Posttraumatic Elbow Stiffness
Lindenhovius, A.L.C.

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CHAPTER 3

Long-Term Outcome of Operatively Treated Fracture-Dislocations of the Olecranon
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Abstract

Objectives: To report the long-term results of operative treatment of anterior and posterior olecranon fracture-dislocations and compare them with the results recorded fewer than 2 years after surgery.

Design: Retrospective case series with long-term evaluation.

Setting: Level I trauma center.

Patients and Participants: Ten patients with anterior olecranon fracture-dislocation and ten patients with posterior olecranon fracture-dislocation were evaluated after an average of 18 years (range, 11 to 28 years) after injury. Fifteen patients had an early follow-up available at an average 14 months (range, 6 to 24 months) after surgery. The average age at injury was 30 years (range, 14 to 53 years).

Intervention: Treatment included plate and screw fixation (11 patients), tension band wiring (8 patients), and radiocapitellar transfixation (1 patient). Six patients had additional elbow surgery before the final evaluation.

Main Outcome Measurements: Flexion arc, arthrosis, Mayo Elbow Performance Index (MEPI), Disability of Arm Shoulder and Hand questionnaire (DASH).

Results: The mean arc of elbow flexion was 105 degrees (range, 15 to 140 degrees) at 1 year and 122 degrees (range 10 to 145 degrees; P = 0.01) at final evaluation. Radiographic arthrosis was observed in 14 patients (70%): severe in 3, moderate in 2, and mild in 9 patients. Five patients (25%) had ulnar nerve dysfunction at the final evaluation. The MEPI was excellent in 13 patients, good in 4, fair in 2, and poor in 1. The mean DASH score was 9 points (range, 0 to 53 points).

Conclusion: The initial results of operative treatment of fracture-dislocations of the olecranon are durable over time.

Key Words: fracture-dislocation of the olecranon, long-term outcome, elbow

Background

Fracture-dislocations of the olecranon can occur in an anterior or a posterior direction.1-7 Anterior olecranon (transolecranon) fracture-dislocations are characterized by an anterior radiocapitellar dislocation, but they are distinct from anterior Monteggia injuries because the relationship between the radius and ulna usually remains intact (ie, the proximal ulna and radius both dislocate anteriorly).2 Posterior olecranon fracture-dislocations are often considered the most proximal type of posterior Monteggia injury and are usually associated with fracture of the radial head.1,4,8 The relationship between the ulna and radius remains intact with these proximal injuries, and some authors argue that this injury is not a true Monteggia or forearm fracture-dislocation.9
The olecranon fractures associated with anterior and posterior olecranon fracture-dislocations can be comminuted and often include a fracture of the coronoid process. Operative repair, although often challenging, can usually salvage satisfactory elbow function in the short term; however, many develop degenerative changes, particularly if the coronoid process is not adequately realigned and secured. The long-term results of operative treatment of olecranon fracture-dislocations are less well studied, and it is unclear if the early results are durable and how often salvage procedures are performed in the long-term. The purpose of this case series was to document the long-term outcome of operative treatment of anterior and posterior olecranon fracture dislocations and to compare the early and late results of treatment of anterior and posterior injuries to test the hypothesis that flexion arc deteriorates over time.

**Patients and Methods**

Between 1974 and 1994, all trauma patients treated in a Level 1 trauma center were prospectively documented in a trauma database and classified according to the Comprehensive Classification of Fractures. Among 201 patients treated for an olecranon fracture during this time, 43 skeletally mature patients (21%) had an anterior or posterior fracture-dislocation of the olecranon. This relatively high proportion of complex fractures may reflect the referral patterns in our region.

Of these 43 patients, 14 were deceased, 6 could not be located, and 3 declined participation, leaving 20 patients for evaluation. The 14 deceased patients had an average age of 66 years (range, 27 to 81 years) at the time of injury. Thirteen of these patients were older than 60 years, and all but 1 were women. Eleven had a posterior fracture-dislocation (10 women), and 3 had an anterior fracture-dislocation. Seven of these patients (all women) died an average of 15 years (range, 7 to 23 years) after injury; in the other cases, the date of death was unknown. Twenty patients returned for a free evaluation and radiographs at a minimum of 10 years after injury under a protocol approved by our Institutional Review Board.

