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Fractures of the Capitellum and Trochlea

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David Ring, MD, PhD, and Peter Kloen, MD, PhD

Investigation performed at the Academic Medical Center, Amsterdam, The Netherlands

Background: Recent work has established that apparently isolated fractures of the capitellum are often more complex and involve the lateral epicondyle, trochlea, and posterior aspect of the distal part of the humerus. We assessed the experience with operative stabilization of fractures of the capitellum and trochlea at one level-I trauma center over a twenty-eight-year period.

Methods: Thirty classifiable partial articular fractures involving the capitellum and trochlea were included in the study. Twenty-seven patients were followed for a minimum of twelve months, and fourteen patients returned for long-term follow-up at a median of seventeen years. The early and long-term results were evaluated according to the Broberg and Morrey Functional Rating Index. The long-term results were also evaluated according to the Mayo Elbow Performance Index (MEPI), the American Shoulder and Elbow Surgeons (ASES) score, and the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire.

Results: Eighteen patients (67%) had one or more subsequent surgical procedures, and eight of these patients had the procedure to address surgical complications. Five of the eight patients with complications and ten additional patients underwent routine removal of implants; these fifteen patients included twelve of the fourteen patients in the long-term cohort. In addition to the fracture of the distal part of the humerus, four patients had a dislocation of the elbow; three, a fracture of the olecranon or the proximal part of the ulna; and two, a fracture of the radial head. The median arc of flexion improved from 106° at the time of early follow-up to 119° at the time of long-term follow-up ($p < 0.05$). In the group of fourteen patients with long-term follow-up, the median Broberg and Morrey score was 93 points at the time of early follow-up and 95 points at the time of late follow-up. The functional results were worse for patients with a Type-3 fracture, as classified with the system of Dubberley et al., than they were for those with a Type-1 fracture. The fourteen patients with long-term follow-up had a median MEPI of 98 points, a median ASES score of 88 points, and a median DASH score of 8 points; nine of the fourteen patients had radiographic signs of arthrosis.

Conclusions: The vast majority of what appear to be capitellar fractures are actually complex fractures of the articular surface involving both the capitellum and the trochlea. More complex fractures have worse functional results; however, the functional results of operative treatment seem to be durable over time.

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

Fractures that appear to involve the capitellum alone are often in reality much more complex. Extension of these fractures into the lateral aspect of the trochlea has been recognized for years¹⁻¹⁰ and can be diagnosed on the basis of a characteristic radiographic finding, termed “the double-arc sign” by McKee et al.⁸. Three recent papers confirm that these fractures often involve a greater portion of the anterior aspect of the trochlea, the lateral epicondyle, the posterior aspect

of the lateral column, and sometimes the posterior aspect of the trochlea and the medial epicondyle, as compared with the small amount covered in the concept of the “coronal shearing fracture.”¹⁰⁻¹²

Most orthopaedic surgeons have limited experience treating fractures of the capitellum and trochlea. While nonoperative treatment and fragment excision have been considered reasonable options in the past^{1-5,7,9}, recognition of the relative complexity of many of these fractures has made operative treatment the preferred

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management strategy. Despite the limited soft-tissue attachments of the fracture fragments, osteonecrosis has rarely been observed in prior studies^{6,8,10,11}.

A long-term fracture registry allowed us to analyze how these fractures were treated during a time when they were perhaps less well appreciated as well as an opportunity to study the long-term outcome after operative treatment. The purposes of this retrospective study were to describe the fracture patterns and to evaluate the functional and radiographic outcomes of open reduction and internal fixation of fractures of the capitellum and trochlea.

