Acute Shortening Versus Bridging Plate for Highly Comminuted Olecranon Fractures

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Abstract

Severely comminuted olecranon fractures, for which elbow stability becomes the main goal of surgery, remain a challenge for surgeons.

We conducted a study to determine the percentage loss of articular surface at which a bridge plating (BP) construct becomes too unstable and an acute shortening (AS) construct is required. The olecranon process of 8 fresh-frozen cadaveric upper limbs was serially resected. At each resection, the simulated fracture was fixed first with BP and then with AS. Stability was tested by performing valgus and varus stress tests at various angles under fluoroscopy.

As many as 6 serial resections were made on the cadaveric models. Maximum resection was 88%. The ulnohumeral joint remained stable to valgus and varus stress at all resections for both BP and AS. The elbow joint lost a significant amount of flexion with AS above 20% resection.

The ulnohumeral joint can tolerate substantial loss of articular surface in the olecranon before becoming unstable. In this study, range of motion was preserved more with the BP construct than with the AS construct. The presented data may be considered when approaching a severely comminuted olecranon fracture in which the articular surface cannot be reconstructed.

Olecranon fractures constitute about 10% of all forearm fractures.[1] Many are low-energy fractures in osteoporotic bone in the elderly.[1,2] Unstable fractures require operative fixation in which the goal is restoration of articular congruity and stability.[3] Various fixation methods are used to treat unstable olecranon fractures, and outcomes are good overall.[3-21] However, severely comminuted olecranon fractures, especially in osteoporotic bone, pose a unique challenge, where reconstruction may not be feasible.[9] Although the articular surface can be reconstructed in most cases, reconstruction is not feasible with severe comminution or low bone mineral density. When articular congruity is no longer possible, the primary goal of fixation becomes elbow stability. Postoperative stability is linked to favorable outcomes, as it allows patients to engage in early range-of-motion (ROM) exercises, which improves joint function.[5,21,22]

When treating these severely comminuted olecranon fractures, surgeons have 2 options: bridge plating (BP) and acute shortening (AS). In BP, a plate is used to restore the length of the olecranon. The plate is spanned over the comminuted segment with fixation at proximal and distal pieces but without open reduction of the comminuted pieces.[8] This process may be performed with or without bone grafting.[21] Although any bony defect between the proximal and distal pieces may be filled, there is now a gap in articular congruity

Take-Home Points

- The ulnohumeral joint can tolerate substantial articular surface loss without compromising stability.
- Consider BP as an alternative to AS in unreconstructable olecranon fractures.
- Both BP and AS of olecranon fractures maintain elbow stability.
- BP has the advantage of maintaining elbow range of motion.

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within the sigmoid notch. One concern with this fixation method is that joint stability is lost when this gap becomes too large. Surgeons therefore may decide to forgo BP and perform AS instead, as long as the coronoid is intact.[21] In AS, often referred to as *olecranon excision,* comminuted fragments are removed and the triceps muscle advanced distally. AS constructs, often reserved for older, less active patients, yield acceptable results in this population.[5] However, the long-term effects of AS in young, active patients are unclear, and biomechanical studies suggest reduced triceps muscle strength.[23]

Surgeons have had no studies guiding them in deciding which construct to use, BP or AS, in severely comminuted olecranon fractures in which the articular surface cannot be reconstructed.

We conducted a biomechanical study to determine the percentage loss of articular surface at which a BP construct becomes significantly clinically unstable. We also compared BP stability and AS stability for each percentage loss of articular surface and compared initial elbow ROM with the 2 methods. We hypothesized that, at a certain percentage loss of articular congruity, the BP construct would become too unstable and would require conversion to the AS construct.

Materials and Methods

Specimen Preparation

Eight fresh-frozen paired cadaveric upper limbs (2 male, 2 female; mean age, 61.8 years; age range, 56-74 years) were obtained from donors with no history of elbow trauma or prior surgery. Specimens were stored at –20°C, thawed to room temperature before testing, and, using clinical and radiographic evaluation, screened for abnormalities.

Each specimen was positioned with the arm draped in the lateral decubitus position, as in typical olecranon fracture surgery. A standard posterior approach to the olecranon was made with a midline posterior longitudinal skin incision. Subcutaneous flaps were developed, and the subcutaneous border of the proximal olecranon was exposed, preserving the medial and lateral collateral ligaments as well as the extensor mechanism. Baseline maximum flexion and extension of the elbow as well as olecranon length were measured with fluoroscopy (BV Pulsera, Philips) and ImageJ software (National Institutes of Health).