**Patient Characteristics**

The cohort with a long-term evaluation included 13 men and 7 women with a mean age of 30 years (range, 14 to 53 years) at the time of injury. The right arm was involved in 11 patients (all dominant), and the left in 9 patients (3 dominant). At the time of injury, 8 patients were employed as laborers, 6 did desk-based work, 3 were students, 1 was in military service, and 2 were unemployed. Of the 20 patients, 8 fractured an elbow in a motor vehicle collision, 1 was injured in a fall from a standing height, 6 were injured in a fall from a greater height, 2 were injured from a direct blow, 2 sustained a sports-related injury, and 1 patient’s arm was crushed between two tractors.
Classification

The fractures classifications were based on injury radiographs and intraoperative exposure according to the Comprehensive Classification of Fractures\textsuperscript{12} as Group B1 in 10 patients, Group B3 in 3 patients, Group C1 in 2 patients, Group C2 in 2 patients, and Group C3 in 3 patients. Ten patients had posterior olecranon fracture-dislocations, and ten had anterior olecranon fracture-dislocations.

Among patients with posterior fracture-dislocations, 5 had a concomitant fracture of both the radial head (3 Mason type 3, 1 Mason type 2, and 1 Mason type 1)\textsuperscript{13} and the coronoid process (4 Regan and Morrey type 3 and 1 Regan and Morrey type 2)\textsuperscript{14}, 3 had concomitant fracture of the radial head alone (1 Mason type 1, 1 Mason type 2, and 1 Mason type 3), and 1 had a fracture of the coronoid alone (Regan and Morrey type 2). Among patients with anterior fracture-dislocations, there were 5 patients with concomitant fracture of the coronoid process (all were Regan and Morrey type 3). None of the patients with anterior fracture-dislocations had a fracture of the radial head (Table 1).

One patient with an anterior fracture-dislocation had a grade 1 open injury according to the system by Gustilo and Anderson.\textsuperscript{15} Five patients had ipsilateral arm injuries, including fracture of the distal humerus in 2 patients (1 of these also had a distal radius fracture), diaphyseal forearm fractures in 2 patients, and distal radioulnar joint injury in 1 patient. Thirteen patients had other limb and/or visceral injuries.

Operative Technique

Sixteen different orthopaedic and general trauma surgeons cared for these patients, and no standard protocols were used.

Patients were treated operatively under general anesthesia an average of 1 day (range, 0 to 9 days) after the injury. Plate and screw fixation was used in 11 patients (4 with one third tubular plates, and 6 with a 3.5-mm dynamic compression plate; in one patient, both a 3.5-mm dynamic compression plate and a tension band wire was used). In 8 patients, a figure-of-eight tension band wire construct was used.\textsuperscript{16} One patient with a complex anterior fracture-dislocation was treated with closed reduction, percutaneous temporary transfixation of the radiocapitellar joint with a smooth Kirschner wire, and cast immobilization.

Among the 8 patients with concomitant fracture of the radial head, 2 were secured with screws, 1 was excised, and 5 were not addressed at the initial surgery (2 Mason type 1, 1 Mason type 2, and 2 Mason type 3 fractures).\textsuperscript{13} Among the 11 fractures of the coronoid process, 8 were secured with screws, 1 was secured with a Kirschner wire, and 2 were not addressed (1 Regan and Morrey type 2 and 1 Regan and Morrey type 3).\textsuperscript{14}

With the exception of 1 patient treated with radiocapitellar Kirschner wire fixation and cast immobilization, active and active-assisted motion exercises were initiated on the third
postoperative day. The arm was immobilized in a removable splint between exercise sessions until suture removal and for up to 6 weeks in some patients.

