Hinged External Fixator and Open Surgery for Severe Elbow Stiffness With Distal Humeral Nonunion

YUANMING OUYANG, MD; YI LIAO, MD; ZHONGTANG LIU, MD, PhD; CUNYI FAN, MD, PhD

abstract

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Joint stiffness is a common complication of elbow trauma. Treating elbow stiffness is challenging, especially in patients with severe elbow stiffness with distal humeral nonunion.

To improve treatment outcomes, the authors applied a hinged external fixator after performing open reduction and internal fixation and evaluated the clinical outcome. Between 2005 and 2011, eleven patients with elbow stiffness and distal humeral nonunion underwent open arthrolysis, surgical reduction, internal fixation, hinged external fixation, and selective bone grafting. The ulnar nerve was anteriorly transposed in all patients. Elbow range of motion, Mayo Elbow Performance Score, and radiographs were assessed pre- and postoperatively. All patients achieved solid union in an average of 5.6 months. Preoperatively, mean flexion was 86.8°, mean extension was 45.5°, and mean total range of motion was 41.3°. Postoperatively, mean flexion was 125.9°, mean extension was 11.8°, and mean total range of motion was 114.1°. Mean Mayo Elbow Performance Score also significantly improved from 59 points preoperatively to 87.2 points postoperatively, and 6 patients were scored as excellent (more than 90 points), 3 good (75-90 points), and 2 fair (60-74 points) according to the Mayo Elbow Performance Score.

A stiff elbow with distal humeral nonunion can be treated successfully using a unilateral hinged external fixator to supplement the open reduction and internal fixation. A hinged external fixator was an effective rehabilitation method for improving range of motion and maintaining joint stability.

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Figure: Photographs showing flexion (A) and extension (B) preoperatively and flexion (C) and extension (D) at 1-year follow-up.
Joint stiffness is a common complication of elbow trauma. Posttraumatic elbow stiffness has many causes, including fracture nonunion. Recent studies reported that the rate of fracture nonunion and delayed distal humeral union is between 2% and 10% of affected patients who often have a painful, unstable elbow with limited range of motion (ROM) and restricted function. Further treatment of these complex fractures is compounded and difficult due to poor bone quality and the poor soft tissue condition. Consequently, elbow stiffness often recurs after revision surgery.

Therefore, it is important to restore proper elbow joint function when treating distal humeral fracture nonunion. Because hinged external fixators can help repair the bone and ligament injuries of the elbow joint while granting early elbow motion, they have been used to treat elbow trauma, including radial head fractures, fracture dislocations, and elbow contracture releases in recent years. Thus, hinged external fixators play a key role during early rehabilitation.

Based on these observations, the current authors hypothesized that a hinged elbow external fixator could be applied as a supplemental method to achieve an ideal effect that internal fixation cannot obtain for elbow stiffness with distal humeral nonunion and that it would promote early rehabilitation and potentially increase elbow joint stability.

The purpose of this study was to assess the application of a unilateral hinged external fixator with open reduction and internal fixation and open surgery in the treatment of patients with severe elbow stiffness with distal humeral nonunion.

**Materials and Methods**

Between 2005 and 2011, eleven patients with distal humeral nonunion and elbow stiffness underwent revision surgery at the authors’ institution. All patients underwent open arthrolysis, surgical reduction, internal fixation, hinged external fixation, and selective bone grafting. The ulnar nerve was transposed anteriorly. Table 1 shows the patient data. A distal humeral nonunion was defined as a fracture that showed no progress in healing during the 6 months after initial treatment. Average patient age was 41.9 years (range, 19-60 years), and the study group comprised 7 men and 4 women. The dominant elbow was affected in 7 patients, and the nondominant elbow was affected in 4 patients. All fractures were caused by trauma. Three patients fell from a standing height while walking, 3 fell from a greater height following a high-energy impact, and 5 were involved in motor vehicle accidents.