Materials and Methods

Inclusion and Exclusion Criteria

All fractures seen between 1974 and 2002 at the Academic Medical Center, Amsterdam, The Netherlands, were entered into a database organized according to the AO Comprehensive Classification of Fractures¹³. Of 264 patients with a fracture of the distal part of the humerus, forty consecutive adult patients were identified as having had operative treatment of a Type-B fracture of the distal part of the humerus (partial articular; sometimes referred to as a “unicondylar” or “single-column” fracture) according to the AO Comprehensive Classification of Fractures. One patient had been treated nonoperatively for a Type-B fracture of the distal part of the humerus and was excluded. Patients were treated by an attending general orthopaedic surgeon or a general trauma surgeon experienced in AO principles and techniques of internal fixation¹³. Two patients had inadequate preoperative radiographs, and their fractures could not be classified. One patient had an isolated fracture of the medial epicondyle, five had a fracture of the medial column, and two had a fracture of the lateral column. We specifically excluded fractures that involved the medial or lateral column above the base of the olecranon fossa, both because they were too uncommon to allow us to reach firm conclusions and because they are quite distinct from fractures that create primarily entirely articular fracture fragments along with epicondylar fragments. Thirty (79%) of the thirty-eight patients with a classifiable fracture had a fracture of the capitellum and trochlea, and these patients are the focus of the present investigation.

The medical records were reviewed retrospectively, and the patients were invited to return for a comprehensive long-term follow-up evaluation under a protocol approved by our institutional review board. Of the thirty patients with a fracture of the capitellum and trochlea, twelve had died, one patient declined to participate in the study, and three patients had either emigrated or could not be located. The remaining fourteen patients (of eighteen living patients) returned for long-term evaluation performed by an investigator who was not involved in the patient's original care. These patients had a median age of twenty-nine years (range, twenty to eighty-one years) at the time of injury, and they included three of the eleven patients (in the original group of thirty) who had been older than sixty years of age at the time of the injury. The twelve patients who had died before the time of this study had a median age of sixty-seven years (range, twenty-five to eighty years) at the time of injury, and they included eight of the eleven patients who had been

older than sixty years of age at the time of injury. Of the sixteen patients who did not return for a study-specific long-term evaluation, thirteen had adequate records at a minimum of twelve months after surgery and were evaluated on the basis of data from those medical records alone. Therefore, a total of twenty-seven patients were included in the study: twenty-four who had at least an early evaluation (roughly one year after the surgery) and fourteen patients with a comprehensive long-term evaluation performed by an independent observer. We thought that it was worthwhile to present the data for each of these evaluation points (at one year and long-term) as each provides an answer to a slightly different question: (1) What are the early results of operative treatment of this injury? (2) What are the long-term results, in a large subset of patients?

Classification

The fractures of the capitellum and trochlea were classified, on the basis of radiographs made immediately after the injury and the intraoperative findings, according to the Comprehensive Classification of Fractures¹³ as well as the systems described by one of us (D.R.) and colleagues¹² and by Dubberley et al.¹¹. The Comprehensive Classification of Fractures does not account for fractures that extend into the trochlea and have other complexities. All of the fractures involved at least a portion of the trochlea and therefore were classified as subgroup B3.3. According to the classification of fractures of the capitellum and trochlea used by one of us (D.R.) and colleagues, one fracture was Type 1 (a single fragment involving the capitellum and the lateral portion of the trochlea only), one was Type 2 (a Type-1 fracture also involving the lateral epicondyle), nine were Type 3 (a Type-2 fracture also involving the posterior part of the metaphyseal bone of the lateral column), fifteen were Type 4 (a Type-3 fracture also involving a fracture of the posterior part of the trochlea), and one was Type 5 (a Type-4 fracture also involving a fracture of the medial epicondyle). According to the classification system of Dubberley et al., two fractures were Type 1A (involving the capitellum and a small portion of the lateral part of the trochlea without involving the posterior aspect of the distal part of the humerus), seven were Type 1B (similar to Type 1A but with posterior fracture impaction), one was Type 2A (more extensive involvement of the lateral part of the trochlea as one fragment, but no posterior fracture), eleven were Type 2B (the same as Type 2A but with a posterior fracture), and six were Type 3B (more extensive involvement of the trochlea with more than one fragment and with a posterior fracture) (Table I).

Four patients had a dislocation of the elbow in addition to the fracture of the capitellum and trochlea. Three patients had an associated fracture of the olecranon or the proximal part of the ulna, and two of them had a concomitant dislocation of the radial head (i.e., a Monteggia fracture-dislocation). Two patients had an associated fracture of the radial head without an olecranon fracture.

