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Are conventional reconstruction plates equivalent to precontoured locking plates for distal humerus fracture fixation? A biomechanics cadaver study ☆

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Background: The optimal plate type and configuration for distal humerus fracture fixation has yet to be defined. Available biomechanical studies show conflicting results. No existing studies compare conventional reconstruction plates to newer precontoured distal humerus locking plates in both parallel and perpendicular configurations.

Methods: Three groups of humerus specimens were compared via biomechanical testing in a cadaver model simulating metaphyseal comminution. Group 1 consisted of conventional reconstruction plates in a perpendicular configuration. Group 2 used precontoured locking plates in a perpendicular configuration. Group 3 used precontoured locking plates in a parallel configuration. Each group was tested for stiffness in anterior bending, posterior bending, axial compression, and torsion. The specimens then underwent cyclic loading followed by single load to failure in posterior bending.

Findings: There was no significant difference between the three groups for anterior bending, posterior bending, axial compression, or torsional stiffness. There was no significant difference in load to failure for any of the three groups. Screw loosening was significantly higher in Group 1 when compared to Groups 2 and 3 after cyclic loading.

Interpretation: In the early postoperative period, less expensive perpendicular conventional reconstruction plate constructs provide similar stiffness and load to failure properties to newer precontoured locking plate systems regardless of plate configuration.

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1. Introduction

Fractures of the adult distal humerus have been described as grave lesions with poor outcomes since circa 415 BC (Brorson, 2009). Double-plate osteosynthesis is the current standard for treatment in active adults; however, plate type and configuration are topics of controversy within the literature (Green, 2009; Nauth et al., 2011). Historically, the AO group has recommended treatment with conventional reconstruction plates (CRPs) in a perpendicular configuration (Rüedi et al., 2007); wherein the lateral column plate is placed posteriorly and the medial column plate turned approximately 90° and placed medial to the supracondylar ridge. There is a current trend toward use of precontoured distal humerus locking plates (PDHLPs) in a parallel configuration (Nauth et al., 2011; O'Driscoll, 2005); where plates are placed on the medial and lateral columns approximately 180° to each other. These newer plates are attractive as an alternative to CRPs because of angular screw stability and an anatomically precontoured shape, but evidence to recommend the routine use of locking plates over non-locking plates for distal humerus fractures is insufficient (Nauth et al., 2011).

Several biomechanical studies with conflicting results have been published comparing CRPs, PDHLPs, and locking compression plates (LCPs) in various configurations. With regard to biomechanical stability of various plate and screw constructs, the following issues are currently unproven: (a) whether newer PDHLPs are superior to CRPs; and (b) whether the parallel plate configuration is superior to the perpendicular configuration. With a lack of consensus on these issues, individual surgeon preference and experience often dictate the choice of implant and implant position for internal fixation of distal humerus fractures (Abzug and Dantuluri, 2010; Schwartz et al., 2006).

Currently no single study compares the biomechanical properties of perpendicularly placed CRPs to PDHLPs in both parallel and perpendicular configurations. The aim of our study is to make these comparisons using human cadaver specimens in an established biomechanical testing model (Korner et al., 2003, 2004).

☆ Location of work: This study was performed at the University of Colorado School of Medicine, Department of Orthopaedic Surgery Biomechanics Laboratory in Aurora, CO, USA.

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2. Methods

2.1. Specimens

Thirty fresh frozen left human upper extremity specimens were obtained (Science Care™, Phoenix, AZ, USA) and stripped of all soft tissue and visually inspected for pathology. The mean age of human cadaver specimens used was 72.3 years (range 51 to 98, standard deviation 10.8). There were 17 humeri from female cadavers and 13 from male cadavers. Total bone mineral density (BMD) of the distal third of each humerus specimen was measured with a dual energy X-ray absorptiometry (DEXA) machine (Hologic, Inc., Bedford, MA, USA). The mean and standard deviation for bone mineral density were mean 0.69 (SD 0.18 g/cm^2).

After the DEXA scans were completed the humeri were randomly assigned to three groups of ten. The mean BMDs and standard deviations of the three groups were as follows (g/cm^2): Group 1 (0.69,0.19), Group 2 (0.64,0.22), and Group 3 (0.73,0.12). These were statistically compared using one way ANOVA to ensure there was no significant difference in BMD between the three groups ($P = 0.98$). The specimens were then wrapped and stored in saline soaked gauze at −20 °C prior to testing.

2.2. Fracture model

Specimens were thawed for 12 h at room temperature. First, plates with moldable segments were contoured to fit to the bone. Next, the proximal and distal screw holes of medial and lateral/posterolateral plates were drilled into the bone to ensure an anatomical reduction. A supracondylar distal humerus fracture model was then created using a band saw to cut a transverse 5 mm osteotomy gap just proximal to the olecranon fossa to simulate metaphyseal comminution (OTA/AO type 13-A3.3). The gap was large enough to avoid bone contact between proximal and distal fragments during testing.

