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A biomechanical comparison of multidirectional nail and locking plate fixation in unstable olecranon fractures

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Background: The main theoretic advantage of proximal olecranon fracture intramedullary fixation is decreased soft-tissue irritation and, potentially, less subsequent hardware removal. Despite this possible benefit, questions remain as to whether intramedullary devices are capable of controlling olecranon fractures to the same extent as locking plates. This study evaluates the ability of a novel multidirectional locking nail to stabilize comminuted fractures and directly compares its biomechanical performance with that of locking olecranon plates.

Materials and methods: We implanted 8 stainless steel locking plates and stainless steel intramedullary nails to stabilize a simulated comminuted fracture in 16 fresh-frozen cadaveric elbows. Flexion-extension, varus-valgus, gap distance, and rotational 3-dimensional angular displacement analysis was conducted over a 60° motion arc (30° to 90°) to assess fragment motion through physiologic cyclic arcs of motion and failure loading. Displacements in all planes were compared.

Results: Both implants showed less than 1° of motion in all measured planes and allowed less than 1 mm of gapping through all loads tested until ultimate failure. All failures occurred by sudden, catastrophic means. The mean failure weight for the nail was 14.4 kg compared with 8.7 kg for the plate ($P = .02$). The nail survived 1102 cycles, whereas the plate survived 831 cycles ($P = .06$).

Conclusion: In simulated comminuted olecranon fractures, the multidirectional locking intramedullary nails sustained significantly higher maximum loads than the locking plates. The two implants showed no significant differences in fragment control or number of cycles survived. Surgeons can expect the multidirectional locking nails to stabilize comminuted fractures at least as well as locking plates.

Level of evidence: Basic Science Study, Biomechanical Study.

Keywords: Olecranon; fracture; unstable; intramedullary; nail; comparison; plate; prominence; OlecraNail

Traditional operative techniques for simple fracture patterns include tension-band constructs, whereas more complex olecranon fractures require plate fixation. Although no direct comparisons have been published, studies evaluating tension-band fixation have shown higher rates of hardware removal in comparison to nonlocking and

No institutional review board or ethical committee approval was needed for this study because it was a cadaveric investigation.

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locking plate fixation.[2-4,16] Kirschner wire prominence is a common postoperative problem, with reports showing a rate of hardware removal as high as 100%.[18] Furthermore, the tenuous fixation of tension-band constructs may require prolonged immobilization, resulting in potential elbow stiffness.[10]

More unstable fractures that are comminuted or extend distal from the center of the trochlear notch require more rigid fixation, usually in the form of plating. Although plate fixation has led to excellent outcomes,[3,16] hardware irritation has been a well-documented complication that often requires a secondary procedure for removal, with rates ranging between 20% and 100%.[3,16,24] Locking plates offer the advantages of superior fixation, particularly in osteoporotic bone,[26] but removal rates have been reported to be nearly 50%.[2,3]

Promising anecdotal clinical results using intramedullary olecranon fracture fixation may reflect several advantages inherent with this construct. The intramedullary nail location offers more efficient load transfer than conventional plating systems. The inherent shorter lever arm has an expected decreased tensile implant strain. With less insult to surrounding tissues, periosteal vascularity is maintained, theoretically leading to more predictable fracture union, decreased rates of infection, and faster rates of healing. In the periarticular setting, the intramedullary location shields the implant from the triceps tendon and superficial skin during normal motion and reduces adhesions that may hamper postoperative rehabilitation.

The OlecraNail (Mylad Orthopedic Solutions, McLean, VA, USA) is a multidirectional locking nail that is indicated to stabilize unstable, comminuted fractures of the proximal ulna. This study aims to evaluate the ability of this multidirectional locking nail to stabilize comminuted fractures and to biomechanically compare fracture displacement and ultimate load with those of a locking olecranon plate (Synthes, West Chester, PA, USA).