Early Evaluation

Of the twenty-four patients who had an early evaluation (at a median of thirteen months [range, twelve to nineteen months]),

TABLE I Classification of Twenty-seven Fractures of the Capitellum and Trochlea

Classification System	No. of Fractures
Dubberley et al. ¹¹	
1A	2
1B	7
2A	1
2B	11
3A	0
3B	6
Ring et al. ¹²	
1	1
2	1
3	9
4	15
5	1

nine were men and fifteen were women. Their median age was forty years (range, twenty to eighty-one years) at the time of the surgery. Eight patients were known to be employed at the time of the injury.

Open reduction and internal fixation was performed at a median of one day (range, zero to twenty days) after the injury. Surgery was delayed in four cases because of nonoperative treatment at another institution.

Long-Term Evaluation

Of the fourteen patients who returned for a research-specific long-term evaluation, six were men and eight were women. Their median age was thirty-five years (range, twenty-two to eighty-one years) at the time of the surgery and fifty-two years (range, twenty-nine to ninety years) at the time of final follow-up. One patient had a dislocation of the elbow in addition to the fracture of the capitellum and trochlea. Three patients had an associated fracture of the olecranon or the proximal part of the ulna, and two of them had a concomitant dislocation of the radial head (a Monteggia fracture-dislocation).

Operative Technique

At least twenty different surgeons participated in the treatment of these fractures, and no standard protocols were used. All twenty-seven fractures were treated operatively. Two patients underwent excision of fracture fragments, and twenty-five were treated with open reduction and internal fixation.

A lateral skin incision was used in twenty-two patients, a posterior incision was used in four patients, and one fracture was addressed through the extension of an open wound. An olecranon osteotomy was used for exposure in three patients, and an existing olecranon fracture was used for exposure in two patients¹⁴. The patient with a traumatic wound had subcutaneous anterior transposition of the ulnar nerve in addition to fracture fixation through an extension of that wound; ulnar nerve transposition was not performed in any other case.

Internal fixation was performed with 3.5 or 2.7-mm screws for fifteen fractures (with ancillary Kirschner wires for four of

them), with Kirschner wires alone for five fractures (with additional use of figure-of-eight tension-band wiring for one of them), and with a plate and screws for five fractures. The sites of four of the five olecranon osteotomies or fractures were secured with figure-of-eight tension-band wiring, and the fifth was secured with a screw alone.

Fourteen elbows were immobilized for a median of seven days (range, three to twenty-eight days) postoperatively. Eight patients started elbow exercises the day after the surgery. The postoperative management was not clearly documented for five patients. Active-assisted range-of-motion exercises were initiated for all patients after use of the splint was discontinued.

Evaluation Criteria

The twenty-four patients for whom early (approximately one-year) data from the medical record were available were evaluated according to the system of Broberg and Morrey¹⁵. Additionally, patients with a Type-1 fracture, according to the system of Dubberley et al.¹¹, were compared with those with a Type-2 and those with a Type-3 fracture. The four patients with a fracture-dislocation and the five with other elbow fractures (three olecranon or proximal ulnar fractures and two radial head fractures) were also considered separately.

Fourteen patients returned for a research-specific evaluation at a median of seventeen years (range, seven to twenty-three years) after the injury. Eleven patients had both early and long-term follow-up data available, and the results at the two evaluation times were compared in this group.

