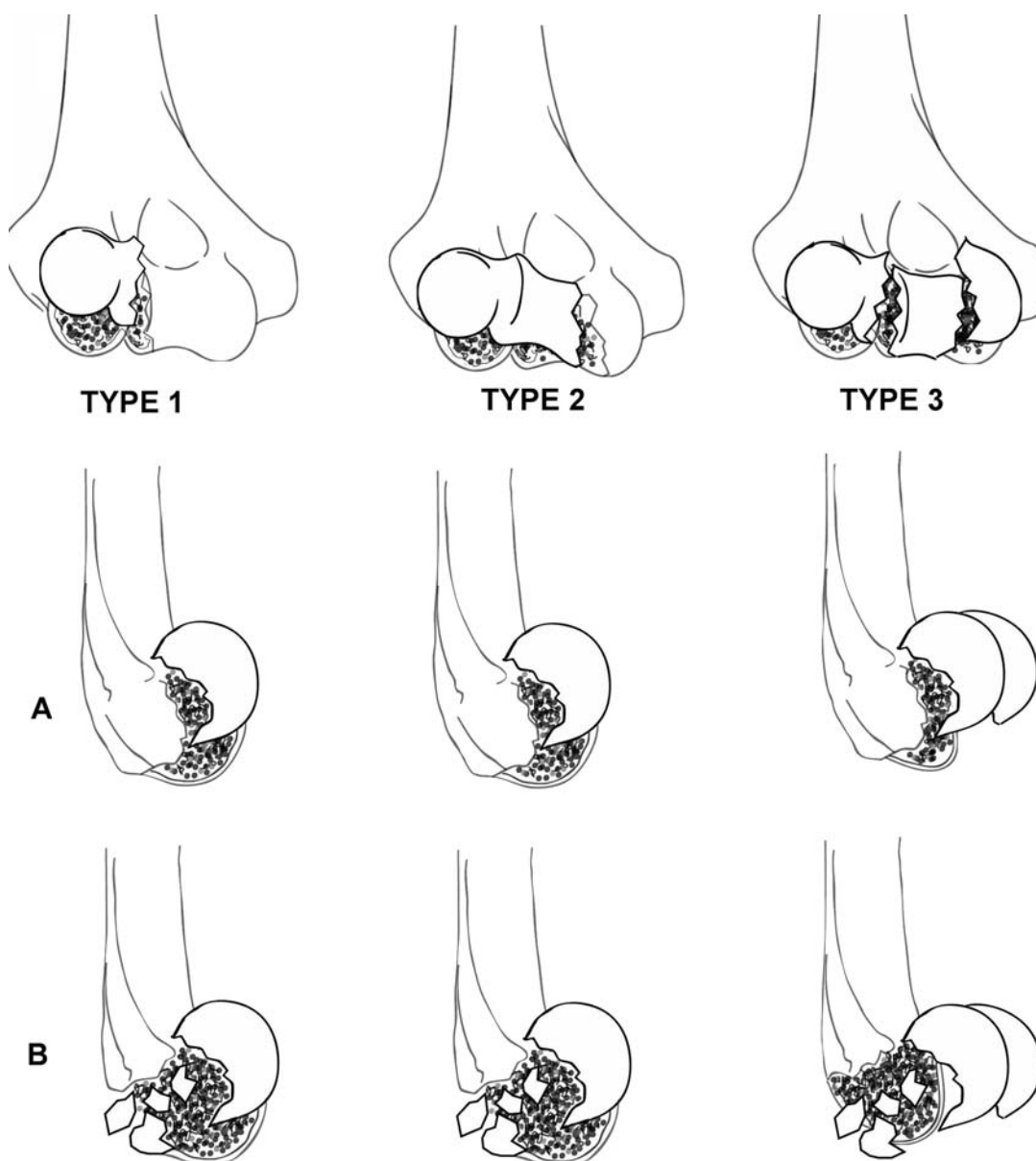


Fig. 1
Classification of capitellar and/or trochlear fractures

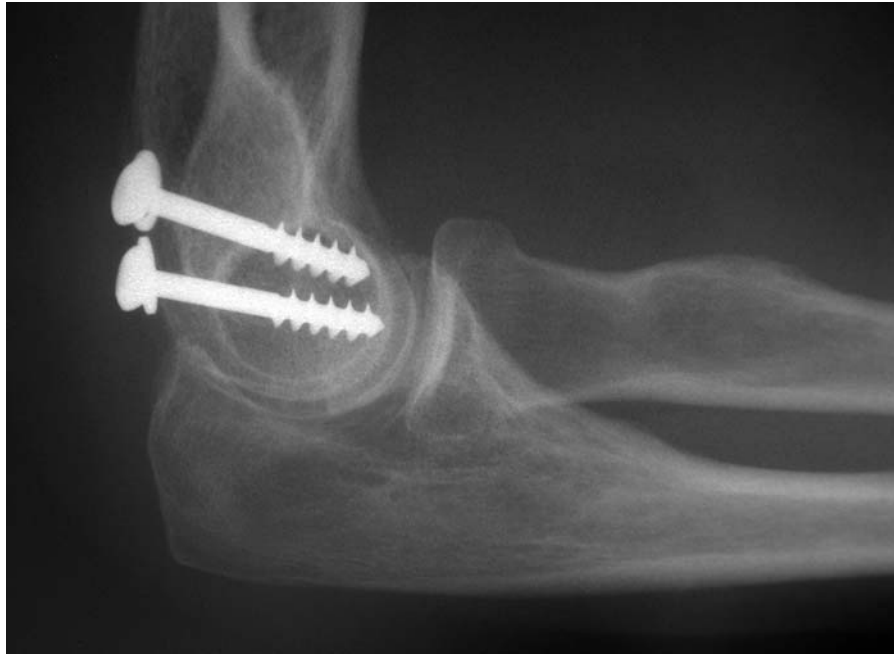


Fig. 2
Radiograph showing fixation of a Type-1 fracture.

lum and the trochlea as one piece (Type 2), and those consisting of fractures of both the capitellum and the trochlea as separate fragments (Type 3). Eleven fractures were Type 1, four were Type 2, and thirteen were Type 3. These fractures were further characterized with respect to the absence (A) or presence (B) of posterior condylar comminution. No isolated trochlear fractures were identified in this series.

Fourteen patients had isolated capitellar and/or trochlear fractures, and fourteen had associated ipsilateral elbow, forearm, or wrist injuries. Associated injuries to the affected limb included a scaphoid fracture treated in a cast, a distal radial fracture requiring a closed reduction and percutaneous pinning, and a triceps rupture in one patient each; a medial collateral ligament tear in two patients (one treated with a hinged brace); a radial head fracture in three patients; and lateral ligamentous complex injuries in eleven patients, including four who had lateral ligament disruptions and seven who had avulsion fractures of the lateral epicondyle.

Surgical Technique and Postoperative Care

A posterior midline skin incision was used for twenty-four patients. Four patients had lateral skin incisions. One patient had a revision of an open reduction and internal fixation done elsewhere, and the initial posterolateral skin incision was reused. One anterolateral incision and two lateral incisions were used in three of the patients seen earliest in the series.