Complications and Subsequent Procedures
One patient who experienced loosening of a one-third tubular plate 2 months after injury healed after repeat internal fixation with a 3.5-mm dynamic compression plate and application of autogenous cancellous bone graft. This patient sustained a refracture 2 weeks after routine implant removal 18 months after the second procedure (5 months after the early follow-up). The refracture was treated with a 3.5-mm dynamic compression plate, and this surgery was complicated by infection. The patient had a final surgery for implant removal. Two patients had a subsequent elbow contracture release after fracture consolidation (one with excision of heterotopic ossification blocking ulnohumeral motion); both procedures took place after the early follow-up. One patient that developed a proximal radioulnar synostosis declined surgery. In contrast to our current practice, implant removal was routine at our institution during the study period. All 19 patients with plates or tension band wires had implant removal an average of 18 months (range, 6 to 74 months) after surgery. Two patients with signs of ulnar neuropathy had a transposition of the ulnar nerve during the procedure for implant removal (5 weeks before the early follow-up in 1 patient, and there was no early follow-up in 1 patient). One patient had excision of the radial head during implant removal (this patient did not have an early follow-up available). One patient fractured the olecranon a second time 10 years after implant removal performed 14 months after injury and was treated with 1 month of cast immobilization.

Evaluation
Two investigators that were not involved in the initial care of the patients evaluated the 20 patients in a research-specific follow-up visit, which consisted of an interview, physical examination, radiographs and the completion of 4 commonly used questionnaires and elbow evaluation instruments: (1) the Mayo Elbow Performance Index (MEPI)\textsuperscript{17}, (2) the Broberg and Morrey rating system\textsuperscript{18}, (3) the American Shoulder and Elbow Surgeons (ASES) Elbow Evaluation Instrument\textsuperscript{19}, and (4) the Disabilities of the Arm Shoulder and Hand (DASH) questionnaire\textsuperscript{20}.

The MEPI\textsuperscript{17} consists of the physician’s assessment of pain, ulnohumeral motion, stability, and ability to perform functional tasks. Categorical ratings are assigned as follows: 90 to 100 points is excellent; 75 to 89 is good; 60 to 74 points is a fair outcome; and a score of less than 60 points is considered poor. The rating system of Broberg and Morrey\textsuperscript{18} is a 100-point system based on the physician’s assessment of motion, strength, stability, and pain. In the categorical rating, 95 to 100 points is rated excellent; 80 to 94, good; 60 to 79, fair; and less than 60 points, poor. The ASES Elbow Evaluation Instrument\textsuperscript{19} is a 100-point scale that
combines the patient’s assessment of pain and ability to perform functional tasks with the physician’s evaluation of flexion arc, forearm rotation, strength, and stability. The scores range from 0 to 100, with higher scores indicating better function. The patient-completed DASH questionnaire\textsuperscript{20} evaluates difficulty with performing specific tasks, as well as symptoms, social function, work function, sleep and confidence. The score is scaled between 0 and 100, with higher scores indicating worse upper extremity function. For this study, a validated Dutch language translation of the DASH questionnaire was used.\textsuperscript{21}

\begin{figure}
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\includegraphics[width=\textwidth]{figure1}
\caption{A 26-year-old woman was injured in a motor vehicle accident (Patient 15). (A) A lateral radiograph taken at the time of injury demonstrates a very complex fracture of the proximal ulna including the coronoid process. The fracture was open (grade 1). The radial head is dislocated anteriorly and unfractured. This represents an anterior olecranon fracture-dislocation of the elbow. (B) A lateral radiograph after operative debridement and radiocapitellar wire fixation. (C) A lateral radiograph obtained 16 years after injury demonstrates a posttraumatic proximal radioulnar synostosis and distortion and arthrosis of the ulnohumeral joint. She has a 90-degree flexion arc.}
\end{figure}
Pain
As a quantitative measure of pain for use in all analyses, we used the pain subscales of the ASES Elbow Evaluation Instrument. Patients rated their pain from 0 (no pain) to 10 (worst imaginable pain) on five scales: pain when it is at its worst; pain at rest; pain lifting a heavy object; pain when doing a task with repeated elbow movements; pain at night. The summary pain score ranges from 0 to 50 points, with 0 points indicating no pain.

