Intra-articular osteotomy for malunited articular fractures of the distal end of the humerus

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Background: The precarious anatomy of the articular surface of the distal humerus, as well as its meager subchondral bony support and limited soft-tissue attachments, presents enormous challenges for the operative correction of post-traumatic intra-articular deformities. This study presents 8 patients who underwent articular osteotomy with a mean follow-up period of 10.6 years, with an emphasis on functional, patient-rated, and radiographic outcomes.

Methods: Eight patients (mean age, 39 years; range, 17-60 years) were followed up for a mean period of 10.6 years. The original fracture was a type C variant in 4 patients, a type B unicondylar fracture in 2, and a type B articular shearing fracture in 2. The initial injury was treated operatively in 5 patients and non-operatively in 3. The osteotomy and reconstruction were performed on average 8 months after injury (range, 6-11 months). The mean preoperative elbow arc of motion was 37°. Two patients had ulnar nerve dysfunction.

Results: All the osteotomies healed after the index procedure without evidence of avascular necrosis. Two patients required a second procedure for stiffness. At follow-up, the mean arc of elbow motion improved to 104° (P = .001), with a mean flexion contracture of 26°. The mean Disabilities of the Arm, Shoulder and Hand score at follow-up was 13 (range, 1-37); the mean patient satisfaction rating on a Likert scale (from 0 to 10) was 9.1; and the mean Mayo Elbow Performance Index score was 83 points (range, 70-100 points). Grade II osteoarthritic changes were seen in 3 patients, grade I in 3, and grade 0 in 2.

Conclusions: In selected patients with a defined intra-articular malunion, the results of our experience support corrective osteotomy.

Level of evidence: Level IV, Case Series, Treatment Study.

Keywords: Distal humeral fracture; malunion; outcomes; fracture fixation; elbow; intra-articular fracture; shear fracture

The precarious structural anatomy of the articular surface of the distal humerus, as well as its limited soft-tissue attachments, creates a serious technical challenge when one is considering corrective osteotomy of an intra-articular malunion after fracture. The problem may be further compounded by associated soft-tissue contracture, failed...
Corrective osteotomy carries the risks of avascular necrosis and subsequent arthrosis. Unfortunately, given the uncommon nature of this problem, there is a relative paucity of published surgical experience.

To best address these concerns, we have chosen to review a cohort of 8 patients who underwent corrective osteotomy of a malunited intra-articular fracture with a mean follow-up period of 10.6 years.

Materials and methods

This is a retrospective case-control study of 8 patients who presented with functional disability associated with a malunited intra-articular fracture of the distal end of the humerus and were treated with corrective osteotomy by 2 surgeons between 1992 and 2011 (Table I). The patients were invited to return for a physical examination and radiographic evaluation under a protocol approved by the human research committees of both authors’ institutions. Informed consent was obtained from each patient. Evaluations were performed by independent examiners for the purposes of this study.

The indications for deformity correction included the degree of disability involving the upper limb, a deformity that was well delineated on both standard radiographs and computed tomography, and the absence of advanced articular loss or arthrosis.

The study group included 5 women and 3 men with a mean age at the time of surgery of 39 years (range, 18-60 years). The left arm was involved in 6 patients (5 of whom were right hand dominant) and the right arm in 2 (1 of whom was right hand dominant). The initial injury was the result of a fall from a standing height in 4 patients, a sporting event in 3 patients, and a fall from a horse in 1 patient whose fracture was open and contaminated. The original fracture involved both articular and metaphyseal bony columns (AO type C) in 4 patients, a partial articular fracture and 1 metaphyseal bony column (AO type B) in 2 patients, and a complete articular shearing fracture (AO subtype B3.3) in 2 patients. Two patients were previously reported on but were included because of the unique opportunity to observe their outcomes 16 and 18 years after osteotomy (cases 5 and 6). The original fracture was treated operatively in 5 patients and nonoperatively in 3. The operative treatment included plates and screws in 3 patients, Kirschner wires alone in 1, and external fixation alone in 1. In the one patient with an open fracture, extensive polymicrobial infection developed, necessitating multiple debridements and loss of subchondral and distal metaphyseal-diaphyseal bone, resulting in an intra-articular malunion.

The mean preoperative elbow arc of motion was 37\(^\circ\) (range, 0\(^\circ\)-95\(^\circ\)). Two of the eight patients presented with ulnar nerve dysfunction involving both motor and sensory deficits.

Operative technique

The location and type of osteotomy and internal fixation were specific to the unique morphologic characteristics of each deformity. The surgical corrections were performed on average 8 months after injury (range, 6-11 months).