To ensure reproducible anatomical reduction during plating, a 3.5-mm 4-hole nonlocking periarticular anatomically contoured plate (Zimmer
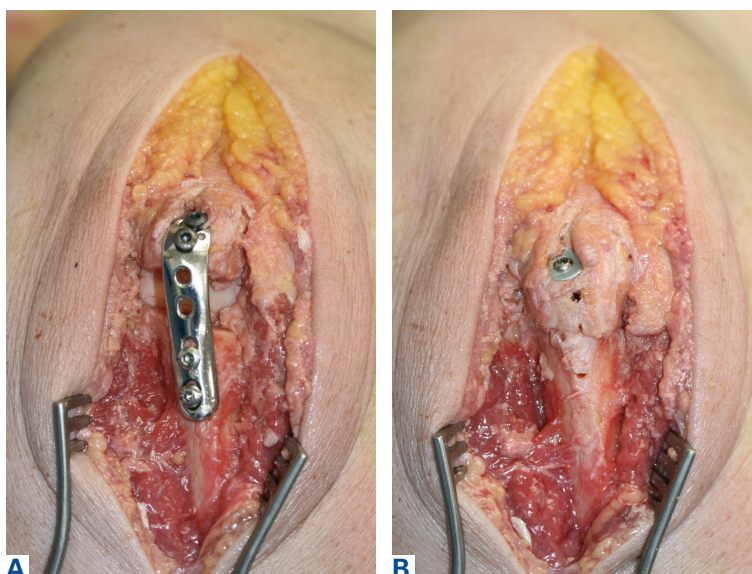

Figure 1. (A) Partially resected olecranon is repaired with a predrilled 3.5-mm plate. (B) Acute shortening is achieved by advancing the proximal fragment and securing with a 3.5-mm screw.

Biomet) was applied posteriorly to the intact olecranon through a longitudinal slit in the distal triceps tendon. The plate was predrilled to house 4 nonlocking screws, 2 proximal and 2 distal.

Fracture Generation and Testing of Fixation Constructs

Comminuted olecranon fractures were simulated by resecting a portion of the bone using an oscillating saw with a blade 2 mm thick. Resections were made perpendicular to the dorsal apex of the sigmoid notch under fluoroscopy guidance and were performed off the proximal and distal fragments interchangeably. At each resection, the specimen was repaired with the predrilled 3.5-mm BP and later with an AS construct (**Figures 1A, 1B**). For AS, the proximal fragment was advanced to the distal fragment and secured with a 3.5-mm screw, with the near cortex overdrilled to create a lagging effect. The resected surfaces of the olecranon were beveled without changing intra-articular length, and the proximal fragment was positioned to create a congruous surface for articulation with the trochlea. Both fixation methods, BP and AS, were used for each specimen at each resection. Serial resections were continued until the proximal fragment was too small for adequate fixation with 2 screws.

After each fixation, radiographs were taken for measurement of maximum flexion and extension and amount of olecranon removed (**Figures 2A, 2B**). Gross stability to valgus and varus stress was
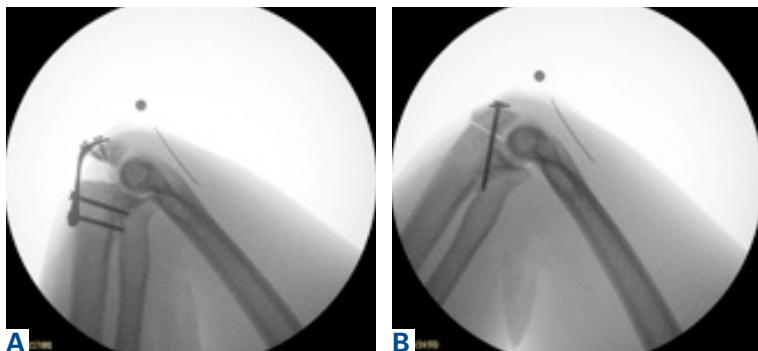
Figure 2. (A) Radiograph of the bridge plating construct at full flexion shows gap within sigmoid notch. (B) Radiograph of the acute shortening construct in full flexion shows the proximal piece advanced to the distal piece.
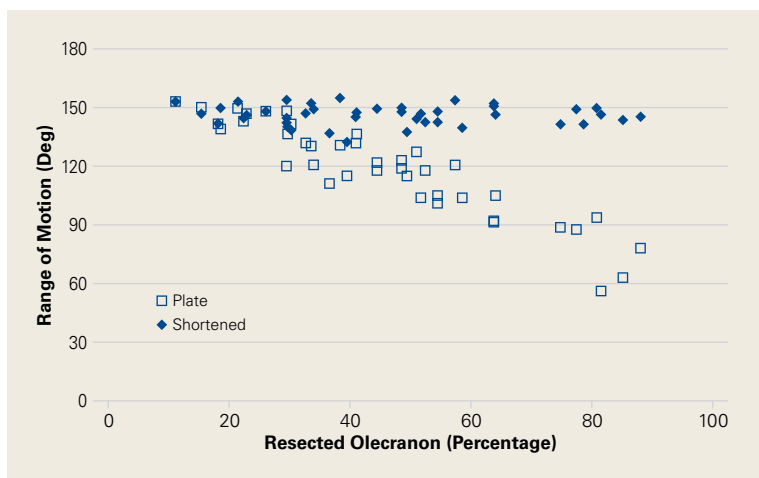

Figure 3. Percentage resection calculated from measurements A and B on radiographs.

