

Biomechanical Analysis of Proximal Radial Shaft Fracture Fixation

, ¹Gaski, G, ¹Quinnan, S, ²Kaimrajh, DN, ²Milne, EL, +^{1,2}Latta, LL
¹Dept. Orthop., Univ. Miami, Miami, FL, ²Max Biedermann Instit. for Biomech., Miami Beach, FL

Introduction:

Fractures of the proximal radius pose a unique challenge in obtaining proximal fixation without disrupting ligamentous complexes of the elbow. Metaphyseal bone available for screw purchase is limited proximally by the annular ligament and medially by the bicipital tuberosity. Several biomechanical studies have tested different fixation constructs of radial head and neck fracture models under various loading conditions (bending, torsion, axial) in an effort to determine construct strength and stiffness¹⁻³. In addition, 2.7 mm and larger plates can lead to impingement with forearm rotation⁴. To our knowledge, there are no known studies assessing a variety of proximal radius fracture fixation constructs. We hypothesize that orthogonal plating with lower profile mini-fragment plates will reduce the problems of impingement while providing equal or greater construct stiffness and strength than traditional 3.5 mm plates.

Methods:

In part one of the study, impingement testing was undertaken with five fresh-frozen cadaveric upper extremities that were disarticulated at the shoulder. A volar approach to the proximal radius was performed preserving all soft tissue attachments. A transcondylar 2.0 mm horizontal reference wire was inserted through the elbow and a second parallel wire inserted through the radial styloid with the forearm fully supinated in the anatomic position. With the arm in full supination, the following plates were applied to the volar surface of the proximal radius (radial to the bicipital tuberosity and without violating the annular ligament): 2.0 mm, 2.4 mm, 2.7 mm, and 3.5 mm. The forearm was ranged through an arc of pronosupination without implants, and then successively with each plate affixed with screws proximally and distally. Impingement was observed when pronation of the radius led to contact with a one millimeter wire resting on the volar/radial surface of the ulna and goniometric measurements were taken between the two reference wires. Secondly, the same test was performed under live fluoroscopy to verify impingement (in which further forced pronation caused rotation of the transcondylar wire).

In the second part of the experiment, eleven matched pairs of formalin-fixed, human cadaveric radii were harvested and stripped of soft tissue attachments. Bone mineral density for each group was 0.632 g/cm². A transverse osteotomy was created two centimeters distal to the bicipital tuberosity. Group 1 consisted of eleven radii affixed with a five-hole 3.5 mm non-locking plate

with two bicortical screws proximal to the osteotomy and three bicortical screws distal. Group 2 included eleven radii with one ten-hole 2.0 mm non-locking plate applied volarly and a second 2.0 mm plate radially, both with three bicortical screws proximal and distal to the osteotomy. Specimens were loaded in a servohydraulic materials testing machine. Stiffness was calculated after applying bending loads within the elastic range, in three different directions: tension band mode (TB) (volar plate served as reference plate in 90-90 construct), 90 degree out-of-plane mode (OOP), and with the plate on the compression side (CS). Torque loads were then applied and torque stiffness data were generated from the slope of the moment-angulation curve (TQ). Implants were then loaded to failure and torque strength measures were recorded (determined by peak torque achieved just prior to screw pullout and/or fracture propagation). Comparisons were made by use of a two-tailed Student's t-test with statistical significance being set at p<0.05.

Results:

In all cases, the dynamic fluoroscopic method corresponded to the direct measurement method. All specimens exhibited 90° of supination. With no hardware affixed, mean pronation of the five specimens was 71 degrees. There was no impingement observed with the 2.0 mm plate. Pronation with the 2.4 mm plate construct reduced pronation by 19%; the 2.7 mm plate, by 44%; the 3.5 mm plate, by 60%, see Table 1.

The 3.5 mm plate constructs were stiffer than 2.0 mm plate constructs with all modes of bending, with statistically significant differences in TB (p<0.01) and OOP (p<0.02), but no significant difference in CS mode (p=0.38) or TQ (p=0.11), see Fig. 1. There also was no significant difference in torque load-to-failure testing (3.72 N-m vs. 3.82 N-m, p=0.90).