In the 2 patients with a malunited articular shearing fracture (cases 3 and 8), the deformity was exposed through an extended lateral approach, which has been described for the management of coronal shear fractures.\(^{11}\) This approach also permitted excision of the contracted anterior and/or posterior capsules. The osteotomy was created through the original fracture line by use of a thin-bladed osteotome, followed by realignment of the articular fragment to its original anatomic position. Provisional fixation was obtained with smooth Kirschner wires. Stable internal fixation was achieved with headless screws placed from anterior to posterior. A small amount of autogenous bone graft was placed beneath the fragment that had undergone osteotomy to fill incongruences of the joint reconstruction and aid in union (Fig. 1). In case 3, the graft

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age at injury (y)</th>
<th>Pattern of malunion</th>
<th>Preoperative motion ((^{\circ}))</th>
<th>Follow-up (y)</th>
<th>Postoperative motion ((^{\circ}))</th>
<th>Arthritis grade</th>
<th>Mayo score</th>
<th>DASH score</th>
<th>Likert score</th>
<th>Complications</th>
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<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>Articular and metaphyseal</td>
<td>45 Extension, 75 Flexion</td>
<td>10</td>
<td>130 Extension, 7.5 Flexion</td>
<td>I</td>
<td>85</td>
<td>37</td>
<td>8</td>
<td>None</td>
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<tr>
<td>2</td>
<td>17</td>
<td>Articular and metaphyseal</td>
<td>60 Extension, 65 Flexion</td>
<td>15</td>
<td>140 Extension, 7.5 Flexion</td>
<td>I</td>
<td>85</td>
<td>1</td>
<td>10</td>
<td>Stiffness</td>
</tr>
<tr>
<td>3</td>
<td>44</td>
<td>Articular shear</td>
<td>45 Extension, 80 Flexion</td>
<td>35</td>
<td>120 Extension, 0 Flexion</td>
<td>0</td>
<td>100</td>
<td>3</td>
<td>10</td>
<td>Stiffness</td>
</tr>
<tr>
<td>4</td>
<td>33</td>
<td>Partial articular and 1 column</td>
<td>40 Extension, 135 Flexion</td>
<td>10</td>
<td>140 Extension, 0 Flexion</td>
<td>0</td>
<td>85</td>
<td>3</td>
<td>10</td>
<td>None</td>
</tr>
<tr>
<td>5</td>
<td>43</td>
<td>Articular and metaphyseal</td>
<td>60 Extension, 80 Flexion</td>
<td>70</td>
<td>125 Extension, 2 Flexion</td>
<td>II</td>
<td>70</td>
<td>35</td>
<td>6</td>
<td>Stiffness</td>
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<tr>
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<td>50 Extension, 80 Flexion</td>
<td>35</td>
<td>120 Extension, 18 Flexion</td>
<td>II</td>
<td>80</td>
<td>18</td>
<td>10</td>
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<td>7</td>
<td>47</td>
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<td>35</td>
<td>135 Extension, 12 Flexion</td>
<td>II</td>
<td>85</td>
<td>8</td>
<td>9</td>
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<tr>
<td>8</td>
<td>18</td>
<td>Articular shear</td>
<td>80 Extension, 80 Flexion</td>
<td>0</td>
<td>130 Extension, 18 Flexion</td>
<td>I</td>
<td>100</td>
<td>2</td>
<td>10</td>
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</tr>
</tbody>
</table>

DASH, Disabilities of the Arm, Shoulder and Hand.
was obtained from the ipsilateral olecranon process. In case 8, the graft was obtained from the anterior iliac crest.

Among the 4 patients with a type C fracture, surgical exposure was performed through an olecranon osteotomy in 3 patients (cases 2, 4, and 6) and through a triceps-splitting approach in 1 patient (case 1). The ulnar nerve was mobilized from surrounding scar by use of high-power loupe magnification to permit it to reside in the adjacent soft tissue (Fig. 2). The intra-articular deformity underwent osteotomy through the original fracture line extending into both medial and lateral distal metaphyseal columns. Internal fixation was achieved with plates and screws in a manner similar to that used when treating acute intra-articular distal humeral fractures \(^{13,16}\) (Figs. 2 and 3).

Of the 2 patients whose original fracture involved a partial articular fracture and one distal metaphyseal bony column, patient one was approached with an extended lateral exposure with the articular and metaphyseal correction secured with lateral and posteriorly placed plates and screws (case 7), and patient two, whose deformity involved the medial side of the distal humerus, was approached through a trans-olecranon osteotomy (case 4). In the latter patient, the original plate was removed, the articular and metaphyseal deformity was corrected through the original fracture line, and internal fixation was achieved with separate interfragmentary screws across the articular surface and a medially based plate and screws. In case 7, autograft was obtained from the cancellous bone graft harvest should be noted. The patient did not recover full elbow mobility but refused an elbow release procedure.