The fourteen patients who returned for a long-term study-specific follow-up were evaluated according to the Mayo Elbow Performance Index (MEPI)¹⁶, the Broberg and Morrey Functional Rating Index¹⁵, and the American Shoulder and Elbow Surgeons (ASES) score¹⁷. These fourteen patients also completed a validated Dutch-language translation of the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire^{18,19} to measure upper-extremity-specific disability. As a quantitative measure of pain, we used the pain subscales of the ASES score¹⁷—with which patients use a 10-point ordinal scale ranging from 0 (no pain) to 10 (the worst imaginable pain) to rate (1) pain when it is at its worst, (2) pain at rest, (3) pain when lifting a heavy object, (4) pain when doing a task with repeated elbow movements, and (5) pain at night. As dictated by the ASES scoring system, we added the scores of these five categories and subtracted the sum from 50. The resulting value was divided by 2 for a summary pain score ranging from 0 to 25 points, with 25 points indicating no pain. Patients rated their satisfaction on an ordinal scale ranging from 1, indicating that the patient is highly dissatisfied, to 10, indicating that he or she is highly satisfied. The range of motion of the elbow and forearm was measured with use of a handheld goniometer.

Anteroposterior and lateral radiographs of the involved elbow were evaluated for evidence of arthrosis by an independent observer using the classification system of Broberg and Morrey¹⁵. Grade 0 indicated no arthrosis; Grade 1, slight joint-space narrowing with minimum osteophyte formation; Grade 2, moderate joint-space narrowing with moderate os-



Fig. 1-A



Fig. 1-B

Figs. 1-A through 1-D A sixty-one-year-old woman fell at home from a standing height and injured the right, dominant elbow. **Fig. 1-A** Posteroanterior and lateral radiographs demonstrating an apparent capitellar fracture that turned out to be far more complex: Type 4 according to the classification of one of us (D.R.) and colleagues¹² and Type 3B according to the system of Dubberley et al.¹¹ **Fig. 1-B** Anteroposterior and lateral radiographs made after operative treatment through a lateral incision.



Fig. 1-C

Figs. 1-C and 1-D Anteroposterior and lateral radiographs made twenty-three years after the fracture, showing mild joint irregularity and osteophyte formation. At that time, elbow flexion was from 10° to 160°.

teophyte formation; and Grade 3, severe degenerative change with gross destruction of the joint.

Statistical Analysis

Continuous data are presented as the median and range. Differences in continuous variables were evaluated with use of the Student t test for independent groups and with a paired t test when the same group was evaluated over time. Analysis of variance with post hoc Tukey analysis was used to compare a continuous variable among more than two groups. Differences in categorical variables were evaluated with the Fisher exact test. Two-tailed p values of <0.05 were considered to be significant.

Source of Funding

Outside funding consisted of unrestricted research grants only.

Results

Subsequent Procedures

In the entire cohort of twenty-seven patients, eighteen patients (67%) had one or more subsequent surgical procedures. Seven patients had the surgery to address complications and are described below. Five of the eight patients with complications and ten additional patients underwent removal of implants; this group included twelve of the fourteen patients in the long-term cohort. Implant removal was routine during the study period but was not recommended when the implants were buried in bone.

Complications

Two of the four patients with a fracture-dislocation of the elbow had a redislocation after the surgery. One of these two patients had an arthrodesis five months after the index procedure because of persistent subluxation of the elbow and nonunion of



Fig. 1-D

the fracture. That patient was considered to have had a failure and was excluded from the final analysis of motion and function. The other patient had a closed reduction of the dislocation while under anesthesia, followed by cast immobilization, and subsequently underwent resection of heterotopic bone to treat osseous ankylosis.

One patient had a postoperative radial nerve palsy that resolved completely. The index surgery was complicated by a deep infection in two patients. One was treated with débridement and skin-grafting with subsequent implant removal thirty-three months after the index surgery. The other patient, who had diabetes mellitus, was treated with irrigation and débridement and implant removal. One patient underwent two subsequent procedures to address nonunion of the olecranon, with final removal of hardware at eight years. Two patients had a subsequent elbow contracture release; one of them also had removal of loose bodies.

Early Results

In the group of twenty-three patients (excluding the patient with an arthrodesis who was counted as having had a failure) who had an early evaluation based on adequate data in the medical record,

the median arc of elbow flexion was 106° (range, 70° to 145°) with a median amount of flexion of 128° (range, 110° to 150°) and a median flexion contracture of 20° (range, -5° to 45°). The median arc of forearm rotation was 180° (range, 15° to 180°). The median Broberg and Morrey rating was 93 points (range, 56 to 100 points), with an excellent result in eleven patients (48%), a good result in eleven, and a poor result in one (4%). Three patients had crepitation with elbow motion, and none of the patients had symptoms or signs of ulnar neuropathy.