Table 1	Pronation	Loss of pronation
Plate size	In degrees	In percent
2.0 mm	71.0°	0%
2.4 mm	57.2°	19.5%
2.7 mm	40.0°	43.7%
3.5 mm	28.2°	60.3%

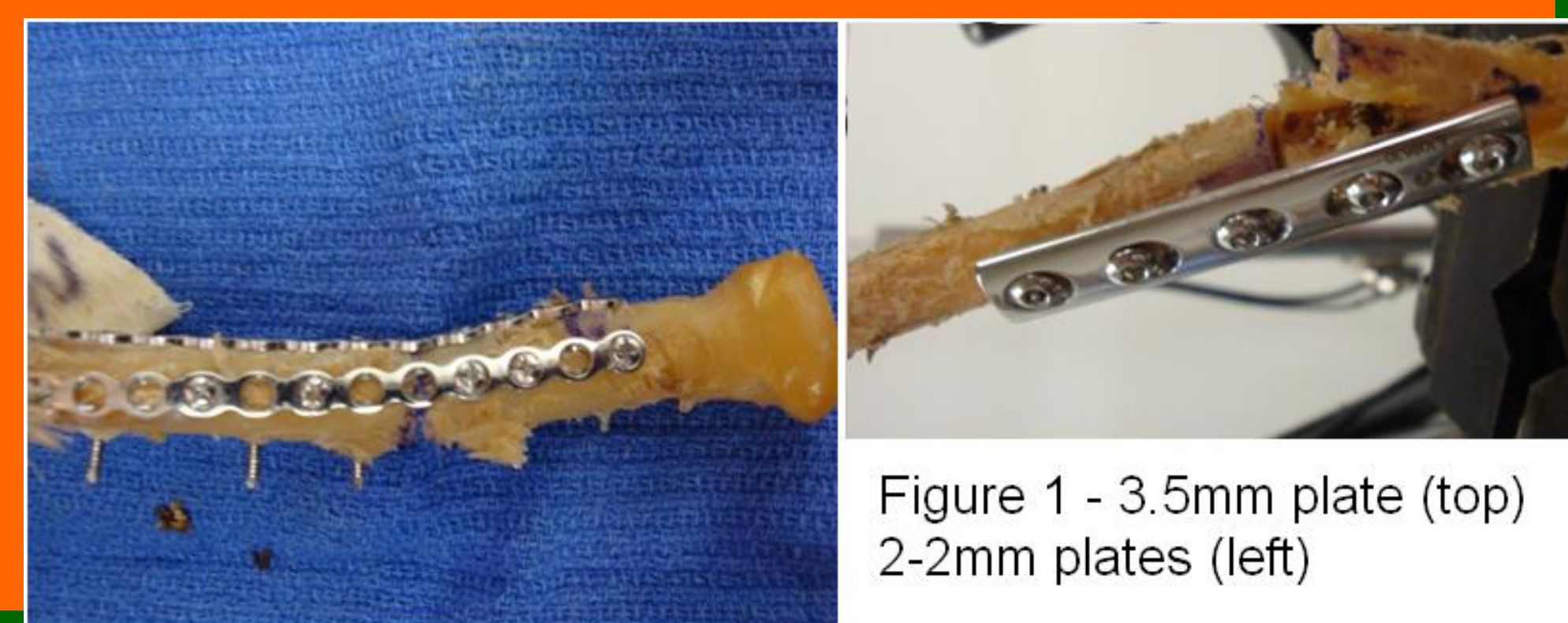
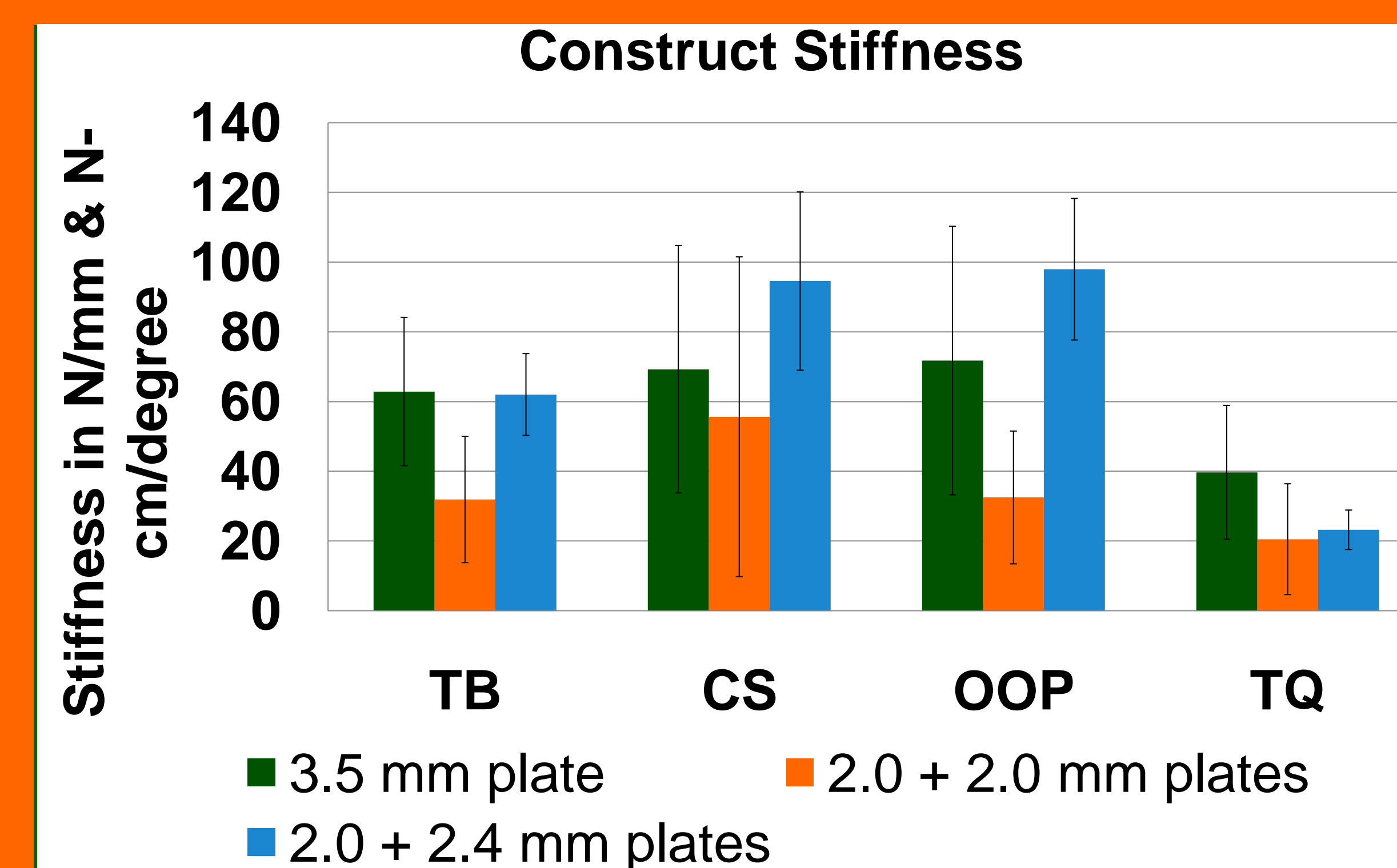


