Outcomes Following Distal Humeral Fracture Fixation with an Extensor Mechanism-On Approach

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Background: Distal humeral fractures have traditionally been managed with surgical approaches that disrupt the extensor mechanism. We hypothesized that an extensor mechanism-on approach for operative fixation of distal humeral fractures with parallel or orthogonal plate constructs would allow excellent healing, a motion arc of the elbow exceeding 100°, and maintenance of extensor mechanism strength.

Methods: Distal humeral open reduction and internal fixation (ORIF) was performed with either orthogonal or parallel plate constructs in seventy-nine elbows. Thirty-seven elbows were fixed via an extensor mechanism-on surgical approach, and twenty-four of them were available for additional evaluation. Radiographs as well as MEPI (Mayo Elbow Performance Index), DASH (Disabilities of the Arm, Shoulder and Hand), and SF-36 (Short Form-36) scores were obtained.

Results: All thirty-seven fractures healed primarily. Three elbows underwent later release because of stiffness. The median arc of elbow motion was 126° (range, 60° to 141°). The mean MEPI was 91.5 points and the mean DASH score was 15.9 points, indicating excellent scores with mild impairment. The median percent loss of triceps strength was 10% (range, 0% to 49%) compared with the contralateral, normal elbow.

Conclusions: Open treatment of distal humeral fractures with an extensor mechanism-on approach results in excellent healing, a mean elbow flexion-extension arc exceeding 100°, and maintenance of 90% of elbow extension strength compared with that of the contralateral, normal elbow.

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

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Intercondylar and low transcondylar distal humeral fractures frequently require operative exposure and stabilization of the medial and lateral columns as well as the articular surface. Traditionally, these fractures have been managed in an operative fashion with various extensor mechanism-disrupting surgical approaches. These approaches are often associated with delayed union or nonunion of the olecranon, triceps weakness, and osteotomy-related prominent implants. To avoid these problems, various extensor mechanism-sparing approaches that provide bicolumnar exposure of the distal part of the humerus have been described, including triceps-splitting and reflecting techniques.

The two-window approach to the distal part of the humerus was described in 1972 by Alonso-Llames for treatment of pediatric supracondylar fractures for which closed reduction had failed. In 2003, Schildhauer et al. expanded on this approach for treatment of distal humeral fractures with intra-articular extension. They described an extensor mechanism-sparing, paratricipital, anconeus-preserving approach with bicolumnar visualization through medial and lateral windows with the triceps insertion on the olecranon kept intact.

To our knowledge, no prior report discusses the objective evaluation of elbow extension strength following distal humeral open reduction and internal fixation (ORIF) done with Schildhauer’s technique. Although Ali et al. reported functional outcomes following distal humeral fixation with this technique, dynamometric extension strength evaluation was not conducted. We intended to determine whether this exposure would allow adequate visualization for anatomic reduction and lead to
patient outcomes comparable with those after more invasive exposures. We evaluated functional outcomes and elbow extension strength following distal humeral fixation with Schildhauer’s paratricipital approach.

Materials and Methods

Our study was approved by the University of Nebraska Medical Center’s Institutional Review Board for the Protection of Human Subjects (IRB# 542-08-FB).

From January 2002 to January 2009, distal humeral ORIF was performed with either orthogonal or parallel plate constructs in seventy-nine elbows by the two senior authors (M.A.M. and E.V.F.). Thirty-seven of the seventy-nine elbows were fixed via the paratricipital posterior approach described by Schildhauer et al.

Forty-two patients were excluded from this study for the following reasons: a surgical approach other than the one described by Schildhauer et al. (seven elbows), an associated olecranon fracture (six elbows), preoperative triceps avulsion (two elbows), an olecranon osteotomy (nineteen elbows), and previous elbow surgery (eight elbows). During the time period studied, three of the forty-two excluded elbows were converted to an olecranon osteotomy after an initial extensor mechanism-on approach was attempted because visualization was inadequate to allow anatomic restoration of the fracture fragments with the extensor mechanism-on approach alone. These cases were excluded from the study. The decision to address the remaining thirty-seven with the Schildhauer approach was made preoperatively by the treating surgeon after review of imaging studies.