The seven patients who had a Type-1 fracture according to the system of Dubberley et al. had a median arc of elbow flexion of 130° (range, 100° to 145°). The median Broberg and Morrey rating was 99 points (range, 80 to 100 points), with six excellent results and one good result. In the group of ten patients with a Dubberley Type-2 fracture, the median arc of elbow flexion was 114° (range, 80° to 140°). The median Broberg and Morrey rating was 95 points (range, 82 to 100 points), with five excellent and five good results. The six patients with a Dubberley Type-3 fracture had a median arc of elbow flexion of 90° (range, 70° to 106°). The median Broberg and Morrey rating was 87 points (range, 56 to 94 points), with five good results and one poor

result. There was a significant difference between the Type-1 and Type-3 categories with regard to the total arc of elbow flexion and extension ($p < 0.05$) and the Broberg and Morrey score ($p < 0.05$). Of the nine patients with either an additional fracture or a concomitant dislocation, one did not have an early evaluation and one had an arthrodesis, and those two patients were excluded from the analysis. The remaining six patients did not have a significantly worse total arc of elbow flexion and extension or Broberg and Morrey outcome score ($p = 0.5$ and $p = 0.1$, respectively) than did the other patients.

Long-Term Results

The fourteen patients with a long-term research-specific evaluation had a median arc of elbow flexion of 119° (range, 70° to 160°), with a median of 139° of flexion (range, 110° to 154°) and a median flexion contracture of 28° (range, 10° of hyperextension to a 40° flexion contracture). The median arc of forearm rotation was 180° (range, 78° to 180°). None of the fourteen patients had symptoms or signs of elbow instability. Only two complications developed in this group of patients: redislocation, with additional osseous ankylosis, in a patient who had had a fracture-dislocation and nonunion of the olecranon.

The median MEPI score was 98 points (range, 60 to 100 points), and the median Broberg and Morrey score was 95 points (range, 62 to 100 points). According to the MEPI, nine patients had an excellent result, four had a good result, and one had a fair result. According to the Broberg and Morrey system, there were seven excellent results, six good results, and one fair result. The median ASES score was 88 points (range, 57 to 100 points), with a median patient satisfaction score of 10 (of 10) points (range, 7.5 to 10 points) and a median ASES pain score of 22 (of 25) points (range, 6 to 25 points), with 25 points indicating no pain and 0 points indicating maximal pain. The median DASH score was 8 points (range, 0 to 64 points), with lower scores indicating less disability. Nine elbows had radiographic signs of arthrosis, which were rated as Grade 1 in four elbows, Grade 2 in three, and Grade 3 in two.

Comparison of Early and Late Results

In the group of eleven patients for whom both early follow-up data (at approximately one year) and long-term follow-up data were available, the median arc of elbow flexion increased from 106° (range, 70° to 140°) to 125° (range, 70° to 160°) ($p = 0.14$), with the median amount of flexion improving from 128° (range, 110° to 140°) to 140° (range, 110° to 154°) ($p = 0.017$) and the median flexion contracture increasing from 20° (range, 0° to 40°) to 26° (range, -10° to 40°) ($p = 0.31$). There was no significant difference between the early and late arcs of forearm rotation. The median Broberg and Morrey score was 94 points (range, 56 to 100 points) at the early evaluation and 95 points (range, 62 to 100 points) at the longer-term follow-up evaluation.

Discussion

When this study was initiated, our goal was to learn more about partial articular fractures (sometimes referred to as “unicondylar” or “single-column” fractures) of the distal part of

the humerus, which have been estimated to account for only 3% to 4% of distal humeral fractures^{6,20,21}. A preliminary review of the database revealed that 15% of the fractures of the distal part of the humerus that had been treated operatively at our institution over the study period were partial articular fractures and that thirty (79%) of the thirty-eight partial articular fractures that could be accurately classified on the basis of available radiographs involved both the capitellum and the trochlea. This finding is consistent with that in the only other large series, of which we are aware, in which the authors focused on partial articular, or unicondylar, fractures; in that study, by Jupiter et al., 77% of the unicondylar fractures involved both the capitellum and the trochlea⁶. We can conclude that single-column fractures of the distal part of the humerus are uncommon and that the great majority of partial articular fractures are in reality fractures of the capitellum and trochlea.