Figure 1 - 3.5mm plate (top) 2-2mm plates (left)



Significance:

Clinically, many different modes of radial neck and head fracture fixation failure have been observed and the causative forces debated (1-3). We observed that orthogonal plating with two 2.0 mm plates have a torsional strength equivalent to single 3.5 mm plate constructs in a proximal radius fracture model, but are 50% less stiff than 3.5 mm plate constructs when a bending load is applied in TB mode and OOP mode. The proper stiffness to achieve healing is not well defined, so the clinical relevance of this reduction of stiffness is not known. Also, the increase in loading on the construct caused by impingement is unknown, so it is difficult to predict which parameters are the most important clinically. This study does demonstrate that lower profile, 2.0 mm plate constructs avoid mechanical impingement to forearm rotation in the proximal radius and are equivalent in torsional strength to 3.5 mm plate constructs.

References:

- 1) Burkhart KJ, et al: Stability of radial head and neck fractures: a biomechanical study of six fixation constructs with consideration of three locking plates. J Hand Surg 2007;32A:1569-1575.
- 2) Patterson JD, et al: Stiffness of simulated radial neck fractures fixed with 4 different devices. J Shoulder Elbow Surg 2001;10:57-61.
- 3) Giffin JR, et al: Internal fixation of radial neck fractures: an in vitro biomechanical analysis. Clin Biomech 2004;19:358-361.
- 4) Soyer AD, et al: Optimal position for plate fixation of complex fractures of the proximal radius: a cadaver study. J Orthop Trauma 1998;12(4):291-293.

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