At the time of this study, twenty-four of the thirty-seven patients treated with the Schildhauer technique returned for additional evaluation beyond the standard clinical follow-up; they were evaluated by an orthopaedic surgery chief resident other than the surgeon of record. Of the thirteen patients who did not return, one had died and twelve were either unable to or declined to return for the additional evaluation.

The mean age at the time of surgery was forty-seven years (range, fourteen to eighty-five years). Thirteen injuries were in females and eleven were in males. The dominant extremity was involved in ten patients (42%). The mechanism of injury included fifteen ground-level falls, three falls from a height, and six motor-vehicle accidents.

The fractures were classified according to the AO/ASIF classification. Six patients had a type-A fracture, one had a type-B fracture, and seventeen (71%) had a type-C fracture (Figs. 1-A and 1-B). Of the type-C fractures, eight were C1, six were C2, and three were C3. Six injuries (25%) were in extremities that had associated ipsilateral fractures. Five fractures (21%) were open: four of them were grade 1 and one was grade 2 according to the Gustilo and Anderson open-fracture classification. Osteosynthesis was performed with sixteen parallel and eight orthogonal plate orientation constructs at the surgeon’s discretion.

Surgical Technique

A consistent technique, except for plate configuration and ulnar nerve management, was used in all patients. All patients were placed in the lateral decubitus position on a beanbag with an axillary roll and with the affected arm allowed to rest over a support. A slightly lateral to midline posterior incision was utilized. Full-thickness fasciocutaneous flaps were developed. The ulnar nerve was identified and was dissected to the arcade of Struthers proximally and to the first motor branch in the flexor carpi ulnaris muscle belly distally (Fig. 2). The ulnar nerve was transposed to an anterior subcutaneous position in ten patients at the surgeon’s discretion. The remaining fourteen patients had the ulnar nerve decompressed in situ, and the nerve was allowed to rest in this position at the time of closure. The medial and lateral borders of the triceps muscle were then elevated.
from their respective intermuscular septae. The distal lateral dissection was con-
tinued anterior to the anconeus muscle, allowing the muscle to be elevated along
with the triceps and preserving its neurovascular supply (Fig. 3). Three closed
fractures and all of the open fractures violated the triceps muscle. A figure-of-eight
absorbable suture was placed to approximate the muscle edges as needed. In these
cases, the triceps violation may have aided reduction and fixation. Otherwise,
medial and lateral windows were connected with blunt dissection, freeing the
triceps muscle from the posterior aspect of the humerus in an extraperiosteal
fashion, and the intra-articular fat pad was excised. This provided visualization of
the entire posterior articular surface, comprising roughly 50% of the overall ar-
ticular surface of the distal part of the humerus.

The distal part of the humerus was anatomically reduced with direct
visualization posteriorly and indirectly with fluoroscopy. The intact sigmoid
notch was used as a template for reduction. Fracture fragments were reduced
and provisionally fixed with smooth Kirschner wires, and the reduction was
verified with fluoroscopy. A sponge or 0.25-in (0.6-cm) Penrose drain was
placed into the ulnohumeral joint to allow distraction of the joint by pulling
distally on the olecranon via the sigmoid notch to aid in visualization and
facilitate the reduction through ligamentotaxis. Extreme flexion can also be
helpful to further visualize the posterior aspect of the distal part of the humerus.
The reconstructed distal articular block was then approximated to the humeral
diaphysis. Kirschner-wire fixation was converted to definitive fixation with the
application of either parallel or orthogonal plate constructs, depending on the
surgeon’s choice. One surgeon preferred parallel plating; the other preferred
orthogonal plating. Fixation stability and motion arcs were assessed prior to
closure. A Hemovac drain was placed, the wound was closed, and a bulky
dressing was applied with the elbow in full extension. The dressing was