The deep surgical interval chosen to address the fracture was determined either preoperatively, on the basis of imaging studies (radiographs, tomograms, or computed tomography scans), or intraoperatively, depending on the complexity of the fracture or the difficulty of obtaining or maintaining a reduction. Intermuscular exposures were used either alone or in com-

bination to access the capitellum laterally. They included the Boyd exposure²⁶ (the anconeus and supinator elevated off the subcutaneous border of the ulna), which was used in seven patients; the exposure described by Kocher²⁷ (between the extensor carpi ulnaris and the anconeus), in five patients; and the exposure described by Kaplan²⁸ (between the extensor digitorum communis and the extensor carpi radialis longus and brevis), in fourteen patients. Greater access to the joint was possible in patients whose lateral ligamentous complex was avulsed from the distal aspect of the humerus with or without the lateral epicondyle. This allowed the joint to be hinged open on the medial collateral ligament. In two patients, the ligamentous complex was intentionally released from the distal aspect of the humerus to allow greater exposure and was subsequently repaired. When the medial reduction of the trochlea could not be adequately visualized from a lateral approach, further exposure was achieved with a medial flexor pronator split²⁹ (two patients), a flexor pronator elevation (one patient), or an olecranon osteotomy³⁰ (fourteen patients). Osteotomies were done either primarily, because of the radiographic appearance of a comminuted trochlea, or after attempts to achieve adequate exposure through one of the intermuscular intervals had failed. Olecranon osteotomy fixation included a reconstruction plate³¹ (four patients), tension band and Kirschner wires³² (four patients), or tension band and a screw³¹⁻³³ (six patients).

