Reconstructing Proximal Humerus Fractures with Locking Plates: Don't Miss High?

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Introduction

Upper extremity fractures account for one-third of the total incidence of fractures in the elderly [1] and the incidence of proximal humeral fractures significantly increases in osteoporotic bone.[1,2] Current rates of clinical failure are unacceptably high, with humeral head collapse, fixation failure, and hardware-related complications leading to revision rates between 27% and 59.2% in some studies.[3,4] Previous research has indicated that utilizing the calcar as an anchor point for screws is an effective method to provide medial column support (Fig 1).[5,6] These studies make comparisons of groups that either utilize a calcar screw as an anchoring point or do not; however, they do not characterize the clinically relevant consequence of "missing" the calcar with screw placement during surgery. This study sought to elucidate the mechanisms associated with proximal and distal placement of locking plates in two-part proximal humeral fractures. We hypothesized that neutral placement of the plate would provide the best fixation, while distal and proximal plate locations would exhibit significant reductions in fixation strength.

Methods

This study was first performed with 9 left osteoporotic humerus Sawbones models (Pacific Research). Specimens were assigned either neutral calcar screw insertion (SN; n =3), 8 mm distal calcar screw insertion (SD; n = 3), or 8 mm proximal calcar screw insertion (SP; n = 3) (Fig 1). The study was repeated and expanded with nine matched pairs of cadaveric specimens (4 M, 5 F, average age 81.2) in the following groups: CN, n = 6; CD, n = 6; CP, n = 6. All specimens received a two-part 30° wedge osteotomy at the surgical neck of the humerus. Fractures were stabilized using locking proximal humerus plates (LCP Proximal Humerus, DePuy Synthes) with six locking screws. Quasi-static torsional stiffness tests were performed, and quasi-static axial compression tests at 0, +20, -20 degrees of ab/adduction were conducted for all specimens. Cadaveric specimens underwent an additional cyclic fatigue protocol consisting of axial compressive loads between 50-250 N for 5000 cycles at a rate of 1 Hz. A ramp to failure at a rate of 0.1 mm/s was performed after completion of the fatigue test. Maximum humeral head displacement during fatigue loading was measured with optical 3-D motion tracking techniques (OptiTrack), and ultimate load was recorded. One-way ANOVAs with alpha = 0.05 were performed to determine differences within the Sawbones and cadaveric groups.

Results

In the Sawbones experiment, distal placement provided significantly improved construct stiffness over proximal placement in 3 out of 5 assays (Fig 2 and 3). In two cases, distal placement of the implant improved construct stiffness when compared to neutral placement. There were no significant biomechanical differences in angular or axial stiffness between the cadaveric groups. No significant differences were found for maximum displacement or ultimate load. In general, the Sawbones constructs were much more compliant than the cadaveric constructs.

Discussion

Contrary to our overall hypothesis, the results from the Sawbones experiment suggest that distal implant placement is either equal to or stronger than neutral placement while proximal implant placement seems to decrease construct stiffness. However, the results from the cadaveric experiment did not provide similar significant results, as plate placement did not have a significant effect on torsional stiffness, axial stiffness, humeral head displacement, or ultimate load. Variations in human anatomy and bone mineral density led to variations in experimental data and future studies should include higher sample sizes. When comparing between the

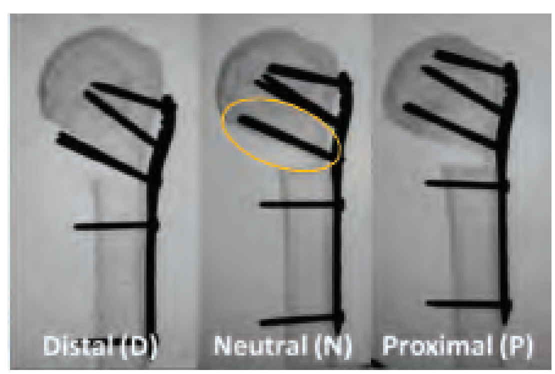

Figure 1: Fluoroscopic images of the 3 groups tested in the experiment. The screws circled in yellow are inserted into the calcar.

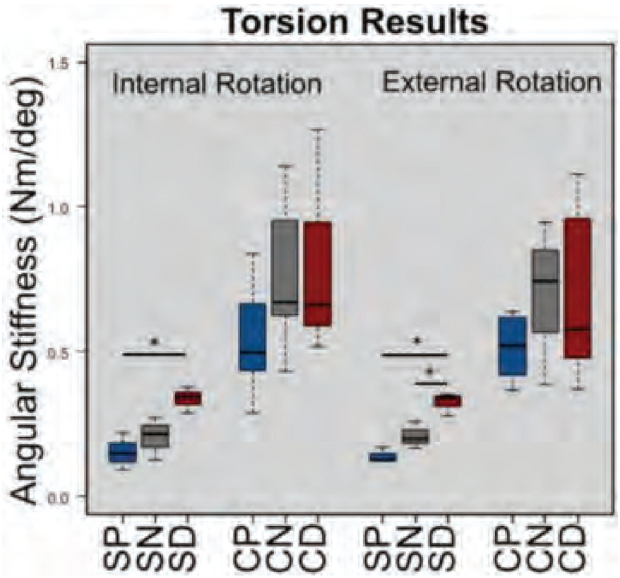

Figure 2: Plots of angular stiffnesses for Sawbones and cadaveric specimens. Significant differences between groups are marked with a *.

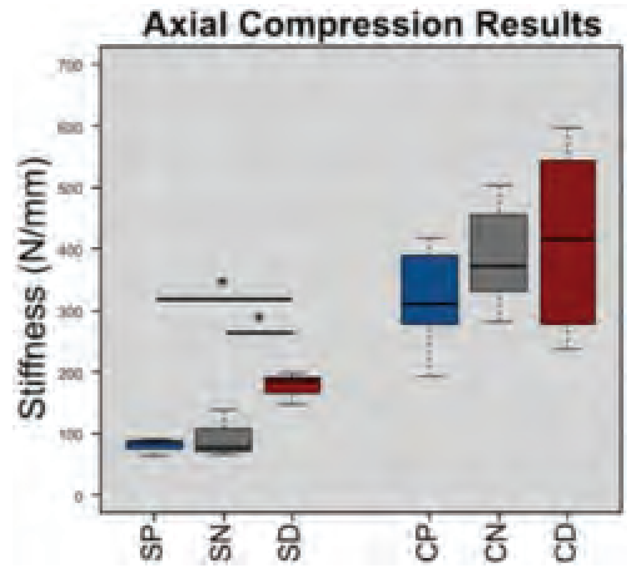

Figure 3: Plots of stiffnesses for Sawbones and cadaveric specimens during the 0° axial test. Significant differences between groups are marked with a *.

Sawbones and cadaveric models, it is clear that this surrogate for osteoporotic bones do not provide the same mechanical properties as the human condition. However, it is our belief that a Sawbones model, which includes realistic geometry, thinned cortical walls, and soft cancellous bone, provides a useful surrogate for biomechanical testing, despite the large decrease in mechanical strength.

Clinical Relevance

The purpose of this study was to provide guidance for surgeons who may not achieve idealized screw placement during a proximal humerus reconstruction. Results suggest that screws inserted below the calcar may act as an effective buttress to provide support to the medial column of the humerus, whereas "missing high" results in decreased construct stiffness.

References

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