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Patterns of Failure in the Distal Radius Following Treatment for Extra-Articular Fractures (AO 23-A3.2) Using Two-Column Volar Plates

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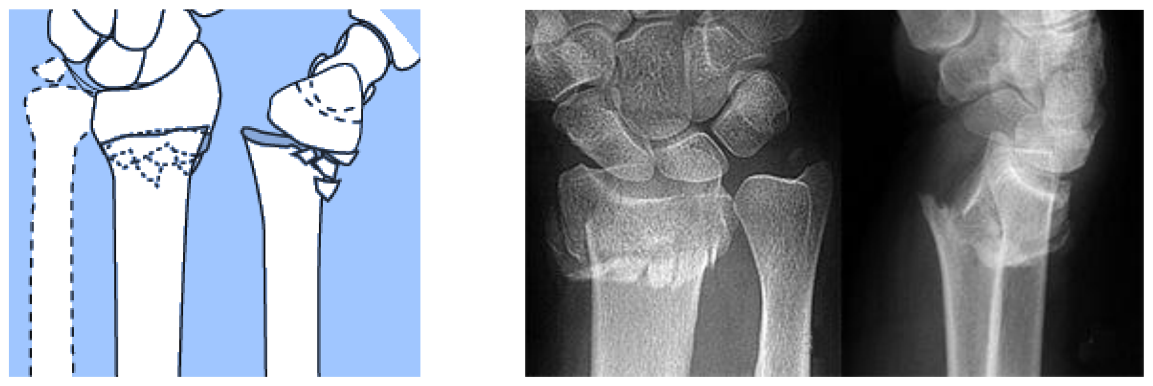
INTRODUCTION

- **The distal radius is the most common fracture site in the upper extremity.**
- **Dorsally displaced, unstable fractures are commonly treated with locked plate fixation using a volar approach.**
- **Damage analysis of matched paired specimens with simulated AO 23-A3.2 fracture treated with volar plating may provide information on whether implant geometry may affect fracture stability. (Fig. 1)**



A B

Figure 1: A. Extra-articular multi-fragmentary fracture of the distal radius with angulated dorsal wedge fragment (AO 23-A3.2). B. Radiographic depictions of AO 23-A3.2 fracture.

PURPOSE

- **The purpose of our study was to characterize the damage accumulated in a model of extra-articular distal radius fracture with dorsal comminution treated using two-column volar distal radius plates during a simulated post-operative healing period. Patterns of failure of the bone and implant are reported from cyclic testing and ramped load to failure experiments.**