Initial operative treatment included conservative treatment (n=1), pinning with tension-band wiring (n=2), pinning with tension-band wiring and lag screw fixation (n=2), reconstructive plate fixation (n=4), Y-shaped plate fixation (n=1), and anatomic plate fixation (n=1). Mean duration between initial trauma and revision was 22.1 months (range, 13-52 months). Preoperative anteroposterior and lateral radiographs revealed that all patients had distal humeral nonunion. Of the nonunions, 4 were supracondylar, 2 were intercondylar, 1 was medial condylar, and 1 was lateral condylar. Preoperatively, mean total ROM was 41.3° (range, 25°-65°), mean extension was 45.5° (range, 30°-65°), and mean flexion was 86.8° (range, 60°-100°). All patients were independently followed for an average of 29 months (range, 12-60 months). Preoperative Mayo Elbow Performance Score (MEPS) assessment revealed that elbow function was good (more than 75 points) in 2 patients and poor to fair (less than 75 points) in 9 patients.

**Surgical Technique**

Surgery was performed with the patient under brachial plexus block in the supine position. The incision was determined by a few factors, such as previous incision sites, the nonunion location, and heterotopic bone location. Surgical exposure was performed through a posterior incision incorporating previous incisions in 5 patients and by combined lateral and medial incisions in 6 patients. Lateral and medial skin flaps were elevated. The ulnar nerve was examined, released, transposed anteriorly, and stabilized by fascial slings, which allowed the flexion and extension of the nerve to accommodate the newly gained ROM. Heterotopic bones around the olecranon in the posterior part of the distal humerus were resected together with the posterior capsule. All previous internal fixations were removed.

The nonunion site was debrided, and the dead bone was cleared off until the bleeding bone edges were exposed. The sclerotic fracture surfaces were perforated using a drill. Fibrous tissues that prevented anatomical reduction of the fracture fragments and synovial tissues were excised.

After the fracture site was cleared and the distal humerus was anatomically reduced, an appropriate internal fixation apparatus was used to fix the fracture. Combined internal fixation of the humeral shaft and condyles was performed using various devices, including cannulated compression screws and anatomic or locking plates. The devices were chosen on a patient-by-patient basis to optimize the anatomic reconstruction and compressive fixation between the bone fragments.

For patients with an unstable fracture or osteoporosis, distal humeral locking plates were chosen. If the fracture was stable, anatomic plates combined with cannulated screws and tension-band wires were placed. Shape-memory bone staples were an alternative option for patients with stable fractures with rigid bone density. The devices used in this group are shown in Table 2.

The decision of whether to perform an olecranon osteotomy for exposure is typically based on the location of the nonunion. In the case of an intra-articular nonunion of a low transcondylar fracture, the best exposure is through a chevron intra-
### Table 1

**Summary of Preoperative Patient Characteristics**

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Time From Injury to Presentation, mo</th>
<th>Preop Elbow Extension/Flexion, deg</th>
<th>No. of Previous Operations</th>
<th>Etiology</th>
<th>Preop MEPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/19</td>
<td>15</td>
<td>30/90</td>
<td>1</td>
<td>Fall</td>
<td>65</td>
</tr>
<tr>
<td>2/F/23</td>
<td>18</td>
<td>45/95</td>
<td>2</td>
<td>MVA</td>
<td>55</td>
</tr>
<tr>
<td>3/M/42</td>
<td>20</td>
<td>55/85</td>
<td>1</td>
<td>Fall</td>
<td>40</td>
</tr>
<tr>
<td>4/M/47</td>
<td>24</td>
<td>35/100</td>
<td>1</td>
<td>Fall</td>
<td>60</td>
</tr>
<tr>
<td>5/M/</td>
<td>52</td>
<td>60/85</td>
<td>2</td>
<td>MVA</td>
<td>45</td>
</tr>
<tr>
<td>6/F/60</td>
<td>30</td>
<td>40/75</td>
<td>3</td>
<td>Fall</td>
<td>70</td>
</tr>
<tr>
<td>7/M/49</td>
<td>19</td>
<td>65/95</td>
<td>1</td>
<td>MVA</td>
<td>60</td>
</tr>
<tr>
<td>8/F/56</td>
<td>21</td>
<td>45/60</td>
<td>2</td>
<td>MVA</td>
<td>40</td>
</tr>
<tr>
<td>9/M/48</td>
<td>17</td>
<td>40/85</td>
<td>1</td>
<td>Fall</td>
<td>75</td>
</tr>
<tr>
<td>10/F/33</td>
<td>14</td>
<td>35/95</td>
<td>2</td>
<td>MVA</td>
<td>80</td>
</tr>
<tr>
<td>11/M/29</td>
<td>13</td>
<td>50/90</td>
<td>3</td>
<td>MVA</td>
<td>60</td>
</tr>
</tbody>
</table>