Figure 1  Frontal (A), oblique (B), and lateral (C) radiographs of a 44-year-old woman (case 3) who presented 6 months after a coronal shear fracture of the distal humerus treated nonoperatively. (D) Three-dimensional computed tomographic reconstruction depicting malunion with displaced articular fragment. One should note the small comminuted piece medially. (E) Intraoperative photograph of the initial view of the humerus after extensive lateral exposure with release of the extensor and ligament attachments from the lateral humerus and posterior reflection of the triceps tendon. The asterisk marks the intact medial trochlear segment. The arrow indicates the malunited articular fragment (anterior trochlea and capitellum), which was translated proximally and rotated. (F) Osteotome used to re-create initial fracture plane. (G) Provisional fixation with Kirschner wires followed by cannulated headless screws. (H) Reduction of trochlea as observed from distal view. Final anteroposterior (I), oblique (J), and lateral (K) radiographs after osteosynthesis. The lateral soft-tissue sleeve including the collateral ligament origin was repaired with transosseous sutures tied posteriorly over an EndoButton (Smith & Nephew Endoscopy, Andover, MA, USA). The olecranon defect from the cancellous bone graft harvest should be noted. The patient did not recover full elbow mobility but refused an elbow release procedure.
graft was taken from the medullary canal of the ulna distal to the olecranon osteotomy site to fill a small articular defect.

**Postoperative management**

The upper extremity was immobilized in extension overnight. Gravity-assisted elbow motion was begun depending on the level of patient comfort, as well as the security of the internal fixation. No patient was immobilized for more than 14 days. When wound healing was ensured and controlled motion permitted, the patient was encouraged to use the arm for basic activities of daily living and advanced to full activities once fracture healing was ensured.

A long arm splint was used for 4 to 6 weeks for comfort and support as needed in selected cases.

**Evaluation**

Each patient was evaluated at final follow-up by an independent examiner. Physical examination consisted of evaluation of elbow and forearm motion, grip strength, and ulnar nerve function, as well as testing for elbow stability. Patient pain was documented with a Likert scale from 0 to 10, and each patient completed a Disabilities of the Arm, Shoulder and Hand evaluation. The final outcome was also assessed according to the

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**Figure 2** (A) Initial injury film of a 17-year-old right hand–dominant student (case 2) who sustained a left intra-articular type C fracture with a shearing component of the capitellum and trochlea and proximal extension into both metaphyseal columns while snowboarding. Postoperative frontal (B) and lateral (C) radiographs after initial treatment, which included an attempt at open reduction and internal fixation with smooth Kirschner wires. Anteroposterior (D) and lateral (E) images on presentation. (F) Three-dimensional computed tomographic image showing malunion. One should note the coronoid process of the ulna, which is positioned within the split, as well as the malunited trochlea. (G) Intraoperative photograph showing view after olecranon osteotomy. Decompression and protection of the ulnar nerve (Penrose drain) should be noted. (H) Osteotome used to re-create original fracture line. (I) View after internal plate fixation. Final frontal (J) and lateral (K) radiographs after reconstruction. The patient underwent a second procedure 7.5 months after osteotomy. Final extension (L) and flexion (M) of elbow.
Mayo Elbow Performance Index. Data management and statistical analysis were performed with SPSS for Windows (version 13; SPSS, Chicago, IL, USA). Paired t tests were used to evaluate preoperative and postoperative differences. These were regarded to be significant at $P \leq .05$. A 2-tailed test was used in all cases.

Radiographic evaluation for articular congruity and/or arthrosis was performed using the system of Broberg and Morrey: grade 0, normal; grade I, slight joint space narrowing with minimum osteophyte formation; grade II, moderate joint space narrowing with moderate osteophyte formation; or grade III, severe degenerative change with gross destruction of the articular surface.

**Results**

The final evaluation of all 8 patients was performed at a mean of 10.6 years (range, 2-18 years) postoperatively. All osteotomies healed after the index reconstructive procedure. Two patients (cases 2 and 5) required a secondary surgical procedure at 7.5 months and 9 months, respectively, to release a capsular contracture and improve mobility. The total elbow motion in these cases improved from a mean of 48° after the osteotomy procedure to 90° at final follow-up.