Fixation varied depending on the complexity of the fracture and on the stability of the reduction. Fractures identified as involving the capitellum alone or with the lateral ridge of the trochlea (Type 1) were treated with cancellous screws placed from the posterolateral column of the distal aspect of the humerus into the fracture fragment (seven patients) (Fig. 2), except for three patients treated with Herbert screws (Zim-



Fig. 3
Radiograph showing fixation of a Type-2 fracture.

mer, Warsaw, Indiana) and one with biodegradable pins (Orthosorb; Johnson and Johnson, Raynham, Massachusetts) directed from the articular surface into the posterior column. Larger one-piece fragments involving the capitellum and trochlea (Type 2) required additional screws directed from the posterolateral column into the trochlea, or additional fixation was placed from the posteromedial column with use of a limited medial approach (Fig. 3). Fractures separating the capitellum and the trochlea from the distal aspect of the humerus and from each other (Type 3) required screws of various types, and, in four patients, screws were supplemented with threaded Kirschner wires (Fig. 4).

Fractures with extensive posterior comminution of the distal humeral columns required supplemental bone-grafting alone (seven patients), additional fixation such as pelvic reconstruction plates alone (two), or a combination of both (four). Bone graft was obtained from the iliac crest in ten patients and from the distal aspect of the radius in one patient.

Fractures of the lateral epicondyle (seven patients) were fixed with screws or a plate if the fragment was large enough (six patients). Otherwise, they were treated as a lateral ligament tear (one patient) and were repaired primarily with use of drill-holes and a locking suture technique. Four lateral ligament tears were treated with a lateral ligament repair.

Simultaneous ipsilateral operative elbow procedures included excision of a radial head fracture fragment, open reduction and internal fixation of a radial head fracture, a radial head arthroplasty, a triceps repair, and a medial collateral ligament repair in one patient each.

Two patients had early postoperative complications that required operative treatment. The first complication was an olecranon osteotomy screw impinging on the proximal radioulnar joint that was discovered during the initiation of postoperative range-of-motion exercises. The offending screw was replaced. The second complication was a fracture malreduction that was evident on postoperative radiographs but not visible through the lateral intermuscular intervals used for the original surgery. The malreduction was corrected with revision of the internal fixation through an olecranon osteotomy with use of an iliac crest bone graft and a medial collateral ligament repair.

Twenty-six patients were treated with early active-assisted range-of-motion exercises of the elbow under the supervision of a therapist, commencing on the first or second postopera-



Fig. 4
Radiograph showing fixation of a Type-3 fracture addressing posterior comminution.

time day. Daytime resting splints with the elbow at 90° of flexion were worn between exercises for six weeks. Nighttime extension splints were used in an effort to minimize flexion contractures. Passive stretching and strengthening exercises commenced six weeks postoperatively. Patients with lateral ligamentous injuries or who had open reduction and internal fixation of lateral epicondylar fractures were managed for the first six weeks with a splint with the forearm maintained in full pronation and 90° of elbow flexion between active-assisted range-of-motion exercises. Active extension was performed with the arm maintained in pronation to prevent posterolateral rotatory instability³⁴. Supination and pronation were permitted with the elbow flexed to ≥90°. One patient with a medial collateral ligament tear and one with a medial collateral ligament plication were treated with a cast brace with the forearm maintained in supination³⁵.

Eighteen of the twenty-eight patients were prescribed indomethacin (25 mg three times daily) for three to six weeks postoperatively to control swelling and to retard the development of heterotopic ossification. The decision to use indomethacin was made on an individual basis by each surgeon. Indomethacin was not used in patients with a history of allergy to nonsteroidal anti-inflammatory medications, those with peptic ulcer disease, or in patients greater than sixty-five years of age.

Clinical Patient Review

Twenty-eight patients were independently evaluated with use of questionnaires, a personal interview, physical and radiographic examinations, and strength testing. A surgeon who did not participate in their original management reviewed the case of each patient.

Outcome Measures

The Short Form-36 (SF-36) health survey was completed, and the physical component and mental component summary scores were calculated. These scores cover the two global aspects of overall health and are standardized so that the mean score of the United States population is 50. They have been shown to be reliable in patients with pathological conditions of the elbow³⁶. Elbow-specific outcome was measured with use of the American Shoulder and Elbow Surgeons Elbow Assessment Form³⁷, the Mayo Elbow Performance Index³⁸, and the Patient-Rated Elbow Evaluation³⁶. The NK Hand Evaluation System (NK Biotechnical Engineering, Minneapolis, Minnesota) was used to measure grip strength and range of motion with use of methods with established reliability^{39,40}. Strength testing was performed with the patient seated in a sturdy chair with the shoulder in neutral position and the elbow flexed at 90°. The Lido Workset⁴¹ (Loredan Biomedical, West Sacramento, California) was used to measure isometric strength of elbow flexion, extension, pronation, and supination.