**Abbreviations:** deg, degrees; MEPS, Mayo Elbow Performance Scores; MVA, motor vehicle accident; Preop, preoperative.

### Table 2

**Summary of Postoperative Patient Characteristics**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Surgical Method</th>
<th>Postop Elbow Extension/Flexion, deg</th>
<th>Increased ROM, deg</th>
<th>Follow-up, mo</th>
<th>Postop MEPS</th>
<th>Time to Union, mo</th>
<th>Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Anatomical plate, tension band, cannulated screw, bone grafting, and hinged external fixator</td>
<td>10/120</td>
<td>50</td>
<td>36</td>
<td>95</td>
<td>8</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>Locking plate and hinged external fixator</td>
<td>15/115</td>
<td>50</td>
<td>24</td>
<td>85</td>
<td>4</td>
<td>Pin-tract infection</td>
</tr>
<tr>
<td>3</td>
<td>Anatomical plate, tension band, cannulated screw, and hinged external fixator</td>
<td>20/125</td>
<td>75</td>
<td>12</td>
<td>70</td>
<td>6</td>
<td>Radial transient nerve injury</td>
</tr>
<tr>
<td>4</td>
<td>Shape-memory bone staple and hinged external fixator</td>
<td>5/135</td>
<td>65</td>
<td>18</td>
<td>95</td>
<td>3.5</td>
<td>None</td>
</tr>
<tr>
<td>5</td>
<td>Anatomical plate, tension band, cannulated screw, bone grafting, and hinged external fixator</td>
<td>10/130</td>
<td>95</td>
<td>26</td>
<td>90</td>
<td>6</td>
<td>Mild donor-site pain</td>
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<tr>
<td>6</td>
<td>Locking plate and hinged external fixator</td>
<td>5/135</td>
<td>95</td>
<td>32</td>
<td>95</td>
<td>4.5</td>
<td>None</td>
</tr>
<tr>
<td>7</td>
<td>Anatomical plate, tension band, cannulated screw, and hinged external fixator</td>
<td>10/125</td>
<td>85</td>
<td>30</td>
<td>90</td>
<td>5</td>
<td>None</td>
</tr>
<tr>
<td>8</td>
<td>Shape-memory bone staple and hinged external fixator</td>
<td>20/125</td>
<td>90</td>
<td>60</td>
<td>70</td>
<td>6</td>
<td>Ulnar transient nerve palsy</td>
</tr>
<tr>
<td>9</td>
<td>Anatomical plate, tension band, cannulated screw, bone grafting, and hinged external fixator</td>
<td>15/120</td>
<td>60</td>
<td>16</td>
<td>85</td>
<td>7</td>
<td>Mild donor-site pain</td>
</tr>
<tr>
<td>10</td>
<td>Anatomical plate, cannulated screw, and hinged external fixator</td>
<td>0/140</td>
<td>80</td>
<td>38</td>
<td>100</td>
<td>8</td>
<td>None</td>
</tr>
<tr>
<td>11</td>
<td>Locking plate and hinged external fixator</td>
<td>20/115</td>
<td>55</td>
<td>28</td>
<td>85</td>
<td>4</td>
<td>Transient pain</td>
</tr>
</tbody>
</table>

**Abbreviations:** deg, degrees; MEPS, Mayo Elbow Performance Score; Postop, postoperative; ROM, range of motion.
articul ar olecranon osteotomy, which was used in 2 patients (Figure 1).

For nonunions involving the articular surface of the distal humerus, comminuted bone fragments were first fixed with Kirschner wires to form the intact medial or lateral condyles or both (Figure 2). The trochlear articular surface of the distal humerus was aligned with the olecranon articular surface for reduction. After reduction of the articular surface, transverse fixation was performed using 1 or 2 lag screws to convert the intracondylar fracture to a supracondylar fracture.