Fig. 2
Fig. 2-A Medial dissection along the medial triceps border and intermus-
cular septum. The ulnar nerve is released from the arcade of Struthers
proximally and to the first motor branch in the flexor carpi ulnaris muscle
belly distally. The dotted line indicates the arthrotomy. Fig. 2-B Medial
dissection and arthrotomy posterior to the humeroulnar ligaments. A =
ulnar nerve, B = medial epicondyle, C = trochlea, and D = olecranon tip.
(Reproduced, with permission, from: Schildhauer TA, Nork SE, Mills WJ,
Henley MB. Extensor mechanism-sparing paratricipital posterior approach
to the distal humerus. J Orthop Trauma. 2003;17:374-8.)

Fig. 3
Fig. 3-A Lateral dissection along the lateral triceps border and intermus-
cular septum. The dotted line indicates the arthrotomy anterior to the
anconeus. Fig. 3-B Lateral view with the reflected capsule and anconeus
muscle elevated with the triceps. A = radial nerve, B = lateral epicondyle,
C = reflected anconeus muscle and capsule, D = trochlea, and E = olec-
ranon tip. (Reproduced, with permission, from: Schildhauer TA, Nork SE,
Mills WJ, Henley MB. Extensor mechanism-sparing paratricipital posterior
removed on postoperative day two, and a full active-assisted elbow motion and grip-strengthening therapy program was initiated. Radiographs were obtained at regular follow-up intervals to assess for fracture union.

Once full institutional review board approval was obtained, all eligible patients were invited to return for evaluation beyond the standard clinical follow-up. The two senior authors were not involved in the questionnaire administration, follow-up examination, or data collection. Functional results were assessed with the MEPI (Mayo Elbow Performance Index), DASH (Disabilities of the Arm, Shoulder and Hand), and SF-36 (Short Form-36) questionnaires.\(^{15-17}\) Elbow motion was assessed with a handheld goniometer. Isometric elbow-extension strength was assessed with the elbow at the side, in 90° of flexion, and with neutral forearm rotation with use of a Commander PowerTrack II muscle dynamometer (JTECH Medical, Salt Lake City, Utah) and compared with that on the contralateral side. This has been shown to be the optimal position for elbow strength assessment.\(^{18-20}\) The unaffected elbow served as a control for each patient. The mean of three trials was utilized for each side.\(^{20}\) Anteroposterior and lateral elbow radiographs were obtained at the time of examination and assessed for reduction, alignment, fracture union, posttraumatic arthrosis, and heterotopic ossification (Figs. 4-A and 4-B).

**Statistical Analysis**

The SAS/STAT software package, version 9.2 of the SAS System for Windows XP (copyright 2002-2008, SAS Institute, Cary, North Carolina), was utilized, and descriptive summaries were performed. Nonparametric analysis of variance (ANOVA) and nonparametric Wilcoxon and Kruskal-Wallis tests were used to establish whether there were any significant relationships between the plate orientation or fracture type and the range-of-motion values or loss of triceps strength. A value of \(p < 0.05\) was considered to be significant. SF-36 scores for each patient were compared with published age and sex-matched population control values.\(^{17}\)

**Source of Funding**

An intradepartmental grant was used to fund this study (radiographs only) and did not play a role in the investigation. No external funding was utilized for this study.

**Results**

All thirty-seven fractures healed primarily. The patients had completed all postoperative physical therapy at the time of the study and were determined to have achieved maximum function and elbow motion. The mean duration of follow-up was twenty-seven months (range, five to eighty-two months). The median elbow flexion was 130° (range, 90° to 146°), median supination was 90° (range, 0° to 90°), and median pronation was 90° (range, 0° to 90°). The median arc of motion was 126° (range, 60° to 141°), with a mean motion arc of 115° (range, 60° to 141°) and a median fixed flexion deformity of 9° (range, 0° to 48°). The median loss of range of motion, as compared with that of the contralateral elbow, was 11° (range, 0° to 83°). The median percent loss of triceps muscle strength was 10% (range, 0% to 49%). The plate construct orientation did not significantly affect elbow motion (\(p = 0.586\)) or elbow extension strength (\(p = 0.478\)). The effect of handedness on extension strength loss was analyzed with nonparametric Wilcoxon testing, and no significant difference was found (\(p = 0.739\)) between the dominant and nondominant elbows.