Ulnar Nerve Function
Ulnar neuropathy was graded according to the McGowan scale: grade 1, minimal lesions with no detectable motor weakness of the hand; grade 2, intermediate lesions; grade 3, severe lesions with paralysis of 1 or more of the ulnar intrinsic muscles.

Radiographic Analysis
Arthrosis was rated by an independent observer according to the system of Broberg and Morrey: Grade 0, normal joint; Grade 1, slight joint-space narrowing with minimum osteophyte formation; Grade 2, moderate joint space narrowing with moderate osteophyte formation; Grade 3, severe degenerative change with gross destruction of the joint.

Statistical Analyses
Continuous variables are presented in terms of mean, standard deviation, and range. We compared ulnohumeral motion and forearm rotation at early and late follow-up in the 10 patients with anterior and the 10 with posterior olecranon fracture-dislocations using Student t test and change in motion in the entire patient cohort between early and late follow-up using a paired t test. Differences in DASH, MEPI, ASES Elbow Evaluation Instrument, and Broberg and Morrey scores between cohorts were compared using Student t test. Differences in arthrosis and ulnar neuropathy were tested using the Fisher Exact Test. A univariate analysis was performed to look for significant or near significant predictors (P, 0.08) of final flexion arc, DASH, MEPI, ASES, and Broberg and Morrey scores using Spearman correlations for continuous independent variables (final flexion arc, additional surgeries, duration of follow-up, age, and patient-rated pain), and using the Mann-Whitney U test for dichotomous independent variables injury type (anterior vs. posterior fracture-dislocation), treatment (plating vs. tension band wiring), gender, arthrosis, and ulnar neuropathy). All significant or nearly significant predictors were included in a stepwise multivariate model to determine the strongest predictors of the final flexion arc, DASH, Mayo Elbow Performance Index, and Broberg and Morrey scores. The SPSS statistical software package was used for all statistical calculations (SPSS version 10.0, SPSS Inc., Chicago, IL).
Results

Early Follow-Up

An early follow-up (fewer than 2 years) was available from the medical record for 15 patients at an average of 14 ± 4 months (range, 6 to 24 months) after surgery. Medical records of the remaining 5 patients could not be found in our archives. Eight had a posterior olecranon fracture-dislocation, and seven had an anterior olecranon fracture-dislocation. At this timepoint, the average ulnohumeral arc of motion was 105 ± 36 degrees (range, 15 to 140 degrees), with an average flexion of 124 ± 16 degrees (range, 90 to 145 degrees) and an 19 ±
25-degree flexion contracture (range, 0 to 95 degrees) 1 year after surgery. The average arc of forearm rotation was 146 ± 60 degrees (range, 0 to 180 degrees) with an average pronation of 69 ± 39 degrees (range, −40 to 90 degrees) and an average supination of 77 ± 23 degrees (range, 10 to 90 degrees).

**Final Follow-Up**

A final evaluation was performed an average of 18 ± 5 years after surgery (range, 11 to 28 degrees) in all 20 patients. The average arc of ulnohumeral motion was 122 ± 35 degrees (range, 10 to 145), with an average flexion of 134 ± 11 degrees (range, 110 to 145) and an average flexion contracture of 12 ± 26 degrees (10 degrees of hyperextension to a 100-degree flexion contracture). There was a significant average improvement of 14 ± 18 degrees (loss of 20 degrees to a gain of 55 degrees) in flexion arc from early to late follow-up in the 15 patients evaluated at both time intervals (P = 0.01). The average arc of forearm rotation was 151 ± 42 degrees (range, 0 to 180 degrees), with an average pronation of 70 ± 30 degrees (−40 to 90 degrees) and an average supination of 81 ± 15 degrees (range, 40 to 90 degrees). The improvement in forearm rotation of 4 ± 27 degrees (a loss of 30 degrees to a gain of 70 degrees) was not significant (P = 0.57) (Table 1).

Five patients had symptoms and signs suggestive of ulnar nerve compression at the elbow, which were classified as grade 1 in 3 patients and grade 2 in 2 patients according to the scale of McGowan. Together with the 2 patients that had already had a subsequent ulnar nerve release, a total of 7 (35%) of 20 patients developed an ulnar neuropathy within the study period.