Nonunions not involving the articular surface were treated as supracondylar humeral fractures. Anatomic reduction of the humeral shaft and condyles was performed. Autogenous cancellous bone was obtained from the iliac crest. Small bone grafts were trimmed according to the size and shape of bone defects in the medial or lateral condyles or both and were subsequently inserted into the fracture sites.

After satisfactory reconstruction of the humeral condyle, the olecranon osteotomy was reduced. Anterior and posterior capsulotomy was performed to achieve a complete elbow release. If sufficient ROM cannot be maintained after the above efforts, soft tissue release must be performed in the next stage. Triceps V-Y pIasty was performed in 2 patients. Thereafter, an Orthofix hinged external fixator (Orthofix, Verona, Italy) was routinely used on the patients as reported by Pugh et al.4 The key step of applying a hinged external fixation was to identify the rotational axis of the elbow. The incision was sutured, and 2 suction drains were left in place.

**Figure 1:** Preoperative anteroposterior and lateral radiograph (A), 1-week postoperative anteroposterior and lateral radiograph (B), and 1-year postoperative anteroposterior and lateral radiograph (C) showing nonunion of a low transcondylar fracture in the distal humerus (patient 7 in Table 1).

**Figure 2:** Intraoperative images showing fixation with Kirschner wire (A) and Kirschner wire and plates (B) and photograph (C) showing comminuted bone fragments fixed with Kirschner wire to form the intact medial or lateral condyles, then fixed with an anatomical plate and cannulated screw.

**Postoperative Management**

All patients followed a vigorous protocol of postoperative exercises with passive, active-assisted elbow flexion and extension exercises. Continuous postoperative exercises were started on postoperative day 2 as tolerated. All postoperative exercises continued for at least 3 months after discharge. Emphasis was placed on a minimum of 6 hours each day and a slow stretching of the elbow. The external fixator was locked at night in extreme flexion or extension alternately depending on what was tolerable for the patient. Due to the postoperative exercises, a high volume of exudate drained. Drainage was maintained for 3 to 10 days postoperatively. Drains were removed when the volume of exudate over a 24-hour period was less than 50 mL. The fixator was removed without anesthesia during postoperative week 8. All patients took 25 mg of indomethacin 3 times daily for the first 6 weeks postoperatively.8 Pin-tract infections were treated with local wound care and oral antibiotics.

**Evaluation**

Standard anteroposterior and lateral radiographs were obtained to assess bone healing every 4 weeks postoperatively. After discharge, follow-up occurred every 4 weeks during the first 6 months, during which MEPS was determined. The MEPS includes the evaluation of stability (10 points), ROM (20 points), activities of daily living (25 points), and pain (maximum score, 45 points) and is used to assess the entire elbow function pre- and postoperatively and during follow-up. Range of motion was evaluated pre- and postoperatively. Complications were also evaluated.

**RESULTS**

Postoperatively, all patients returned to their normal activities of daily living and previous jobs. Primary healing occurred in all patients. No instances occurred of internal fixation breakage, implant loosening, or bone fragment displacement. Mean duration to bone union was 5.6 months (range, 3.5-8 months). Mean elbow ROM at last follow-up was 118° (range, 0°-20°) for extension and 125.9° (range, 115°-140°) for flexion. Mean total elbow ROM was 114.1° (range, 0°-140°). Mean final follow-up MEPS was 87.2 points (range, 70-100 points), and 6 patients were scored as excellent (more than 90 points), 3 good
(75-90 points), and 2 fair (60-74 points). Fair scores were related to extensive soft tissue adhesion around the elbow joint and a lack of sustained postoperative functional exercise. No instability was detected clinically.

Due to the anterior transposition of the ulnar nerve, no patient experienced postoperative ulnar nerve sensory or motor dysfunction. One patient sustained transient radial nerve palsy postoperatively. Two patients reported mild postoperative donor-site pain. One patient sustained a superficial pin-tract infection and was treated with oral antibiotics and local wound care. No other complications, such as repeated nonunion, deep infection, recurrence of heterotopic ossification, or vascular injury, occurred. Postoperative patient characteristics are shown in Table 2. Figures 3 and 4 show a representative case (patient 10 in Table 1).