Anteroposterior and lateral radiographs of the elbow were made to assess the presence of osteonecrosis, heterotopic ossification, and posttraumatic osteoarthritis. Arthritis was graded as described by Broberg and Morrey⁴². Radiographs of

TABLE I General Health and Region-Specific Outcome Measures

Measure	Score*	Range
General health		
Short Form-36		
Physical function	46 ± 13	21-64
Mental function	50 ± 12	21-62
Region-specific		
Patient-Rated Elbow Evaluation	16 ± 21	0-70
American Shoulder and Elbow Surgeons function	29 ± 9	0-40
Mayo Elbow Performance Index		
Pain	39 ± 9	15-45
Motion	19 ± 2	15-20
Stability	10 ± 1	5-10
Function	24 ± 5	0-25
Total	91 ± 11	65-100

*The values are given as the mean and the standard deviation.

the unaffected elbow were made for comparison. The Student paired t test was used for statistical comparisons with regard to range of motion, grip strength, and power of the affected arm compared with that of the unaffected arm and between subgroups.

Results

Outcome Measures

The details of the injury, treatment, and outcome for each patient are presented in the Appendix. The general health and region-specific outcomes are presented in Table I. No significant differences were detected in the physical or mental health component scores on the SF-36 when compared with those of age and sex-matched controls ($p < 0.05$, power = 0.8). The mean function score (and standard deviation) on the American Shoulder and Elbow Surgeons system was 29 ± 9 (range, 0 to 40). The average Patient-Rated Elbow Evaluation score was 16 ± 21 (range, 0 to 70), which corresponds to a rating of minimal pain and disability as specified by subjective ratings applied by the developer of the scale in a previous study on patients with wrist fractures⁴³. The average score on the Mayo Elbow Performance Index was 91 ± 11 (range, 65 to 100), which corresponds to an excellent outcome.

The classification types were then compared statistically (Table II). Analysis showed a significant difference between the groups with respect to the American Shoulder and Elbow Surgeons system ($p = 0.005$), Patient-Rated Elbow Evaluation score ($p = 0.04$), and Mayo Elbow Performance Index ($p = 0.04$), but, because of the small sample size, it was not possible to say which subgroups were different. For the Mayo Elbow Performance Index, Type-1 fractures had a significantly better outcome than Types 2 and 3 ($p = 0.01$).

At the time of the final follow-up, the average motion (and standard deviation) of the affected and unaffected elbows

TABLE II Comparison of Groups According to the Mean Scores on the General and Region-Specific Outcome Measures

Fracture Type	Short Form-36		Mayo Elbow Performance Index (Total Score)	American Shoulder and Elbow Surgeons (Function Score)	Patient-Rated Elbow Evaluation
	Physical Component	Mental Component			
1A (n = 9)	48.5	51.6	100	35	6
1B (n = 2)	56.5	50.9	92.5	33	21
2A (n = 1)	59.2	55.6	85	36	0
2B (n = 3)	51.3	48.1	88	32	6
3A (n = 3)	45.8	51.9	98	24	22
3B (n = 8)*	39.2	46.2	86	23	31
Significance (<i>p value</i>)	0.120	0.747	0.04	0.005	0.04

*Two patients who had a total elbow arthroplasty are not included.

differed significantly with respect to flexion ($138^\circ \pm 10^\circ$ and $147^\circ \pm 6^\circ$, respectively; $p < 0.05$), extension ($19^\circ \pm 15^\circ$ and $3^\circ \pm 8^\circ$; $p < 0.05$), and supination ($74^\circ \pm 11^\circ$ and $80^\circ \pm 6^\circ$; $p < 0.05$) but not pronation ($82^\circ \pm 7^\circ$ and $80^\circ \pm 6^\circ$). The average loss of motion was 25° of flexion-extension (average arc = 119°) and 4° of supination-pronation (average arc = 156°). The average strength of the affected and unaffected elbows was significantly less in flexion (29 Nm and 34 Nm, respectively; $p < 0.05$) and extension (23 Nm and 29 Nm; $p < 0.05$). No difference was found with respect to the strength of forearm rotation or grip between the affected and unaffected extremities. Significant differences were detected between the classification types with respect to grip strength ($p = 0.03$), flexion power ($p = 0.03$), extension power ($p = 0.004$), and supination power ($p = 0.03$) (Table III) but not with respect to range of motion.