Further analysis of the elbow motion arc (\(p = 0.009\)) and percent extension strength loss (\(p = 0.049\)) with nonparametric one-way ANOVA and Kruskal-Wallis testing demonstrated significant differences across fracture types. The median motion arcs for fracture types A, C1, and C2 were 118° (range, 70° to 130°), 130° (range, 91° to 140°), and 131° (range, 95° to 141°), respectively. The median percent losses of extension strength for fracture types A, C1, and C2 were 19.7%, 7.5%, and 0%, respectively.
respectively. Only one of the six patients with a type-C2 fracture pattern exhibited loss of extension strength (a loss of 23%). The single type-B1 fracture in our series had a motion arc of 98° and a percent loss of extension strength of 13.8%. Type-C3 fractures exhibited the greatest losses, with a median motion arc of 75° and a median extension strength loss of 29.7%.

The median time interval from the injury to surgery was four days (range, zero to ten days). Median quantile regression analysis showed no significant correlation between surgical delay and motion arc (b = −2.50, p = 0.5) or MEPI (b = −0.556, p = 0.618). There was a significant positive correlation between surgical delay and percent extension strength loss (b = 2.97, p = 0.011). DASH scores also showed a significant positive correlation with increased surgical delay (b = 2.87, p = 0.034) and increased age (b = 0.308, p = 0.009), indicating worse impairment. Age showed a significant positive correlation with percent extension strength loss (b = −0.498, p = 0.006). The MEPI showed no significant correlation with age (b = −0.125, p = 0.371).

The mean MEPI was 91.5 points (range, 65 to 100 points), with fifteen excellent, seven good, and two fair grades. The mean DASH score was 15.9 points (range, 0 to 65 points), indicating mild impairment. SF-36 scores were not significantly different from known age and sex-matched population medians. There were no postoperative infections. Three elbows underwent a release because of stiffness. If an elbow had less than an approximately 70° arc of motion, the patient was offered a release. Of the three elbows that underwent a release because of stiffness, one had had a type-C1 fracture and two had had a type-C3 fracture.

Radiographic evidence of fracture union was noted in all patients. No articular step-offs of >1 mm were seen. No malalignment of >5° in any plane was noted. However, we recognize the inherent limitations of radiographs and that more accurate measurements of articular reduction would have been provided by follow-up computed tomography scans of the affected elbows. One patient had evidence of posttraumatic arthritic changes at the time of final follow-up.

Two patients in our series experienced ulnar neuropathy. One case was noted preoperatively and resolved by the time of the latest follow-up. The other patient with ulnar nerve dysfunction postoperatively had substantial comorbidities, including peripheral vascular disease and diabetes. The ulnar nerve was transposed subcutaneously to accommodate medial plate placement and to eliminate nerve tension across the elbow. The complete loss of ulnar nerve function is permanent.

**Discussion**

The optimal approach for ORIF of distal humeral fractures that provides the surgeon adequate visualization of the distal part of the humerus and the articular surface but minimizes disruption of the soft tissue and elbow extensor mechanism is still a topic of investigation. Many surgical approaches have been described, each with inherent advantages and complications. Traditionally, an olecranon osteotomy approach has been the gold standard for distal humeral exposure. However, with increased exposure comes additional potential complications, including delayed union or nonunion of the olecranon, additional ulnar nerve exposure, implant-related issues, and implant prominence requiring additional surgery.

