Additional Screw Use in Olecranon Fracture Reconstruction Changes Failure Mode During Fatigue Testing

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Introduction

Olecranon fractures account for 10% of all upper-extremity fractures in adults[1] and are often caused in the elderly population by a fall from standing height. Plate fixation (Fig 1A) has become an accepted method for stabilization of olecranon fractures[2], but the presence of osteoporotic bone can lead to construct failure when the forearm is subjected to external loads.[3] However, it has also been shown that effective post-operative rehabilitation protocols require the patient to perform early range of motion exercises to limit stiffness and facilitate the ultimate performance of activities of daily living.[4] These protocols routinely increase the ranges of motion and the external loads applied to the affected joint over a prescribed course of time, which may ultimately lead to premature implant failure. Anecdotal clinical experience has led us to believe that a novel technique in which an additional non-locking screw, targeted from distal to proximal through the plate and aimed towards the tip of the olecranon (Fig 1B), may improve implant performance. It is currently unknown if the use of an additional screw improves the load bearing capacity of the implant. Therefore, the goal of this study was to assess the biomechanical efficacy of this technique by applying an accelerated fatigue test consisting of elbow flexion/extension motion under increasing loads. We hypothesized that the additional screw would improve the stability and fatigue life of the construct in comparison to a control group that did not use the extra screw.

Methods

Nine matched pairs of fresh-frozen, cadaveric upper extremity specimens were used for this study (3M, 6F, average age: 81.2). Specimens underwent trans-humeral and trans-forearm amputations at the midpoints of the bones, making sure to keep the radioulnar interosseous ligament, elbow capsule, and triceps intact. The implants (DePuy Synthes 3.5 mm VA-LCP Olecranon Plates, West Chester, PA) were first properly positioned on intact bones and held into place with Kirschner wires. An oscillating saw was then used to create a 3 mm transverse osteotomy at the center of the sigmoid notch of each specimen. Nine randomly selected arms were reconstructed using the standard surgical technique (CTRL), while the contralateral limbs were reconstructed with the previously described extra screw technique (EXPT). An accelerated fatigue protocol consisting of loaded elbow extensions was simulated by applying controlled displacements to the triceps tendon, similar to previously published protocols.[5] Retroreflective marker clusters were placed on the proximal and distal ulnar bone fragments so that relative motion between fragments was tracked in 3-D space (Optitrack Motive). Prepared specimens were secured to a test frame (TA ElectroForce 3550) and triceps tendons were gripped with a custom-built clamp. A flexible steel cable was routed through a set of pulleys to connect the tendon clamp, actuator, and grounded load cell of the test frame. To create the extension/flexion motion of the elbow, the actuator displaced the triceps tendon 20 mm in a sinusoidal pattern at 0.2 Hz. This tendon excursion corresponded to a range of motion between 90° and approximately 55° of flexion (Fig 2). Arms were initially cycled 30 times at 0.2 Hz with an empty fixture attached to the distal forearm. Additional masses were hung in 0.5 kg increments every 30 cycles until failure occurred. Failure was defined by (1) permanent relative displacement of ulnar bone fragments exceeding 3 mm, or (2) catastrophic failure of the bone or implant. The total number of cycles, maximum torque, and total work performed against gravity were calculated for each specimen. Paired one-tail t-tests were performed for measures of total cycles and total work. The level of significance was set at $p<0.05$.

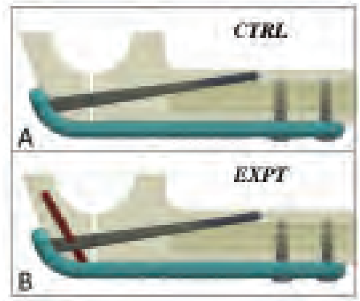

Figure 1. Computer aided drawing representations of the **(A)** control group and **(B)** experimental group.

Results

Modes of failure were different between the CTRL and EXPT groups. Permanent displacement

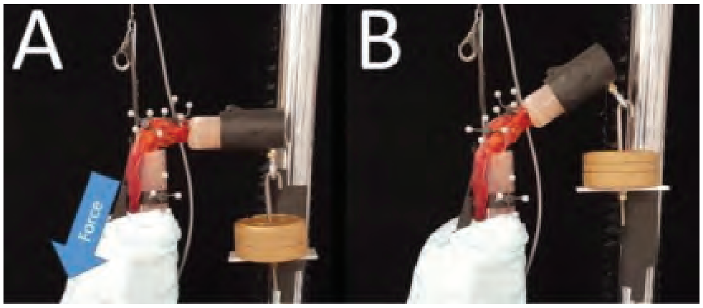

Figure 2. Photographs depicting the testing protocol. **(A)** Displacement of a cable attached to the triceps tendon results in a downward force. **(B)** The displacement of the tendon results in approximately 35° of loaded elbow extension.

exceeding 3 mm (i.e. loosening (Fig 3A)) occurred in seven out of nine cases for the CTRL group. Instantaneous catastrophic failure (Figure 3B) prior to 3 mm of fragment displacement occurred once, and there was one instance where the specimen completed the loading protocol and did not fail. Out of the nine specimens tested in the EXPT group, seven specimens failed via catastrophic failure, where the bone sheared through the screws. Two specimens failed due to fragment displacement exceeding 3 mm.

There were no significant differences in terms of number of survived cycles, maximum torque sustained, or work performed. The CTRL group sustained an average of 200 (±167) cycles before failure, while the EXPT group sustained an average of 192 (±131) cycles ($p = 0.33$). The CTRL group sustained an average maximum torque of 8.60 (±6.55) Nm before failure, while the EXPT group sustained an average maximum torque of 8.56 (±5.24) Nm ($p = 0.825$). Finally, the CTRL group experienced an average of 1123.4 (±1746.6) J of work against gravity before failure, while the EXPT group sustained an average of 1063.6 (±1246.4) J before failure ($p = 1.00$).

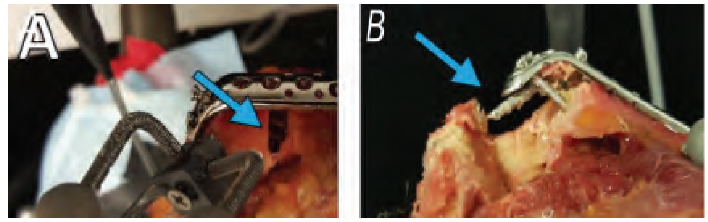

Figure 3. Photographic representations of the two failure modes that occurred during testing. **(A)** Fragment migration that exceeds 3mm in width (77% rate for CTRL group). **(B)** Catastrophic failure where the proximal bone fragment fractures and construct stability is lost (77% rate for EXPT group).

Discussion

Addition of a supplemental oblique retrograde non-locking screw does not provide improved fatigue life to a non-locking plate olecranon implant; however, the failure mechanisms suggest that the use of the additional screw enhances the stability of the repair construct, as it effectively reduced relative motions of the ulnar segments during loading. Reduction of the cross sectional area of the additional screw may reduce stress riser intensity and provide improved fatigue life.

Significance

There may be value in an additional screw in the proximal segment; however, biomechanical studies that analyze the effect of reducing the cross sectional area of the retrograde screw are required.

References

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5. Edwards+ *JOT* 2011.