Subsequent surgical procedures were required in twelve patients, including two who had multiple procedures performed. Six patients with olecranon osteotomies had pain associated with the olecranon hardware, which required removal. None of the other surgical approaches resulted in a

recognized complication. Seven patients with a Type-2 or Type-3 fracture had an elbow capsulectomy and hardware removal for loss of function due to a range of motion of less than 30° to 130° . One patient with a nonunion of a Type-3B fracture had the original hardware removed followed by iliac crest bone-grafting and application of a Compass Hinge fixator (Smith and Nephew Richards, Memphis, Tennessee) that was later removed after the fracture healed. Two patients with Type-3B fractures had a total elbow arthroplasty for nonunion or osteonecrosis of the capitellum and trochlea. One of them had a nonunion of an olecranon osteotomy, which was revised before ultimately undergoing total elbow arthroplasty. The other had a painful elbow treated with hardware removal before later having a total elbow arthroplasty.

One complication did not involve the affected elbow. A diagnosis of frozen shoulder was made in the ipsilateral limb of one patient that resulted in substantial residual shoulder stiffness despite therapy. One of the patients who had a total elbow arthroplasty had triceps insufficiency at the time of follow-up.

TABLE III Comparison of Groups According to Objective Physical Outcome Measures

	Type of Fracture						Significance (<i>P Value</i>)
	1A	1B	2A	2B	3A	3B	
Flexion (<i>deg</i>)	144.8	124.5	143.0	139.3	129.3	135.7	0.325
Extension (<i>deg</i>)	10.4	1.0	7.0	21.3	35.0	26.9	0.817
Pronation (<i>deg</i>)	80.2	82.0	79.0	79.7	80.0	85.0	0.488
Supination (<i>deg</i>)	77.6	74.5	74.0	68.7	71.7	71.9	0.431
Grip Strength (<i>kg</i>)	23.7	18.7	23.4	27.73	28.23	24.3	0.03
Flexion power (<i>Nm</i>)	31.3	27.5	35.0	26.7	30.0	26.7	0.03
Extension power (<i>Nm</i>)	25.9	29.0	29.0	23.7	23.0	18.4	0.004
Pronation power (<i>Ncm</i>)	372.9	335.0	313.0	503.3	507.0	360.0	0.084
Supination power (<i>Ncm</i>)	449.0	467.0	505.0	506.0	419.0	404.0	0.03

Radiographic Review

Radiographs of the operative side were compared with those of the nonoperative side and were assessed for hardware loosening, heterotopic ossification, posttraumatic arthritis, and osteonecrosis. One patient had a screw back out, and one had a screw that appeared to be impinging on the joint. Minor periarticular calcification was present in four patients. Nine patients had posttraumatic arthritis classified according to the system of Broberg and Morrey⁴². Five had slight joint-space narrowing and minimal osteophyte formation (Grade 1), and four had moderate joint-space narrowing and osteophyte formation (Grade 2). No patient had severe joint-space narrowing with gross destruction (Grade 3), except for two patients who had already undergone total elbow arthroplasty. One Type-3A and two Type-3B fractures had evidence of osteonecrosis on radiographs. Two of three patients with osteonecrosis of the capitellum or trochlea had radiographic evidence of collapse.

Discussion

To our knowledge, this investigation is the largest reported study of open reduction and internal fixation of capitellar and trochlear fractures to date and the first to evaluate the subjective and objective outcome. We recognize the inherent weakness of a retrospective review; however, a 74% rate of follow-up (twenty-eight of thirty-eight patients) was achieved at an average of 56 ± 33 months. Longer-term evaluation is necessary, particularly as these injuries often occur in younger patients who are at risk for the development of posttraumatic arthritis. In the course of managing the twenty-eight patients in this study, it became apparent that these fractures varied in their complexity. They required different techniques for surgical exposure and internal fixation, and they differed in outcome. A review of the literature provided various classification systems^{1,9-11} that were descriptive in nature and/or were limited with regard to outcome measures.