For the entire series, the total arc of elbow motion improved significantly from a preoperative mean of 37° to a final mean of 104° at follow-up ($P = .001$). Extension improved from 51° before surgery to 26° at follow-up. The one patient who had a 70° flexion contracture at follow-up (case 5) had an open fracture with soft-tissue and bone loss and multiple prior surgeries. Elbow flexion improved from a mean of 88° preoperatively to 130° at follow-up (Table I). Forearm pronation and supination were full in all patients.

No patient had any symptoms or signs of elbow instability. The mean grip strength was 69 lb (range, 42-100 lb) with the Jaymar dynamometer (Sammons Preston Rolyan, Bolingbrook, IL, USA). This was 82% of that of the opposite, uninvolved extremity.

Patient satisfaction averaged 9.1 (range, 6-10) on the Likert scale. By use of the Mayo Elbow Performance Index, the result was rated as excellent in 2 patients, good in 5, and fair in 1. The mean Disabilities of the Arm, Shoulder and Hand score was 13 (range, 1-37).

As noted, second procedure was required because of a capsular contracture and stiffness in two patients (cases 2 and 5), one of whom also had residual ulnar nerve motor and sensory deficits (case 5). The other patient with preoperative ulnar neuropathy had resolution of neurologic symptoms after neurolysis.

The final radiographic evaluation identified grade II osteoarthritic changes in 3 patients (cases 5, 6, and 7),
grade I changes in 3 (cases 1, 2, and 8), and grade 0 findings in 2 (cases 3 and 4). There was no evidence of articular collapse consistent with postoperative avascular necrosis. The articular reduction obtained at surgery was not lost in any patient.

Discussion

Although the experience with reconstruction of an intra-articular malunion of the distal humerus remains limited, the results documented in this study suggest, in selected patients, that the procedure can be effective and durable over time. Factors inherent in the decision-making process include a relatively limited time after fracture, a stable elbow, a well-defined articular deformity, and preferably, a younger, more active individual. Certainly, when one is faced with a similar situation in an older, sedentary individual, total elbow arthroplasty would be an alternative option.

The accurate restoration of the dimensions of the trochlea and its relationship to the greater sigmoid notch (sulcus) of the olecranon sulcus is well recognized as fundamental to providing intrinsic stability to the elbow. The ulnohumeral relationship has to be restored for normal elbow kinematics and function. We presume that the improvement in the articular anatomy in our patients after osteotomy contributed, in part, to the greater arc of motion and function observed at final follow-up. However, re-establishing the precise 3-dimensional anatomy of the distal humerus is often not possible in these cases. Although the total arc of motion significantly improved, only 4 of our 8 patients ended up with elbow motion of 30° to 130° or greater. For example, in case 3 (Fig. 1), the inability to restore the normal angle of the capitellum and the curvature of the lateral column may have contributed to the final 35° loss of elbow extension. Soft-tissue factors, such as capsular scarring and myostatic contracture, could have contributed as well. Fortunately, at final follow-up averaging approximately 11 years, most patients had an absence of cartilage degeneration. Although 3 patients had grade II changes of arthrosis, the findings were not progressive and included periarticular ossification.

Given the extensile surgical exposures, limited residual soft-tissue attachments to the articular and metaphyseal segments, and relatively small size of the articular pieces that had undergone osteotomy, one might ask why avascular necrosis was not observed in these cases. One factor might be the result of stable internal fixation with compression screws either alone or in combination with supporting plates permitting revascularization from the underlying metaphyseal bone. Cancellous autograft might have aided revascularization as well. This mirrors the reported experience with intra-articular osteotomies of malunited fractures of the distal end of the radius. In addition, the distal end of the humerus has been shown by several authors to have a robust arterial supply from the medial and lateral vascular arcades arising from the recurrent ulnar and radial collateral arteries, respectively.

Two patients in our study required a secondary procedure to release a capsular contracture and improve motion. In these individuals, total elbow motion did improve. One additional patient was offered an elbow release but declined (case 3). Thus, for some individuals, intra-articular osteotomy may be the first stage of a 2-stage reconstruction. Certainly, restoration of joint anatomy is paramount in this patient population. Motion can be ultimately improved if the joint relationships are restored.

The limitation of this study is consistent with other retrospective studies of uncommon conditions with a small number of patients. Yet, the fact that these complex articular reconstructions continued to function well over a relatively long duration supports the operative tactics and careful patient selection.

Conclusion

Intra-articular distal humeral malunions represent one of the most complex elbow conditions to treat. A clear understanding of the deformity, followed by osteotomy, accurate reduction, and stable fixation, can lead to satisfactory long-term outcomes in carefully selected patients.

Disclaimer

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References

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