METHODS

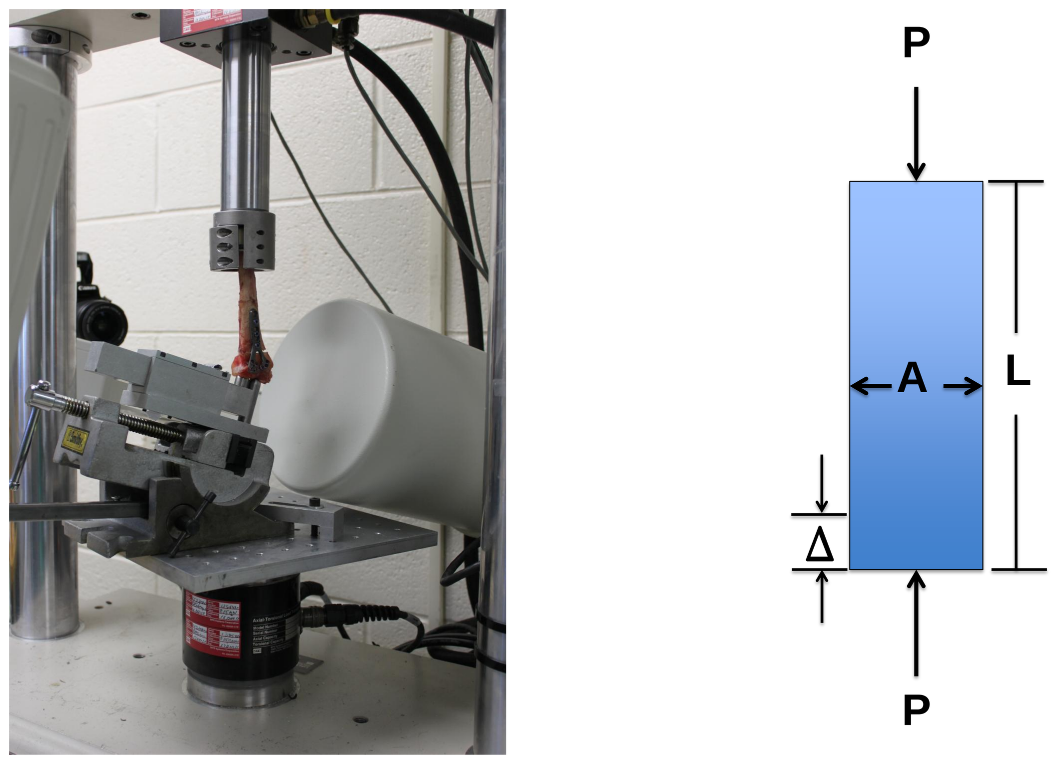
- **Ten matched pairs of fresh-frozen, cadaveric distal radii were used in this study:**
  - **One radius from each donor was randomized to Group I; the contralateral limb from the same donor assigned to Group II**
  - **Group I: Prepared with Geminus® volar distal radius plating system by Skeletal Dynamics. (n=10) This implant uses a dual head design for independent two-tier scaffolding. (Fig. 2A)**
  - **Group II: Prepared with Acu-Loc® 2 Proximal Volar Distal Radius Plate by Acumed. (n=10) This implant uses a single head design for enhanced ulnar butressing. (Fig. 2B)**
- **A custom fixture was designed to apply a 60/40 ratio through scaphoid and lunate facets. (Fig. 3A)**
- **Specimens were subject to cyclic axial loading; sinusoidally compressed from 75-250N at a rate of 1 Hz for 5,000 cycles**

METHODS

A B

Figure 2: A. Group I radius plated with Geminus® volar distal radius plate from Skeletal Dynamics. B. Group II radius plated with Acu-Loc® 2 proximal volar distal radius plate from Acumed.

- **Damage (D), which defines the period between a state of material perfection and the onset of crack initiation, was calculated using the effective Modulus of Elasticity ($E = \frac{PL}{A\Delta}$) from hysteresis data (Fig. 3B)**
- $D = 1 - \left[\frac{E\_final}{E\_initial}\right]$**, where $E\_initial$ is calculated at cycle 5; E_final is calculated at every 500th cycle**
- **Constructs not failed during cyclic loading were subject to a ramped load to failure at 1mm/s**
- **A matched-paired t-test was used to determine statistical significance (p=0.05)**



A B

Figure 3: A. Experimental testing fixture. B. Figure depicting axial loading for calculation of effective Modulus of Elasticity.

RESULTS

- **Group II specimens experienced significantly more damage under cyclic loading than Group I specimens. (0.78+/-0.11 and 0.66+/-0.10, respectively; p=0.02) (Fig. 4A, Fig. 4B)**
- **One specimen in Group II experienced coronal fracture of the dorsal pole of the lunate during cyclic loading and was excluded from load to failure tests.**
- **Group I specimens were significantly stiffer than group II specimens. (481.47+/-161.37 N/mm and 337.90+/-112.04 N/mm, respectively; p=0.04) (Fig. 4C)**
- **Ultimate force at failure in Group I (1268.50+/-307.69 N) and Group II (1025.63+/-496.45 N) specimens was not significantly different (p=0.11) (Fig. 4D)**

RESULTS

- **Specimens failed by distal fragment collapse leading to plate bending (Group I n=5/10; Group II n=2/9) and fracture of the lunate facet (Group I n=5/10; Group II n=7/9)**