Fourteen of twenty patients showed radiographic signs of arthrosis according to Broberg and Morrey. Nine patients had slight joint narrowing with minimum osteophyte formation (grade 1), two patients had moderate joint narrowing (grade 2), and three patients had severe arthrosis (grade 3). One patient that had an elbow contracture release 22 months after the initial procedure had recurrence of heterotopic bone and a flexion arc of only 10 degrees. Another patient had a proximal radioulnar synostosis.

The average score on the MEPI was 90 ± 15 points (range, 50 to 100 points). The categorical ratings were 13 excellent results, 4 good results, 2 fair results, and 1 poor result. The average Broberg and Morrey score was 90 ± 17 points (range, 48 to 100 points), which represented 13 excellent results, 3 good results, 1 fair result, and three poor results. The score on the ASES Elbow Evaluation Instrument averaged 89 ± 16 points (range, 41 to 100 points), with an average patient satisfaction of 8 ± 2 points (range, 0 to 10 points) on a scale from 0 to 10. The ASES pain-scores averaged 10 ± 12 points (range, 0 to 34 points) out of 50 points. None of the patients used pain medication on a regular basis. The average score on the DASH questionnaire was 9 ± 14 points (range, 0 to 53 points).
Fourteen patients remained employed in their usual work. Two patients with severe closed head injuries and one patient with alcohol addiction did not return to work. Three patients either changed jobs or limited their job activity as a result of their elbow injury.

Table 1. Patients with anterior and posterior olecranon fracture-dislocations (early follow-up)

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age at Injury</th>
<th>Dislocation (Regan)</th>
<th>Coronoid Fx (Mason)</th>
<th>Radial Head Fx (Mason)</th>
<th>Ipsilateral Injury</th>
<th>Initial Treatment</th>
<th>Additional Elbow Surgeries*</th>
<th>Early FU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>posterior</td>
<td>2 (not repaired)</td>
<td>3 (not repaired)</td>
<td>TBW</td>
<td>FE Arc</td>
<td>PS Arc</td>
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</tr>
<tr>
<td>2</td>
<td>19</td>
<td>posterior</td>
<td>1 (not repaired)</td>
<td></td>
<td>TBW</td>
<td>125</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>posterior</td>
<td></td>
<td>3 (not repaired)</td>
<td>DCP</td>
<td>100</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>22</td>
<td>posterior</td>
<td>y</td>
<td>DCP</td>
<td>1 (release)</td>
<td>80</td>
<td>180</td>
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<tr>
<td>5</td>
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<td>posterior</td>
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<td>TBW</td>
<td>15</td>
<td>150</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>35</td>
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<td>2 (not repaired)</td>
<td></td>
<td>TBW</td>
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<td>180</td>
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<tr>
<td>7</td>
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<td>2 (repaired)</td>
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<td>TBW</td>
<td>1 (radial head excision)</td>
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<td>1/3 tubular</td>
<td>1 (capsular release)</td>
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<td>3 (excised)</td>
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The number of additional surgeries correlated significantly with the final flexion arc ($r = -0.49; P < 0.05$) and explained 53% of the variability in the final flexion arc in multivariate analysis ($F = 23; P < 0.001$). The DASH score correlated significantly or near significantly with pain ($r = 0.72; P < 0.001$), injury type ($Z = -1.85; P < 0.08$), and ulnar neuropathy ($Z = -2.32; P < 0.05$). In multivariate analysis, a model with all 3 variables explained 53% of the variability in the final flexion arc.