Until recently, capitellar fractures were generally classified according to their size and comminution¹⁶, and involvement of the trochlea was considered uncommon⁸. Three recent investigations consistently demonstrated that what appear to be capitellar fractures are nearly always more complex injuries¹⁰⁻¹². It is now well recognized that apparent capitellar fractures often involve a substantial portion of the trochlea and may also involve the posterior aspect of the lateral column and the posterior part of the trochlea¹⁰⁻¹². In our retrospective review of fractures treated during a nearly thirty-year period, we noted that this level of complexity has always been present but simply was underappreciated.

Computed tomography scans were not used as most of these patients were treated a long time ago. A preoperative computed tomography scan can help to identify this more complex fracture pattern, which may appear to be an isolated fracture of the capitellum on plain radiographs¹². Three-dimensional reconstruction with the ulna and radius subtracted may be particularly useful^{22,23}.

We found that patients with a Dubberley Type-3 fracture have a significantly worse arc of elbow flexion and extension and a worse Broberg and Morrey score than patients with a Type-1 fracture. In other words, the greater the fragmentation of the articular surface, the worse the outcome. The small number of patients who had either a concomitant fracture or an elbow dislocation in addition to the fracture of the capitellum and trochlea did not seem to do worse than the other patients, although one of these patients had an elbow arthrodesis.

It is notable that, although these fractures create entirely articular fragments with little or no soft-tissue attachments, problems with fracture-healing and osteonecrosis were very uncommon in our series or in three other recent series of patients with fractures involving the capitellum and trochlea¹⁰⁻¹². The median arc of elbow flexion in the current series (106° at one year and 119° at the time of the long-term follow-up) is comparable with the arcs found in the other series. The results at a median of seventeen years after injury demonstrate the durability of the elbow after these fractures. Although arthrosis developed in most of the patients, motion, function, and comfort were good and no late salvage procedures were performed (Figs. 1-A through 1-D).

It is notable that four of the thirty fractures of the capitellum and trochlea in this series were associated with an elbow

dislocation, and two of the four were complicated by a post-operative elbow dislocation, with one requiring salvage with an elbow arthrodesis. The definition of an elbow fracture-dislocation has traditionally been a dislocation of the elbow with a fracture of the radial head¹⁵, and papers addressing elbow fracture-dislocations have not mentioned dislocations with associated fractures of the distal part of the humerus²⁴. It makes sense, however, that as the elbow dislocates, osseous failure may also occur on the distal humeral side of the articulation rather than on the radioulnar side, and dislocation of the elbow with fracture of the distal part of the humerus (elbow fracture-dislocation) should be considered among the patterns of traumatic elbow instability²⁴⁻²⁶. Although patients with a fracture-dislocation of the distal part of the humerus did not do worse than those without a dislocation, the patient numbers were small in our series and the need for the arthrodesis in one patient demonstrates the potential for a fracture-dislocation of the distal part of the humerus to be a very troublesome injury.

Limitations of this paper include its retrospective design and therefore its heavy reliance on medical records; variable rates of follow-up at various time points, including the availability of long-term follow-up data for only fourteen of thirty patients; and the fact that nine elbows had other injuries. Additionally, treatment was performed with older techniques, by a large number of different surgeons, and there were no standard treatment protocols. Also, the long-term data reflect the results to be expected in younger, healthier patients since

many of the older patients had died prior to our initiation of the study. On the other hand, given the relative infrequency of these injuries, these data are very useful in further confirming the complexity of apparently isolated capitellar fractures and the ability to achieve healing with infrequent osteonecrosis and reasonable elbow function considering the relative complexity of these injuries. ■

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