Injury, Int. J. Care Injured 45 (2014) 2040–2044

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Plate selection for fixation of extra-articular distal humerus fractures: A biomechanical comparison of three different implants

John A. Scolaro [a,*], Jason E. Hsu [b], David J. Svach [c], Samir Mehta [d]

[a] University of California, Irvine, Department of Orthopaedic Surgery, 101 The City Drive South, Pavilion III, Building 29A, 2nd Floor, Orange, CA 92868, United States
[b] University of Washington, Department of Orthopaedics and Sports Medicine, 4245 Roosevelt Way N.E., Seattle, WA 98105, United States
[c] DePuy Synthes Mechanical Testing Laboratory, 1301 Goshen Parkway, West Chester, PA 19380, United States
[d] University of Pennsylvania, Department of Orthopaedic Surgery, 3400 Spruce Street, 2 Silverstein Pavilion, Philadelphia, PA 19104, United States

ARTICLE INFO

Article history:
Accepted 17 August 2014

Keywords:
Distal humerus
Extra-articular
Biomechanical
Posterolateral plate

ABSTRACT

Operative fixation of extra-articular distal humerus using a single posterolateral column plate has been described but the biomechanical properties or limits of this technique is undefined. The purpose of this study was to evaluate the mechanical properties of distal humerus fracture fixation using three standard fixation constructs.

Two equal groups were created from forty sawbones humeri. Osteotomies were created at 80 mm or 50 mm from the tip of the trochlea. In the proximal osteotomy group, sawbones were fixed with an 8-hole 3.5 mm LCP or with a 6-hole posterolateral plate. In the distal group, sawbones were fixed with 9-hole medial and lateral 3.5 mm distal humerus plates and ten sawbones were fixed with a 6-hole posterolateral plate. Biomechanical testing was performed using a servohydraulic testing machine. Testing in extension as well as internal and external rotation was performed. Destructive testing was also performed with failure being defined as hardware pullout, sawbone failure or cortical contact at the osteotomy.

In the proximal osteotomy group, the average bending stiffness and torsional stiffness was significantly greater with the posterolateral plate than with the 3.5 mm LCP. In the distal osteotomy group, the average bending stiffness and torsional stiffness was significantly greater with the posterolateral plate than the 3.5 mm LCP. In extension testing, the yield strength was significantly greater with the posterolateral plate in the proximal osteotomy specimens, and the dual plating construct in the distal osteotomy specimens. The yield strength of specimens in axial torsion was significantly greater with the posterolateral plate in the proximal osteotomy specimens, and the dual plating construct in the distal osteotomy specimens.

Limited biomechanical data to support the use of a pre-contoured posterolateral distal humerus LCP for fixation of extra-articular distal humerus exists. We have found that this implant provided significantly greater bending stiffness, torsional stiffness, and yield strength than a single 3.5 mm LCP plate for osteotomies created 80 mm from the trochlea. At the more distal osteotomy, dual plating was biomechanically superior. Our results suggest that single posterolateral column fixation of extra-articular humerus fractures is appropriate for more proximal fractures but that dual plate fixation is superior for more distal fractures.

Introduction

Operative reduction and internal fixation of extra-articular distal third humerus fractures provides immediate skeletal stability, allows for early rehabilitation, and decreases soft tissue complications associated with functional bracing [1]. Fixation of these fractures can be problematic due to the unique morphology of the distal humerus and the muscle forces acting on the fracture. A short distal fracture segment provides limited opportunities for fixation; plate selection and application can therefore be difficult depending on the fracture pattern. While some fractures are amenable to single plate fixation others require two or more plates [2].

* Corresponding author. Tel.: +1 714 456 1699; fax: +1 714 456 7547.
E-mail address: jscolaro56@yahoo.com (J.A. Scolaro).

http://dx.doi.org/10.1016/j.injury.2014.08.036
0020–1383/

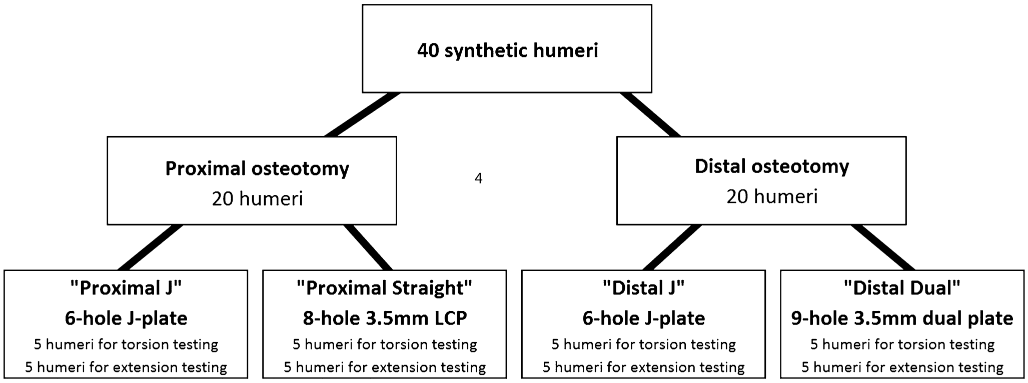

Fig. 1. Flowchart demonstrating study design.