Table 1. Patients with anterior and posterior olecranon fracture-dislocations (final follow-up)

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<tr>
<th>Patient</th>
<th>Final FU (Years)</th>
<th>FE Arc</th>
<th>PS Arc</th>
<th>UN†</th>
<th>Arthroisis‡</th>
<th>ASES</th>
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Fx, fracture; TBW, tension band wiring; DCP, dynamic compression plate; 1/3 tubular, one third tubular plate; RC K-wire, radiocapitellar transfixation with Kirschner wire; FE arc, flexion and extension arc; PS arc, pronation and supination arc; UN, ulnar nerve; E, excellent; G, good; F, fair; P, poor

* Implant removal was standard and is not included among additional surgeries in this table
† Grade 1, minimal lesions with no detectable motor lesions of the hand; Grade 2, intermediate lesions; Grade 3, severe lesions with paralysis of one or more of the intrinsic muscles one or more of the intrinsic muscles
variability in DASH scores (F = 8; P < 0.01). The MEPI correlated significantly with the final flexion arc (r = 0.47; P < 0.05) and pain (r = –0.77; P < 0.001). A multivariate model with both predictors explained 75% of variability in MEPI scores (F = 29; P < 0.001). The Broberg and Morrey score correlated significantly with final flexion arc (r = 0.56; P < 0.05) and pain (r = –0.77; P < 0.001). A multivariate model with pain and flexion arc explained 85% of the variability in Broberg and Morrey scores (F = 54; P < 0.001). The score on the ASES Elbow Evaluation Instrument correlated significantly with the flexion arc (r = 0.49; P < 0.05), pain (r = –0.87; P < 0.001) and ulnar neuropathy (Z = –2.23; P < 0.05). A multivariate model with the flexion arc, pain, and ulnar neuropathy explained 75% of the variability in ASES scores (F = 20; P < 0.001).

Comparison of Patients with Anterior and Posterior Fracture-Dislocations
Patients with anterior fracture-dislocations were comparable to patients with posterior fracture-dislocations in terms of age at surgery (26 ± 5 vs. 33 ± 15 years; P = 0.20), gender (P = 1.00), additional surgeries on the same upper extremity (P = 0.59), and operative technique used (plating vs. tension band wiring; P = 0.37).

At early follow-up, patients with an anterior olecranon fracture-dislocation had a better flexion arc (117 ± 27 vs. 95 ± 41 degrees; P = 0.25) and worse forearm arc (123 ± 80 vs. 166 ± 29 degrees; P = 0.17) than patients with a posterior fracture-dislocation, but differences were not significant with the numbers available, and the diminished forearm rotation among anterior injuries is likely a result of the single patient with a synostosis.

At final follow-up and with the numbers available, there were no significant differences between patients with anterior and posterior fracture-dislocations in terms of final flexion arc (124 ± 30 vs. 120 ± 41 degrees; P = 0.83), improvement in flexion arc (5 vs. 21 degrees; P = 0.08), final arc of forearm rotation (133 ± 54 vs. 168 ± 10 degrees; P = 0.06), pain (13 ± 13 vs. 7 ± 12 points; P = 0.29), and outcomes according to the ASES Elbow Evaluation Instrument (85 ± 19 vs. 92 ± 11 points; P = 0.28), the DASH questionnaire (14 ± 17 vs. 4 ± 7 points; P = 0.09), and Broberg and Morrey (87 ± 18 vs. 94 ± 11 points; P = 0.42). Five patients with an anterior fracture-dislocation had signs of ulnar neuropathy or had a subsequent surgery for ulnar nerve transposition, compared with two among patients with a posterior fracture-dislocation (Fisher Exact Test, P = 0.35). Arthrosis was observed in 5 patients with anterior fracture-dislocations and 9 patients with posterior fracture-dislocations (Fisher Exact Test, P = 0.14).

Discussion
Olecranon fracture-dislocations are relatively uncommon injuries. In this study, we documented the long-term results of olecranon fracture-dislocations for 20 (69%) of 29
patients who were alive. The treatment techniques rendered between 1974 and 1994 reflect greater use of tension band wiring alone than would be used today, when plates would be preferred for all of these injuries. In our study, 1 of 4 one-third tubular plates failed, and these are no longer felt to be of adequate strength for comminuted olecranon fractures and olecranon fracture-dislocations.\textsuperscript{2,8,23} Dynamic compression plates or plates of similar thickness and strength are preferable. Both of the other poor results were related to the development of heterotopic bone. One patient who was treated with closed reduction, percutaneous pinning, and cast immobilization had a proximal radioulnar synostosis at final follow-up, but she had 100 degrees of ulnohumeral motion. The other patient had a final flexion arc of only 10 degrees due to severe heterotopic ossification, despite a release 2 years after initial treatment. It is not our practice to use NSAIDs or radiation to prevent formation of heterotopic bone because of concern about fracture healing.