In 2003, Ring et al.¹¹ reported the results of open reduction and internal fixation of fractures involving the capitellum and trochlea in twenty-one patients (five had a clinical evaluation and the data on sixteen were from medical record reviews) after a mean duration of forty months. They identified five patterns of injury, all of which healed with no residual instability or weakness. Ten patients required a second operation (contracture releases in six, ulnar nerve transpositions in two, removal of hardware in one, and revision after loss of fixation in one). The average arc of ulnohumeral range of motion was 96° . The results according to the Mayo Elbow Performance Index were excellent in four, good in twelve, and fair in five. There was no radiographic evidence of arthritis or osteonecrosis. The small number of patient evaluations limits that study, and there is a question about whether the patterns of injury identified also includes transcondylar fractures (loss of the medial epicondyle and posterior aspect of the trochlea). In 1996, McKee et al.⁹ reviewed the results of open reduction and internal fixation for the treatment with coronal shear fractures of the distal end of the humerus in six patients after a

mean duration of twenty-two months. All went on to heal with no complications or subsequent operations (other than a planned removal of fixation in a ten-year-old child). Flexion averaged 141° with an average flexion contracture of 15° . All patients had a good or excellent result according to the Mayo Elbow Performance Index. Radiographs revealed one patient who had mild arthritis and no evidence of osteonecrosis. The fracture classification described by McKee et al.⁹ is similar to that described by Bryan and Morrey¹ and the AO classification system¹⁰ in that it does not address separate capitellar and trochlear fractures. None of the classification systems address the issue of posterior comminution, which affects the method of fixation and outcome. The results of the current study allow for the proposal of a classification system that directs the deep surgical approach and is predictive of outcome.

We suggest that all fractures be approached through a posterior longitudinal skin incision. This allows access both laterally and medially (if necessary), and it decreases the risk of cutaneous nerve injury. No flap problems or neuromas were noted in this series. When a lateral ligament tear or lateral epicondylar fracture is present, the elbow joint can be hinged open on the intact medial collateral ligament by releasing the anterior and posterior joint capsule.

All Type-1 fractures (a coronal shear fracture of the capitellum and part of the lateral trochlear ridge) were managed with a lateral interval approach and screw fixation from the posterolateral column. The fracture can be reduced through the Kaplan²⁸ interval and fixed through a Kocher approach, which exposes the posterior column. The fracture is reduced with extension, supination, and a varus force followed by flexion once the fragment is slid distally to be captured by the radial head. Provisional fixation is maintained with Kirschner wires. The anterior reduction is confirmed by visualization through the Kaplan interval, and the posterior reduction is checked through the Kocher approach. Three or four screws directed from the posterolateral column into the fracture fragment provide stable fixation. Cannulated screws are helpful, as they allow the provisional placement of the screw guidewire into the thickest portion of the fragment, prior to drilling. One Type-1B fracture required supplemental bone-grafting. All eleven Type-1 fractures went on to heal without complications, and none required a second operative procedure. There was no radiographic evidence of arthritis in any of the patients.

Type-2 fractures (single-fragment capitellar fractures that extend to the trochlear groove) require visualization of the medial aspect of the trochlea to ensure anatomic reduction and may require additional fixation through the posteromedial column. If the medial aspect of the trochlea cannot be seen adequately from the lateral side, then a flexor-pronator split²⁷ should be performed to assess the reduction. If reduction cannot be confirmed, then an olecranon osteotomy²⁸ or sectioning of the lateral collateral ligament is required to allow complete exposure of the distal end of the humerus. The optimal technique to gain further exposure in this circumstance requires further study as the olecranon osteotomy has a risk of

nonunion and hardware problems, while division of the collateral ligament results in instability that may persist despite ligament repair. Once the reduction is achieved, screws are directed from the posterolateral and posteromedial columns into the capitellum and trochlea. Two of the four Type-2 fractures had subsequent capsulectomies and hardware removal to treat residual elbow contractures. At the time of the final follow-up, both of these patients had radiographic evidence of Grade-1 posttraumatic arthritis.

Type-3 fractures (comminuted shear fractures of the capitellum and trochlea) typically require an olecranon osteotomy²⁸ for adequate exposure. However, adequate visualization can be achieved in some patients if the lateral collateral ligament is sectioned or has been disrupted. A variety of fixation techniques, including cannulated screws, variable pitch headless screws, threaded Kirschner wires, and possibly plate fixation for posterior column comminution, is required. Nine of the thirteen Type-3 fractures had complications requiring subsequent operative intervention. One patient required removal of olecranon osteotomy hardware because it was causing pain, and five had residual elbow contractures treated with capsulectomy and hardware removal. One nonunion of the trochlea eventually healed after hardware removal, iliac crest bone-grafting, and fixation with a Compass Hinge fixator. Two patients who had a nonunion of the trochlea and capitellum eventually required total elbow arthroplasty. Three of the thirteen Type-3 fractures had radiographic evidence of Grade-1 posttraumatic arthritis; four had Grade-2 changes, and the two that required total elbow arthroplasty were classified as Grade 3.


