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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Disclosures:

Introduction: The purpose of our study was to characterize the damage accumulated in bone/implant constructs 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 scanned using dual energy X-ray absorptiometry. Specimens were sectioned 140mm proximal to the distal articular surface and soft-tissue was removed. The wrist was disarticulated at the radiocarpal joint leaving the scaphoid and lunate facets in place. A 1cm wedge osteotomy simulating an AO type 23-A3.2 fracture was created 1.5cm proximal to the distal articular surface. One limb of each pair was randomly divided in two groups. The contralateral limb was placed in the alternate group. Group I specimens were treated with the Geminus Volar Distal Radius Plating System by Skeletal Dynamics. This implant provides a dual head design for independent two-tier subchondral scaffolding. Group II specimens were treated with the Acu-Loc 2 Volar Distal Radius Plating System by Acumed. This implant provides a single head design for enhanced ulnar buttressing. Threaded locking screws were sized according to specimen-specific dimensions.

Mechanical testing was performed under cyclic axial loading conditions using a servohydraulic test machine. The proximal radial shaft was fixed to the machine actuator. Load was applied through a custom fixture to ensure a ratio of 60/40 through the scaphoid and lunate facets. Specimens were sinusoidally compressed with 50-250N, at a rate of 1Hz for 5,000 cycles to simulate a 6 month healing period. Damage, which defines the period between a state of material perfection and the onset of crack initiation, was calculated using the effective Young’s Modulus of the bone/implant constructs from hysteresis data at every 500th cycle (D = 1-[E_final/E_initial]). Failure during cyclic loading is defined as catastrophic fracture of the bone or a decrease in modulus of greater than 90%. Constructs not failed during cyclic loading were subject to a ramped load to failure at 1 mm/s. Stiffness and ultimate load data are reported. A matched-paired t-test was used to determine statistical significance (p=0.05).

Video was used for qualitative failure analysis. Regression analysis was used to investigate correlations of ultimate load and stiffness to bone density.

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) (Figure 1) One specimen in group II experienced coronal fracture of the dorsal pole of the lunate (D=0.94) during cyclic loading. 19 specimens were loaded to failure. Group I specimens were significantly stiffer than group II specimens (497.4+160.3 N/mm and 304.1+150.3 N/mm, respectively; p=0.02). Group I specimens experienced a significantly greater ultimate load prior to failure when compared with group II (1280+292 N and 854+611 N, respectively; p=0.04). Specimens failed by complete distal fragment collapse leading to plate bending (Group I n=5 of 10; Group II n=2 of 9) and fracture of the lunate facet (Group I n=5 of 10; Group II n=7 of 9). Regression analyses showed no correlation between bone density and ultimate load (R2=0.13) or stiffness (R2=0.003).

Discussion: In our model, qualitative analysis of the treated radii indicate that the independent two-tier scaffolding of the plate utilized in group one, allowed for better contouring of the volar rim of the lunate facet. It is likely that enhanced contouring reduced the incidence of fracture of the lunate facet under high loads, but further investigation is necessary. Results of our study closely compare with a cadaveric biomechanical study by Koh et al. (2006) investigating 10 single-column volar fixation plates for treatment of extra-articular fractures of the distal radius. Following 5000 cycles of simulated post-operative healing, the failure stiffness ranged from 217.7-605.3N/mm and failure load ranged from 734N-1084.7N, indicating that both two-column volar plates used in our study may provide adequate stiffness and strength for early post-operative healing.

Significance: Two-column volar distal radius plates are designed for independent contouring of the radial and intermediate columns of the distal radius and targeted support of the radial styloid and lunate facet. An understanding of the damage and modes of failure of the distal radius when treated with two commonly used volar plates may offer insight into the benefits of each construct for fixation of extra-articular fractures.
Figure 1: Representative force-displacement hysteresis curves during cyclic testing of single specimen from Group I (A) and control implant in Group II (B). Corresponding damage accumulation plots for Group I (C) and Group II (D) specimens.

References:

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