2.3. Fracture fixation

Three different plating configurations and four plate types were used for fracture fixation. All implants used are Food and Drug Administration approved for distal humerus fracture fixation. *Group 1*: Non-locking 3.5 mm stainless steel 8-hole (94 mm length) CRPs, (Smith & Nephew, Inc., Memphis, TN, USA), were anatomically mounted around the medial epicondyle on the ulnar column and along the posterolateral surface on the radial column in a perpendicular configuration using 3.5 mm non-locking cortex screws (Fig. 1A, D). *Group 2*: Plates were placed in a similar manner to plates in Group 1 using 7-hole medial (103 mm) and 7-hole posterolateral (107 mm) stainless steel posterolateral PDHLPs (Smith & Nephew PERI-LOC) using only locking screws in a perpendicular configuration (Fig. 1B, E). *Group 3*: 7-hole medial (103 mm) and lateral (102 mm) stainless steel PDHLPs (PERI-LOC, Smith & Nephew, Inc., Memphis, TN, USA) were placed on ulnar and radial columns using only locking screws in a parallel configuration (Fig. 1C, F). Plate lengths were chosen to most closely match the overall working distance of the PDHLPs to an 8-hole CRP. Plate thickness is 2.8 mm for all CRPs and 3.1 mm for all PDHLPs.

Pilot holes of appropriate size for the screws per the manufacturers' specifications were made with a power drill. Screws were inserted by hand to a tightness of two fingers. A 1.7 Nm torque limiting screw driver was utilized for all locking screw insertions. Proximal to the osteotomy site, three 3.5 mm bicortical screws were placed in every plate. Distal to the osteotomy site, monocortical screws were used to avoid penetration of articular surfaces. CRPs were fixed distally with three monocortical 3.5 mm non-locking screws. PDHLPs were fixed distally with one monocortical 3.5 mm locking screw and three monocortical 2.7 mm locking screws. Penetration of the olecranon fossa was avoided in all groups.

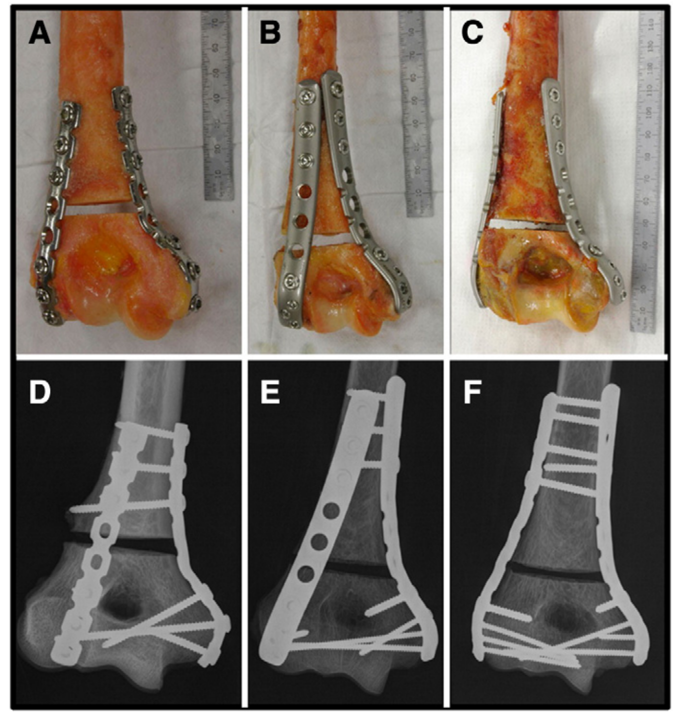

Fig. 1. Photographs and plain X-rays demonstrating three different testing groups. Group 1 (A and D) = perpendicular CRPs; Group 2 (B and E) = perpendicular PDHLPs; Group 3 (C and F) = parallel PDHLPs.

2.4. Potting the specimens

After the humeri were plated they were potted for mechanical testing. The proximal end of the humeri was cut off with a band saw 6 cm from the most proximal end of the plates. Five centimeters of the proximal end of the bone was potted in the center of a 4 in. diameter aluminum tube with Dyna-Cast hard setting urethane (Kindt-Collins Company LLC, Cleveland, OH, USA). Fixing the distal end of the humeri was accomplished by first placing a highly elastic modeling compound (Hasbro, Inc., Pawtucket, RI, USA) over the distal plate and screws. This prevented plates and screws from being rigidly fixed in the potting compound and allowed the screws to back out during testing. The distal end was then potted to within 1 cm of the osteotomy in the center of a 4 in. square tube with Dyna-Cast.

2.5. Mechanical testing

Three different types of mechanical testing were performed: stiffness testing, cyclic loading, and single load to failure. All tests were performed on an Instron Model 1321 closed loop servo-hydraulic test machine (Instron Corporation, Canton, MA, USA). All data were collected at 50 Hz on a PC equipped with a Keithley 1802HC (Keithley Instruments, Inc., Cleveland, OH, USA) analog to digital board and TestPoint (Capital Equipment, Corp., Billerica, MA, USA) data acquisition software. Stiffness testing was performed in axial compression (250 N), torsion (+/−1.6 Nm), anterior 4 point bending (4.5 Nm), and posterior 4 point bending (4.5 Nm) (Fig. 2). These load levels were chosen to avoid plastic deformation of the construct while stiffness testing (Korner et al., 2004). Four point bending was used to provide a constant bending moment across the fracture site. All tests were sinusoidal wave forms run for 4 cycles at 0.2 Hz. The stiffness was measured on the 4th cycle between 20% and 80% of the peak applied load.

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