When posterior comminution has been recognized with any fracture, it is further subclassified as a type B and is managed with bone-grafting, plate fixation, or a combination of the two. A fixed-angle plate system, which can be helpful with severe posterior comminution to maintain the position of the anterior shear fragments, was used twice in this study. Ten of the thirteen Type-3 fractures were subclassified as type B and required additional fixation and/or bone-grafting.

The prevalence of a recognized lateral collateral ligament injury or its equivalent (a lateral epicondylar fracture) associated with the fractures in this series was high, which has not been previously reported, as far as we know. We think that more lateral ligament injuries were missed early in the series

because they were not suspected or looked for. In recent years, partial or complete lateral ligament injuries have been routinely noted during the management of these fractures.

Collectively, our experience with these fractures has demonstrated that patients with a Type-1 fracture of the capitellum have fewer complications, fewer subsequent surgeries, and do better both subjectively and objectively than do those with a Type-3 fracture. The proposed classification system directs the surgical management and, to an extent, predicts the outcome of these injuries.

Appendix

 A table showing clinical data on all patients is available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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References

- Bryan RS, Morrey BF. Fractures of the distal humerus. In: Morrey BF, editor. The elbow and its disorders. Philadelphia: WB Saunders; 1985. p 325-33.
- Foulk DA, Robertson PA, Timmerman LA. Fracture of the trochlea. *J Orthop Trauma*. 1995;9:530-2.
- Milch H. Unusual fractures of the capitulum humeri and the capitulum radii. *J Bone Joint Surg*. 1931;13:882-6.
- Collert S. Surgical management of fracture of the capitulum humeri. *Acta Orthop Scand*. 1977;48:603-6.
- Grantham SA, Norris TR, Bush DC. Isolated fracture of the humeral capitellum. *Clin Orthop Relat Res*. 1981;161:262-9.
- Palmer I. Open treatment of transcondylar T-fracture of the humerus. *Acta Chir Scand*. 1961;121:486-90.
- Johansson O. Capsular and ligamentous injuries of the elbow joint. A clinical and arthrographic study. *Acta Chir Scand Suppl*. 1962;287:1-159.
- Dushuttle RP, Coyle MP, Zawadzky JP, Bloom H. Fractures of the capitellum. *J Trauma*. 1985;25:317-21.
- McKee MD, Jupiter JB, Bamberger HB. Coronal shear fractures of the distal end of the humerus. *J Bone Joint Surg Am*. 1996;78:49-54.
- Mueller ME, Nazarian S, Koch P, Schatzker J. The comprehensive classification of fractures of long bones. New York: Springer; 1990.
- Ring D, Jupiter J, Gulotta L. Articular fractures of the distal part of the humerus. *J Bone Joint Surg Am*. 2003;85:232-8.
- Christopher F, Bushnell LF. Conservative treatment of fractures of the capitellum. *J Bone Joint Surg*. 1935;17:489-92.

