LOCKED VERSUS NON-LOCKED PLATING FOR THE FIXATION OF DISTAL RADIUS FRACTURES: A BIOMECHANICAL COMPARISON

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INTRODUCTION

Distal radius fractures are among the most common orthopaedic injuries, constituting approximately 17% of all fractures (Court-Brown 2006). For intra-articular fractures with dorsal comminution there is a risk for displacement that could result in a poor clinical outcome if not treated surgically. The current trend in orthopaedic practice is to treat many of these fractures with locked volar plating, despite the increased cost of using locked plating. Current literature commonly compares different types of locked volar plating constructs (Rausch 2011, Martineau 2008, Chen 2013). This study investigates whether non-locked plating is significantly different from locked plating during a simulated six week postoperative period in an AO C2 fracture model. It follows from our previous work in Computer-Assisted Distal Radius Osteotomies (Athwal 2003).

MATERIALS AND METHODS

Fourth generation plastic radius bones (Sawbones model 3407) were used to model a fracture of AO classification C2. A custom, fracture model specific, cutting jig and oscillating saw were used to create an intra-articular split that separated the scaphoid and lunate fossa, and also removed a wedge of bone at the dorsal metadiaphyseal junction, to model dorsal comminution. Pre-contoured distal radius plates (PERI-LOC, Smith & Nephew) were fixated to the volar surface using standard diaphyseal fixation by a trained orthopaedic resident surgeon (M.K.). Five of the plates were fixed distally using non-locking screws and five were fixed using locking screws.

An increasing loading protocol was applied as outlined in Table 1. Loads were applied using a 15 kN testing machine with a 5 kN load cell (Mini-Bionix, MTS). A 60:40 scaphoid-lunate fragment load ratio was applied to the bone using a custom, four-bar, remote center of compliance linkage. Bones were securely fixed in an additively manufactured Acrylonitrile Butadiene Styrene (ABS) jig (Stratasys).

Table 1: Loading protocol applied to constructs. This was designed to simulate the mechanical loading in the first six weeks of post-operative care with 5000 cycles representing 8 events per waking hour for 6 weeks.

Loading	Cycles	Number of Tests
10 – 150 N	1000	5
10 – 400 N	1000	2
10 – 600 N	1000	1
10 – 800 N	1000	1
10 – 1000 N	1000	1

Static displacements of fracture fragments were measured using calipers after every 1000 cycles of the test. Groups were evaluated according to their change from initial configuration using 3 failure criteria:

- Dorsal tilt of greater than 10 degrees
- Overall fracture gap shortening greater than 3 mm
- Articular displacement or step-off of greater than 2 mm.

The changes in dorsal tilt of the scaphoid and lunate fragments were calculated, as a worst case approximation, from caliper measurements at the most dorsal part of each fragment assuming no translation of the volar surface relative to the plate. Changes in fracture gaps were calculated based on the average of changes measured at a point at the most dorsal part of the wedge, a point on the volar surface of the bone contacting the plate, and at a point mid-way between the two. Change in the articular displacement and step-off was established by measuring and averaging the step-off and gap distance at three points along the most distal surface of the model. Fiducial markings on each model were used to ensure consistent measurements between tests.

Locking and non-locking groups were compared using a rank sum test after each test to evaluate statistical significance.

RESULTS

Two of the locked constructs failed by articular displacement of greater than 2 mm and also had a locking screw back out of the construct. Three other locked constructs fractured during a late loading cycle, 1000N for two specimen and 800N for the other, which was an undefined failure. None of the non-locked constructs failed, however 2 that were stable when axially loaded had post-test instability when unloaded due to screw loosening.. There were no statistically significant differences between groups.

DISCUSSION

Failures have been defined based on the recommended criteria for surgical fixations of fracture (Lichtman 2010). There were no statistically significant differences between groups although the failure of the 2 locking plate constructs could challenge the current trend towards locked plating. In Rausch's work, a similar failure mode of the articular gap was noted during testing of a polyaxial plate (Synthes Variable-Angle LCP) when a screw broke (Rausch 2011) and could be indicative of an expected failure mode when a screw loosens or breaks. Although there were no failures in the non-locked group, the instability exhibited in 2 of the non-locked specimens could become important in loadings that approximate the dynamics of a non-immobilized wrist.

Plastic bone models were chosen for this study to reduce variability in the size, shape, and density. These models, including previous generations, were chosen in other studies for similar reasons (Martineau 2008, Chen 2013). The fractures observed during testing of the locking specimens show a potential limitation of these plastic bones. Micro-CT analysis of the fragment showed that the fracture propagated from the cancellous foam of the plastic bone to the cortical surface. It is possible the fractures occurred in the locking group because of the construct rigidity or that the screws only had purchase in the cortical shell most proximal to the plate.

The 60:40 scaphoid-lunate load ratio used is consistent with the loading expected in the joint (Viegas 1987) and has been used in other studies (Rausch 2011). The loading was chosen to represent the normal physiologic loads of non-loadbearing wrist motion (150 N) up to a grip expected at the end of a rehabilitation period (200 N grip force corresponds to 1000 N radial load) based on a grip strength model of the distal radius (Putnam 2000).

REFERENCES

- Court-Brown CM, Caesar B. Epidemiology of adult fractures: A review, Int J Care Injured, 37, pp. 691-697, 2006
- Athwal G, Ellis RE, Small C, Pichora DR, Computer-Assisted Distal Radius Osteotomy, J Hand Surg, 28A No. 6, pp. 951-958, 2003.
- Martineau PA, Waitayawinyu T, Malone KJ, Hanel DP, Trumble TE, Volar Plating of AO C3 Distal Radius Fractures: Biomechanical Evaluation of Locking Screw and Locking Smooth Peg Configurations, J Hand Surg, 33A, pp. 827-834, 2008.
- Rausch S, Klos K, Stephan H, Hoffmeier K, Gras F, Windolf M, Gueorguiev B, Hoffmann GO, Evaluation of a polyaxial angle-stable volar plate in a distal radius C-fracture model – A biomechanical study, Int J Care Injured, 42, pp. 1248-1252, 2011.
- Chen AC, Lin Y, Kuo H, Yu T, Sun M, Lin C, Design Optimisation and experimental evaluation of dorsal double plating fixation for distal radius fracture, Int J Care Injured, 44, pp. 527-534, 2013.
- Lichtman DM, Bindra RR, Boyer MI, Putnam MD, Ring D, Slutsky DJ, Taras JS, Watters III WC, Goldberg MJ, Keith M, Turkelson CM, Wies JL, Haralson III RH, Boyer KM, Hitchcock K, Raymond L, AAOS Clinical practice guideline summary: Treatment of Distal Radius Fractures, J Am Acad Orthop Surg, 18, pp. 180-189, 2010.
- Viegas SF, Tencer AF, Cantrell J, Chang M, Clegg P, Hicks C, O'Meara C, Williamson JB, Load transfer characteristics of the wrist. Part I. The normal joint, J Hand Surg, 12(6), pp. 971-978, 1987.
- Putnam MD, Meyer NJ, Nelson EW, Gesensway D, Lewis JL, Distal radial metaphyseal forces in an extrinsic grip model: Implications for postfracture rehabilitation, J Hand Surg, 25(3), pp. 469-475, 2000.

DISCLOSURES

Plates were donated by Smith & Nephew.