The fact that 14 of 43 patients died before the long-term follow-up examination is a reflection of the prevalence of posterior olecranon fracture-dislocations in older, osteoporotic women.\textsuperscript{8} Thirteen of these patients were women with an average age of 66 years at the time of injury. The observation that patients with a documented date of death lived an average of 15 years after their fracture suggests that the fracture is not necessarily associated with increasing frailty or infirmity.

Fractures of the coronoid were secured with screws or Kirschner wire in 9 of 11 patients in our case series. Among the 2 patients in whom the coronoid fracture was not secured, 1 had a small Regan and Morrey\textsuperscript{14} type 2 fragment, and 1 had a large type 3 fracture. Most coronoid fractures associated with olecranon fracture-dislocations are large Regan and Morrey type 3 fractures\textsuperscript{4,6}, and stable fixation of both the olecranon and coronoid fractures is usually needed to achieve restoration of the contour, dimensions, and depth of the trochlear notch and to achieve a good result\textsuperscript{3,4,7}. In the current study, the only patient with an un repaired type 3 coronoid fracture developed a radioulnar synostosis, severe arthrosis, and had a poor result. In addition, 5 of the 8 radial head fractures were not addressed; in 1 patient, the radial head was excised. Today, we would recommend repair or prosthetic replacement of concomitant fractures of the radial head in patients with olecranon fracture-dislocations, and this may improve results further.

The final average flexion arc of 122 degrees was slightly better than that observed in prior studies of anterior (124 degrees in our study)\textsuperscript{2,4,6} and posterior fracture-dislocations (120 degrees in our study).\textsuperscript{4,8} This may reflect the average improvement of 14 degrees between the early and final follow-ups, which might be the result of continued improvement in motion with recovery beyond 1 year after injury or the influence of subsequent surgeries. A prior study suggested that patients with posterior olecranon fracture-dislocations regain less ulnohumeral motion and forearm rotation compared to patients with anterior olecranon-fractures\textsuperscript{4}, but this was not observed with the numbers available in the current study. Our
results according to Broberg and Morrey and the ASES Evaluation Instrument were comparable to the results found in other studies of anterior olecranon fracture-dislocations.\textsuperscript{4,6} For posterior fracture dislocations, our scores were comparable\textsuperscript{8} or slightly better\textsuperscript{4} than those reported in previous studies. DASH and MEPI scores were not previously reported.

Of the 20 patients, 7 (35\%) developed an ulnar neuropathy during the follow-up period. Only 2 of these were identified and treated operatively. The others were identified when the patients were asked to return for the research-related follow-up. These patients apparently did not have sufficient symptoms or dysfunction to bring these to the attention of their treating physician. Nonetheless, this is a notable rate of ulnar neuropathy that further reinforces our increasing tendency to perform an in situ release of the ulnar nerve during the treatment of complex elbow injuries as prophylaxis against subacute and chronic ulnar neuropathy.

Our study demonstrates that the initial results obtained from secure anatomical restoration of the trochlear notch\textsuperscript{2,4,6,8,10,11,24} are durable over the long-term. Pain, the final flexion arc, and ulnar neuropathy were the most important predictors of functional results and outcome. Although 70\% of patients developed ulnohumeral arthrosis, it did not correlate with final flexion arc, any of the evaluation systems, or the DASH scores. Even patients with advanced arthrosis and those rated unsatisfactory did not request reconstructive surgery.

**Acknowledgement**

We are grateful to Dr. E. L. F. B. Raaymakers for managing the fracture database for the Departments of Orthopaedic Surgery and General Surgery at the Academic Medical Center in Amsterdam, the Netherlands, over the last decades. All cases included in the study were identified through this database. We kindly thank the departments of surgery and traumatology for the permission to use the data of their patients.

**References**