- 13.** Ma YZ, Zheng CB, Zhou TL, Yeh YC. Percutaneous probe reduction of frontal fractures of the humeral capitellum. *Clin Orthop Relat Res.* 1984;183:17-21.
- 14.** Ochner RS, Bloom H, Palumbo RC, Coyle MP. Closed reduction of coronal fractures of the capitellum. *J Trauma.* 1996;40:199-203.
- 15.** Alvarez E, Patel MR, Nimberg G, Pearlman HS. Fracture of the capitulum humeri. *J Bone Joint Surg Am.* 1975;57:1093-6.
- 16.** Fowles JV, Kassab MT. Fracture of the capitulum humeri: treatment by excision. *J Bone Joint Surg Am.* 1974;56:794-8.
- 17.** Holdsworth BJ, Mossad MM. Fractures of the adult distal humerus. Elbow function after internal fixation. *J Bone Joint Surg Br.* 1990;72:362-5.
- 18.** Jupiter JB, Neff U, Ragazzoni P, Allgower M. Unicondylar fractures of the distal humerus: an operative approach. *J Orthop Trauma.* 1988;2:102-9.
- 19.** Liberman N, Katz T, Howard CB, Nyska M. Fixation of capitellar fractures with the Herbert screw. *Arch Orthop Trauma Surg.* 1991;110:155-7.
- 20.** McKee MD, Jupiter JB. A contemporary approach to the management of complex fractures of the distal humerus and their sequelae. *Hand Clin.* 1994;10:479-94.
- 21.** Moshieff R, Liebergall M, Elyashov O, Mattan Y, Segal D. Surgical treatment of fractures of the capitellum in adults: a modified technique. *J Orthop Trauma.* 1991;5:297-300.
- 22.** Poynton AR, Kelly IP, O'Rourke SK. Fractures of the capitellum—a comparison of two fixation methods. *Injury.* 1998;29:341-3.
- 23.** Silveri CP, Corso SJ, Roofeh J. Herbert screw fixation of a capitellum fracture. A case report and review. *Clin Orthop Relat Res.* 1994;300:123-6.
- 24.** Simpson LA, Richards RR. Internal fixation of a capitellar fracture using Herbert screws. A case report. *Clin Orthop Relat Res.* 1986;209:166-8.
- 25.** Jakobsson A. Fracture of the capitellum of the humerus in adults; treatment with intra-articular chrom-cobalt-molybdenum prosthesis. *Acta Orthop Scand.* 1957;26:184-90.
- 26.** Boyd HB. Surgical exposure of the ulna and proximal third of the radius through one incision. *Surg Gynecol Obstet.* 1940;71:86-8.
- 27.** Kocher T. Operations at the elbow. In: Kocher T, editor; Stiles HJ, Paul CB, translators. *Textbook of operative surgery.* 3rd ed. London: Adam and Charles Black; 1911. p 313-8.
- 28.** Kaplan EB. Surgical approach to the proximal end of the radius and its use in fractures of the head and neck of the radius. *J Bone Joint Surg.* 1941;23:86-92.
- 29.** Hotchkiss RN. Surgical technique. In: Hotchkiss RN, editor. *Compass universal hinge.* Memphis: Smith and Nephew; 1998. p 8-12.
- 30.** Müller ME, Allgower M, Schneider R, Willenegger H, editors. *Manual of internal fixation: techniques recommended by the AO-ASIF group.* 3rd ed. Berlin: Springer; 1991. p 446-7.
- 31.** Murphy DF, Greene WB, Gilbert JA, Dameron TB Jr. Displaced olecranon fractures in adults. Biomechanical analysis of fixation methods. *Clin Orthop Relat Res.* 1987;224:210-4.
- 32.** Murphy DF, Greene WB, Dameron TB Jr. Displaced olecranon fractures in adults. Clinical evaluation. *Clin Orthop Relat Res.* 1987;224:215-23.
- 33.** Morrey BF. Current concepts in the treatment of fractures of the radial head, the olecranon, and the coronoid. *J Bone Joint Surg Am.* 1995;77:316-27.
- 34.** Dunning CE, Zazour ZD, Patterson SD, Johnson JA, King GJ. Muscle forces and pronation stabilize the lateral ligament deficient elbow. *Clin Orthop Relat Res.* 2001;388:118-24.
- 35.** Armstrong AD, Dunning CE, Faber KJ, Duck TR, Johnson JA, King GJ. Rehabilitation of the medial collateral ligament deficient elbow: an in vitro biomechanical study. *J Hand Surg Am.* 2000;25:1051-7.
- 36.** MacDermid JC. Outcome evaluation in patients with elbow pathology: issues in instrument development and evaluation. *J Hand Ther.* 2001;14:105-14.
- 37.** King GJ, Richards RR, Zuckerman JD, Blasier R, Dillman C, Friedman RJ, Gartsman GM, Iannotti JP, Murnahan JP, Mow VC, Woo SL. A standardized method for assessment of elbow function. Research Committee, American Shoulder and Elbow Surgeons. *J Shoulder Elbow Surg.* 1999;8:351-4.
- 38.** Morrey BF, An KN, Chao EYS. Functional evaluation of the elbow. In: Morrey BF, editor. *The elbow and its disorders.* 3rd ed. Philadelphia: WB Saunders; 1985. p 73-91.
- 39.** MacDermid JC, Alyafi T, Richards RS. Test-retest reliability of static and endurance grip strength tests performed on the Jamar and NK. *Physiother Can.* 2001;53:48-54.
- 40.** Armstrong AD, MacDermid JC, Chinchalkar S, Stevens RS, King GJ. Reliability of range-of-motion measurements in the elbow and forearm. *J Shoulder Elbow Surg.* 1998;7:573-80.
- 41.** Brown LE, Whitehurst M, Bryant JR. Reliability of the LIDO active isokinetic dynamometer concentric mode. *Isokinet Exerc Sci.* 1992;2:191-4.
- 42.** Broberg MA, Morrey BF. Results of delayed excision of the radial head after fracture. *J Bone Joint Surg Am.* 1986;68:669-74.
- 43.** MacDermid JC, Roth JH, Richards RS. Pain and disability reported in the year following a distal radius fracture: a cohort study. *BMC Musculoskelet Disord.* 2003;4:24.