**Discussion**

In the current study, using a unilateral hinged external fixator combined with open reduction and internal fixation and selective autogenous iliac bone grafting improved elbow joint function in patients with elbow stiffness and distal humeral nonunion. The current findings suggest that the use of this approach, combined with early postoperative functional exercise, may be an effective treatment.

Distal humeral nonunion is difficult to treat due to small bone fragments, various degrees of instability, and elbow stiffness. Moreover, due to the complexity of the cases, it is difficult to make decisions regarding the most effective treatment. Many treatment options have been reported in previous studies, including open reduction, internal fixation with plates and screws, intramedullary nailing with interfragmentary wiring, free vascularized bone grafting, and total elbow arthroplasty. However, elbow capsular adhesions appeared in all aforementioned techniques.

Although open reduction and internal fixation is the normal choice for the treatment of distal humeral nonunion, the out-
come is not always satisfying. Early motion with an unstable internal fixation in an osteoporotic or fragile bone might be catastrophic. On the contrary, attempting to maintain stability by prolonging immobilization leads to a high probability of posttraumatic stiffness.

Ramsey et al reported the treatment results of 14 patients with distal humeral nonunion who underwent seconstrained total elbow arthroplasty. Of the 14 patients, 12 had an excellent or good result according to the MEPS, and mean flexion was 101°. However, total elbow arthroplasty has a limited lifespan, is more difficult to perform, and is less predictable in revision procedures. The risk of complications, including infection, triceps insufficiency, and ulnar neuropathy, may be greater when total elbow arthroplasty is performed as a complex posttraumatic reconstruction procedure.

In the current series, the clinical result is comparable with the outcomes from other authors. The current technique has significant advantages in achieving joint stability and allowing early mobilization. All patients exhibited improvement in elbow joint function and attached bone union postoperatively.

The high rate of clinical success may be due to the following factors. First, standard techniques were used to achieve reduction and release the elbow: the fibrous tissue at the nonunion site was thoroughly debrided until bleeding bone was seen, the ulnar nerve was exposed and transposed anteriorly, the anteriorly and posteriorly distal bone fragment was completely released, and bone graft was applied when necessary. Second, an optimal internal fixator was used because the distal humerus has an irregular anatomy. Simple plate fixation on a single plane may not always provide optimal stability at the fracture site. The combined application of different fixation methods promoted stability in the distal humerus and healing of the nonunion. Third, all patients performed early postoperative exercises because the unilateral hinged elbow external fixator was applied. With the controlled motion and stability provided by the external fixator, early postoperative elbow joint mobilization is allowed, which is an important preventive factor in posttraumatic elbow stiffness. This was an important factor underlying the positive outcomes because postoperative exercise can help prevent intra-articular and muscle adhesion around the joint and, therefore, reduce the risk of elbow flexion and extension impairment. Early functional exercise may also help prevent elbow joint stiffness, osteoporosis, muscle atrophy, and joint fibrosis.

Because correctly applying the external fixator is technically demanding, the authors recommend critically applying this device. The most important step is to place the axis pin correctly at the center of rotation to reduce frictional resistance and avoid loosening. A deviation of 5° from the center of rotation results in a 3.7-fold increase in kinetic energy, and a deviation of 10° results in a 7.1-fold increase. The role of decompression of the ulnar nerve in this procedure must be emphasized. Previous authors reported that the ulnar nerve is at risk in procedures that restore elbow flexion after longstanding contractures. No patients in the current series had complications associated with the ulnar nerve.

However, the current study was a retrospective analysis and was limited by a small sample size. Another limitation was the individual difference that existed in the study group of patients, such as the classification of initial fractures, revision times, and bone quality. Furthermore, it is difficult to test the exact magnitude of arm strength during elbow ROM, which may correlate with the recovery result of postoperative elbow function. Biomechanical studies and prospective clinical trials would be helpful in evaluating the validity of the unilateral hinged external fixator for the treatment of these injuries.

**Conclusion**

Regarding the treatment for elbow stiffness with distal humeral nonunion, using a unilateral hinged external fixator to supplement regular open reduction and internal fixation was reliable, effective, and tolerable for patients.

**References**

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