Figure 4. Range of motion remained unchanged throughout resections for the bridge plating construct (dark squares), but decreased at larger resections with the acute shortening construct (white squares).

examined under fluoroscopy after fixation, as it would be performed during surgery using manual valgus and varus load in full extension, 30° of flex-

ion, and full extension in both supination and pronation. Any ulnohumeral joint line opening relative to baseline was considered a sign of instability.[24]

On each radiograph, a marker was used to account for magnification artifacts. ROM was measured using the angle subtended by the longitudinal axis of the humeral shaft referenced by the anterior border of the humerus, and the longitudinal axis of the ulnar shaft referenced by the dorsal border of the ulna. The simulated fracture gap was measured at the articular surface. The articular surface length, measured before the resections, was used to calculate the percentage of the resected olecranon at each serial resection (**Figure 3**).

Analysis

ImageJ software was used to analyze the C-arm radiographs. Measurements were divided into 4 groups of joint surface loss caused by the resections: 0% to 20%, 20% to 40%, 40% to 60%, and >60%. Differences in ROM between the BP and AS constructs were analyzed with a Wilcoxon signed rank test with statistical significance set at $P < .05$ (Prism 6; GraphPad Software).

Results

As many as 6 serial resections were made before the proximal fragment of the olecranon was judged too small to be secured to a plate with at least 2 screws. Only 7 specimens were large enough for the fifth cut, and only 4 were large enough for the sixth cut. After the final resection, mean loss of olecranon length was 77.3% (range, 63.7%-88%; median, 80.6%). All elbow specimens remained stable to manual valgus and varus testing in full extension, 30° of flexion, and full flexion in both supination and pronation. There was no medial or lateral opening of the ulnohumeral joint on fluoroscopy throughout testing, for either the BP or the

Table. **Summary of Measurements**[a]

% Resected	Measurements, n	Mean Flexion, degrees		
		BP	**AS**	***P***[b]
0	8	145.6	145.6	NA
0-20	4	148.1	146.0	.75
20-40	15	145.7	134.1	.0012
40-60	14	146.1	117.6	.0001
>60	9	147.2	84.1	.0039

[a]All specimens remained stable throughout resections and had 0° extension.
[b]Wilcoxon signed rank test.
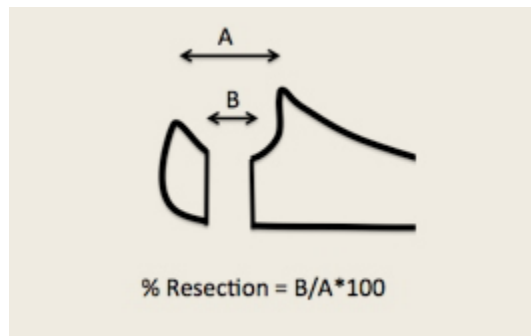Abbreviations: AS, acute shortening; BP, bridge plating; NA, not available.

AS constructs. There was no anterior or posterior subluxation throughout the entire ROM.

Mean extension was 0° initially and did not change over resections in both BP and AS constructs. Mean initial flexion for intact specimens was 145.6° (range, 146°-148°). In the BP constructs, flexion remained relatively unchanged (mean, 146°; range, 135°-155°) throughout testing. With increased resection of the olecranon, there was a significant decrease in flexion in the AS constructs. In AS, flexion decreased to a mean of 134° for 20% to 40% resection of the sigmoid notch, to 118° for 40% to 60% resection, and to 84° for >60% resection (**Table**). About 1° of flexion was lost for each 1% resection above 20% resection of intact length (**Figure 4**).

Discussion

Our goal in this study was to determine the maximum articular surface loss that can be tolerated before a BP construct becomes unstable. This finding applies to situations in which the degree of comminution makes reconstruction of the articular surface impossible. Contrary to our hypothesis, the ulnohumeral joint remained stable despite extensive loss of congruity within the sigmoid notch. In 1 specimen, the joint remained stable at 88% loss of olecranon. However, the 2 constructs had different ROM results: ROM was significantly lower at more resections with AS but remained unchanged from baseline with BP.