The anatomically pre-contoured 3.5 mm LCP Extra-Articular Distal Humerus Plate (DePuy Synthes, West Chester, PA), also referred to as the "J-plate," was specifically designed for fixation of extra-articular distal humerus fractures. This plate is contoured to fit the anatomy of the posterolateral distal humerus and provides an increased number of distal segment fixation points in comparison to standard straight 3.5 mm plates. Single column fixation of extra-articular distal third humerus fractures has been described but the indications and limits of this technique are yet undefined [3–5].

The purpose of this study was to evaluate the biomechanical properties of the J-plate in the fixation of distal and proximal extra-articular distal humerus fractures by comparing them to the properties of two other plating constructs. Our goal was to compare the J-plate to a standard straight 3.5 mm LCP for more proximal fractures and to a dual column plating construct for more distal fractures. Fixation was tested at two osteotomy levels to determine how fracture location affected implant performance. Our hypothesis was that the J-plate would demonstrate greater stiffness and strength than a single 3.5 mm plate when stabilizing a more proximal osteotomy but would provide inferior stiffness and strength to a dual plating construct for a more distal osteotomy where limited distal fixation is available.

Materials and methods

This study did not involve any human or animal subjects and, therefore, no informed consent or authorisation by an ethical committee was required.

Specimens and fracture simulation

Forty synthetic humeri (Model #1028, Pacific Research Laboratories, Inc., Vashon, WA) were used. Two extra-articular distal humerus fractures models were created: a 6 mm transverse osteotomy was marked 80 mm (proximal) and 50 mm (distal) from the centre of the trochlea. Prior to application of the fixation construct, the posterior, medial, and lateral cortices of the osteotomy were scored with a thin reciprocating saw. After the fixation strategy was applied, the osteotomy was completed anteriorly with the reciprocating saw, and the 6 mm wedge of bone was removed. This process was replicated for each specimen in order to ensure consistent application of the plate while avoiding any contact of the reciprocating saw with the plate during creation of the osteotomy to prevent damage.

Study groups

The 40 specimens were divided evenly into proximal and distal osteotomy groups (Fig. 1). The 20 proximal specimens were divided evenly into two groups: one group was fixed with an 8-hole 3.5 mm LCP ("Proximal Straight") (Fig. 2A), and the other was fixed with a 6-hole J-plate ("Proximal J") (Fig. 2B). The 20 distal specimens were divided evenly into two groups: one group was fixed with 9-hole medial and lateral 3.5 mm distal humerus locking plate ("Distal Dual") (Fig. 2C), and the other fixed with a 6-hole J-plate ("Distal J") (Fig. 2D).

Biomechanical testing

After plate fixation, all sawbones were cut 190 mm from the tip of the trochlea to facilitate potting in a metallic die with a polymer casting agent (Smooth Cast 300, Smooth-On, Easton, PA). In each group of ten sawbones, five were used for extension testing and five were used for torsion testing.

The loading set-up for extension testing (Fig. 3A) represented the direction and load distribution experienced by the distal humerus during 120° of flexion [6,7]. The potted end was rigidly fixed at an angle of 4° from the horizontal. Biomechanical testing was performed using an axial/torsional servohydraulic testing machine (MTS, Eden Prairie, MN). 60% of the vertical load was applied to the capitellum while 40% was applied to the trochlea. The sawbones were cycled 5 times in extension at a rate of 20 mm/min to 100 N. Load displacement curves were constructed and stiffness determined from the data points of the fourth cycle of testing.

Motion tracking was performed using a motion analysis system (Optotrak Certus, NDI, Waterloo, Ontario, Canada) by positioning rigid body motion sensors mounted on each side of the osteotomy. One rigid body motion sensor with 3 LEDs was mounted on the

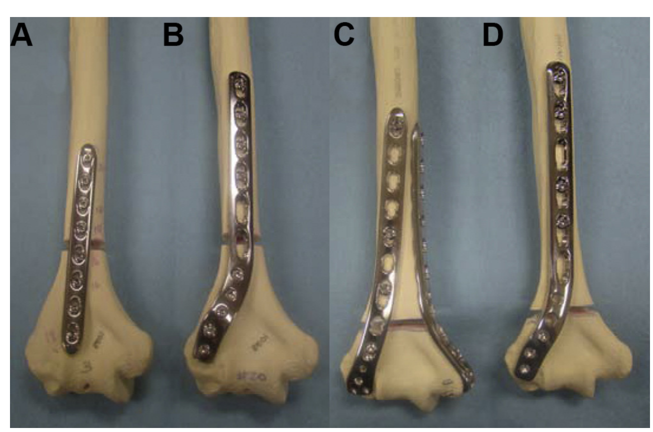

Fig. 2. Figure demonstrating testing constructs: 3.5 mm LCP (A) and 3.5 mm LCP extra-articular distal humerus plate (B) and 6 mm transverse osteotomy 80 mm from trochlea; 3.5 mm LCP extra-articular distal humerus plate (C) and 3.5 mm medial and lateral distal humerus locking plates (D) and 6 mm transverse osteotomy 50 mm from trochlea.