Materials and methods

Specimen preparation

In total, 16 nonpaired, fresh-frozen cadaveric arms (7 male and 9 female cadavers) underwent transhumeral amputation and transforearm amputation 20 cm distal from the center of the semilunar notch. This allowed preservation of the central band of the radioulnar interosseous ligament. All soft tissues were removed except the elbow capsule, triceps, and radioulnar interosseous ligament. The mean age of the specimens was 65 years (range, 53 to 81 years).

All specimens were evaluated on a Hologic QDR 4500 W series dual-energy x-ray absorptiometry (DXA) system (Hologic, Waltham, MA, USA) to determine bone density, by use of the built-in National Health and Nutrition Examination Survey (NHANES)/Bone Mineral Density in Children Study (BMDCS) database (Hologic). Because the region of interest in our investigation, the proximal ulna, had no established database, the distal radius of the same specimen was scanned to generate a basis for evaluation and comparison to the standard databases available for more commonly studied anatomic regions. In addition to bone density readings, for each scan, a T-score was recorded. Traditionally, T-score results greater than −1.0 are considered normal density. T-scores between −2.5 and −1.0 indicate a diagnosis of osteopenia, and T-scores of less than −2.5 indicate a diagnosis of osteoporosis. All DXA results were determined to be appropriate based on age-, race-, and sex-matched controls. The 16 specimens were divided into 2 groups to achieve a similar mean bone density in both groups.

DXA scan results for each specimen are based on the *Physician's Guide to Prevention and Treatment of Osteoporosis*[20] and summarized in Table I. Overall, the DXA bone mineral density (BMD) for all specimens ranged from 0.465 to 0.927 g/cm^2, with a mean of 0.714 g/cm^2. The mean DXA BMD for the nailed specimens was 0.714 ± 0.029 g/cm^2 (range, 0.511 to 0.912 g/cm^2). The mean DXA T-score for the nailed specimens was −2.42 (range, −4.4 to −0.1). The mean DXA T-score for the plated specimens was −2.35 (range, −3.8 to −0.2). There were 3 specimens with normal bone density, 2 with osteopenia, and 3 with osteoporosis. The mean DXA BMD for the plated specimens was 0.718 ± 0.29 g/cm^2 (range, 0.536 to 0.864 g/cm^2). There were 4 specimens with normal bone density, 2 with osteopenia, and 2 with osteoporosis.

The triceps tendon was sutured (No. 2 FiberWire; Arthrex, Naples, FL, USA) to nylon strap that was attached to the cable of the Mini-Bionix II 858 materials testing system (MTS Systems, Eden Prairie, MN, USA). Specimens were initially stored at −20°C and were thawed for dissection. Specimens were refrozen to −20°C until the time of implantation and testing. After implantation, specimens were not refrozen at any time before testing.

Implantation and osteotomy

Each specimen group was randomly assigned to either nail fixation (OlecraNail; Mylad Orthopedic Solutions) or plate fixation (Synthes). Each device (Fig. 1) was implanted by use of the standard surgical technique recommended by each manufacturer. The nail was introduced through a 1-cm longitudinal stab incision through the triceps tendon. Unlike other intramedullary implants currently used, the OlecraNail has screws that thread into the nail and radiate in multiple directions, forming a fixed-angle lattice within the proximal ulnar fragment. This allows the nail to secure the proximal fragment regardless of the extent of the fracture pattern's instability. Of note, the optional proximal hole of the Synthes stainless steel plate was included in the fixation construct for the purposes of this study because this maximizes the fixation potential of the Synthes design. Figure 2 shows the screw arrangements within each specimen.

To simulate a comminuted fracture, a traverse osteotomy was made at the center of the sigmoid notch of each specimen. A second osteotomy was made 5 mm distal to the first osteotomy. The bone between the osteotomies was removed so that there was no bony contact between the proximal and distal portions of the ulna (Fig. 3).

Both plates and nails were first secured to the intact ulna before osteotomy. The implants were removed to allow for osteotomy and replaced through the same screw holes after osteotomy. This ensured anatomic reduction of the ulna despite loss of bony references. This standard technique has been documented in previous biomechanical studies.[8,14] Every effort was made to