Dorsal plating has become standard treatment for comminuted olecranon fractures, and many studies, both clinical and biomechanical, have reported favorable results, good functional outcomes, and acceptable ROM.[3,7,10,13,18-20,25] However, the multiple studies on the use of various plates in comminuted olecranon fractures did not address whether articular congruity was maintained during reductions or how much articular surface was reconstructed. Although we may reasonably assume larger studies included cases with some unmeasured loss of articular congruity, it is difficult to directly compare our findings with those of other studies. In addition, it is possible those studies did not include fractures that were deemed unfit for BP (because of very severe comminution) and underwent AS instead. Only 1 case series has focused on BP without complete articular reconstruction.[8] The cases in that series had good outcomes with good stability—consistent with our finding of extreme comminution in a worst-case scenario.

Complete elbow stability after AS is consistent with findings in the literature.[4,6,12,14,16] As AS is reserved for severely comminuted fractures and bone resections,[21,23,26] our findings can be compared with the earlier findings. In AS, either the proximal pieces or the intermediate pieces are removed to create a smaller but congruent articular surface, with less concern for nonunion.[21] When the proximal piece is removed, the triceps muscle is advanced to the ulnar shaft, creating a slinglike structure for the trochlea.[4,11,16,23] When the intermediate piece is removed, the proximal piece is advanced to the shaft along with the triceps.[12,14,27] In either technique, the triceps muscle is advanced distally, potentially affecting its extensibility and moment arm.[23]

Although small in numbers, case series and retrospective reviews have found that AS has good outcomes,[4,14,16] whereas our study found significantly decreased ROM. A few patients in these studies lost ROM or triceps strength,[12,14,16] but the cause, AS or fracture severity, is unclear. It is possible only 0% to 20% of the olecranon was resected in those cases, whereas our study found no significant change in ROM. It is also possible that cadaveric muscles do not stretch as well as muscles in vivo. Biomechanical studies have demonstrated changes in triceps stretch and strength,[23,26] but perhaps these changes are subclinical or overcome with therapy and time.[12,14] There are no data regarding whether patients who undergo AS (vs another fixation method) need more physical therapy. In extreme resection, some reduction in ROM is expected.[13]

The ulnohumeral joint is a primary static stabilizer of the elbow joint.[28-30] Recent studies on the role of the ulnohumeral joint in elbow stability have focused mainly on the coronoid process in the setting of dislocation.[28,29,31,32] According to these studies, 50% of the coronoid must remain intact for the elbow to be stable when all other stabilizers are intact.[32] In our study, resections preserved the coronoid and the ligamentous stabilizers of the elbow. It is therefore possible that the elbow joint remained stable despite the considerable articular surface loss. Although the term *ulnohumeral joint* refers to both the coronoid and the remaining articular surface, our findings support the coronoid as a primary stabilizer and the remaining articular surface as a secondary static stabilizer.

This study had several limitations. First, its fractures were simulated by serial resection of only the middle portion of the olecranon. In reality, comminution could extend farther proximally or

distally and involve the surrounding tissues, which help stabilize the elbow. However, our focus was on loss of articular surface and stability, so keeping surrounding structures intact avoided confounding factors that could contribute to stability. A second possible limitation is that the implant used here may be different from the implant used in a clinical setting. However, our focus was not on fixation quality, and stability alone should not be affected by plate type. Third, stability was measured not quantitatively but instead subjectively under manual stress and fluoroscopy. We chose this method because it mimics what happens during surgery and is the clinical standard for stability assessment.[24] Fourth, soft-tissue properties of the cadaver models used in this biomechanical study may differ from soft-tissue properties in vivo. This study could not evaluate possible long-term complications, such as posttraumatic arthritis and heterotopic ossification.[5,10] There are no long-term studies comparing BP and other olecranon fixation methods in terms of postoperative elbow arthritis.

Conclusion

The ulnohumeral joint can tolerate substantial articular surface loss without compromising stability. As a result, in the management of highly comminuted olecranon fractures, BP may be considered before AS is performed. Quality and amount of intact proximal bone, rather than degree of comminution, may be more important factors in deciding which fixation method to use.

This biomechanical study is the first to focus on olecranon fracture BP without complete reconstruction of the articular surface. When treating a highly comminuted olecranon fracture that has an unreconstructible articular surface, surgeons may consider BP with or without bone graft, as well as AS. Our study findings suggest that, though both constructs maintain elbow stability, BP may have the advantage of maintaining ROM too. BP can avoid effects on triceps and elbow ROM, which may be more important in younger, more active patients. Clinical correlates are needed to validate these findings, as overall outcomes may be affected by concurrent fractures and injuries to surrounding structures.

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