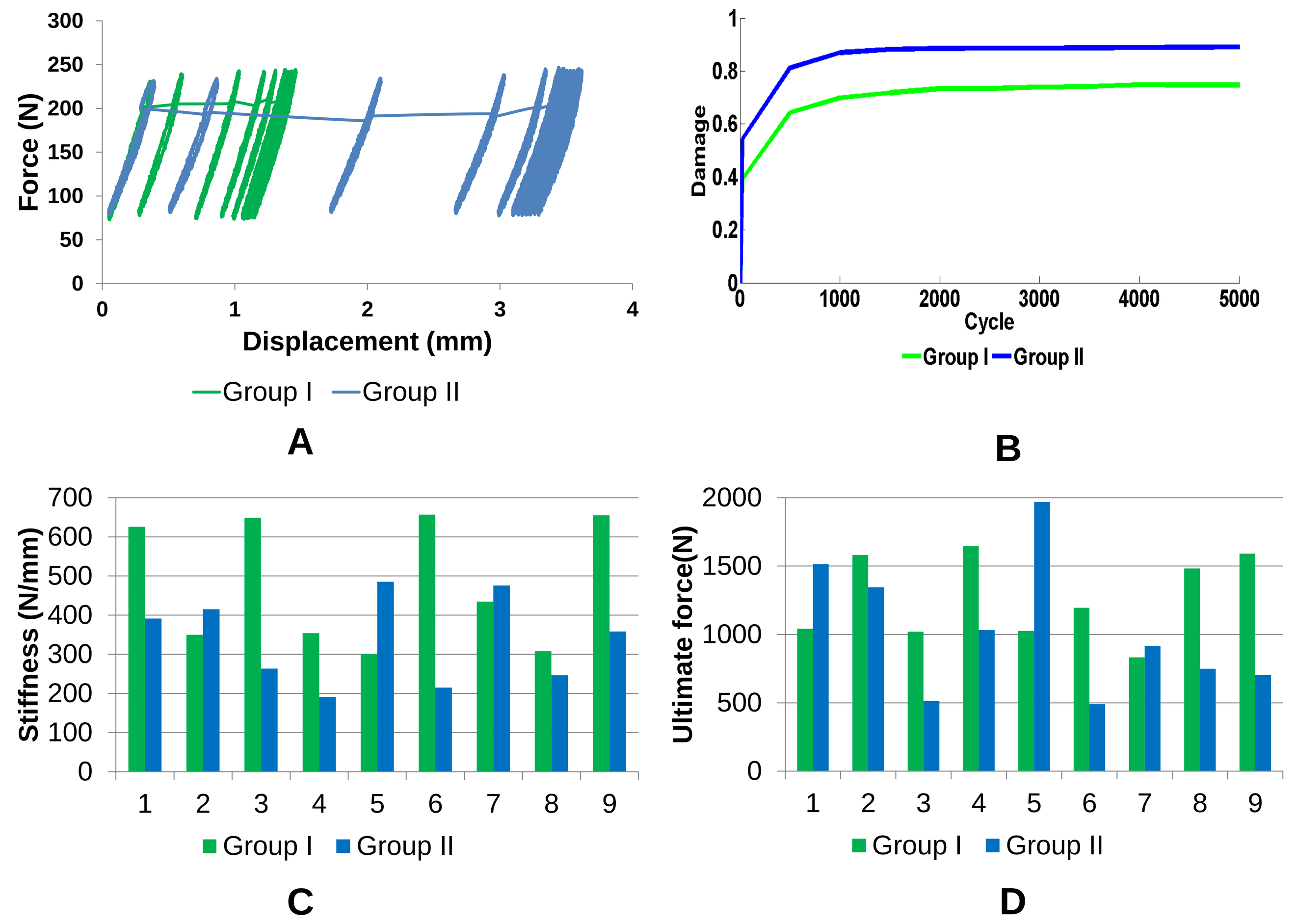


Figure 4: A. Representative force-displacement hysteresis curves of a single specimen from Group I and contralateral limb in Group II. B. Representative damage plots. C. Stiffness results from load-to-failure testing. D. Ultimate failure force results from load-to-failure testing.

CONCLUSIONS

- **Structural damage, though greater in Group II specimens during low cycle loading, did not significantly affect the ultimate failure force of the bone/implant constructs**
- **In order to determine the cause of the low-cycle structural damage to Group I and Group II specimens, a patient-specific computational analysis is underway, developed using pre-study calibrated quantitative computed tomography scans of the bones and solid models of the implants**

CLINICAL RELEVANCE

- **If a patient is subject to high impact loading of the distal radius (fall on outstretched hand) prior to the end of their post-operative healing period, both implants may provide equivalent resistance to fracture**
- **Should the post-operative healing period be delayed, it is likely that increasing damage may lead to fracture with Group II implants; high frequency fatigue testing is necessary to confirm**

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