There is limited literature regarding elbow motion, functional outcomes, and objective strength assessment following the extensor mechanism-on approach utilized in this study. We hypothesized that an extensor mechanism-on approach for distal humeral fractures with parallel or orthogonal plate constructs would allow excellent healing, an elbow motion arc exceeding 100°, and maintenance of extensor mechanism strength.

All et al. reported that 82% of their patients had normal and 18% had good postoperative triceps muscle strength in their study of elbows treated with an extensor mechanism-on approach; however, objective measurement of triceps strength loss was not reported. We utilized a dynamometer to quantify a median 10% loss of triceps strength and utilized each patient’s uninvolved upper extremity as a control for comparison. Triceps strength loss did not differ significantly between dominant and nondominant elbows. This provides a treating surgeon with a tangible number when discussing postoperative function expectations with patients. We recognize that additional studies are clearly needed to more accurately assess triceps muscle strength loss with this technique and to compare this strength loss with that associated with other triceps-sparing techniques.

In our series, the mean DASH score of 15.9 points indicates mild impairment, which is comparable with the DASH scores ranging from 12 to 20 points reported in other studies. Overall elbow function assessment revealed a mean MEPI of 91.5 points, with fifteen excellent, seven good, two fair, and no poor grades, which is consistent with the results in other published studies. There were no significant differences between the SF-36 scores and age and sex-matched controls. The median arc of elbow motion was 126°, which is a functional motion arc that is comparable with those in other published studies. Morrey et al. studied fifteen common activities of daily living and determined that a 100° arc of elbow motion was necessary to accomplish those tasks. The reported rate of heterotopic ossification following posterior approaches to the distal part of the humerus has ranged from 0% to 49%. We observed only one case of heterotopic ossification, in a patient who developed radioulnar synostosis following severe ipsilateral forearm fractures in addition to the distal humeral fracture. No prophylaxis against heterotopic ossification was utilized for patients in this study.

In our series, the patients with a type-C3 fracture had the worst elbow motion, with a median arc of 75° (range, 60° to 100°) and a median extension strength loss of 29.7%. Because of the small numbers and many variables in our study, we are unable to clarify whether this lesser motion arc was due to the fracture severity or surgical technique.

During the time period in which we performed the surgical procedures, there were three cases in which we attempted to perform an extensor mechanism-on approach but converted it to an olecranon osteotomy approach to allow better exposure of a comminuted type-C3 fracture. Although the senior authors still perform olecranon osteotomies for patients with...
more intra-articular comminution, extra-articular or simple intra-articular split fractures seem amenable to an extensor mechanism-on approach. We do not claim that this approach can be used for all distal humeral fractures. However, it can be used to achieve high healing rates and restoration of elbow function in some cases. The decision to use this approach for more complex fracture types with substantial intra-articular comminution, such as type-C3 fractures, should be made on a case-by-case basis after careful review of imaging studies and consideration of the surgeon’s familiarity with the approach. One of the advantages of this approach is the ease with which it can be converted to an olecranon osteotomy without additional soft-tissue trauma if the reduction cannot be obtained or be adequately assessed intraoperatively.

Our study had limitations. First, it had the limitations inherent in its retrospective nature. Second, our patient numbers were small overall and across fracture types. The inability to reach conclusions regarding elbow motion arc and extension strength loss according to fracture type should be considered a limitation. Third, the patients in whom the approach was converted to an olecranon osteotomy were not included in the study. If this investigation had been a prospective, comparative study, this would have been an important limitation. However, our goal was to establish a baseline for functional elbow outcomes and motion following a specific approach for which follow-up data have been very limited to date. Fourth, many of these patients had simpler fracture patterns. It is important to keep this in mind when comparing elbow motion findings with those of previous studies that involved more aggressive exposures with or without more complicated fracture patterns. Fifth, a portion of our study population (six patients) had associated fractures of the upper extremity involving the shoulder, forearm, or wrist that added confounding variables. These limitations may diminish the value of this study with regard to assessing fracture healing and functional outcomes following open reduction and internal fixation of distal humeral fractures with an extensor mechanism-on approach.

References