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LOCKED VS. UNLOCKED PLATING FOR HUMERAL SHAFT NON-UNIONS: A BIOMECHANICAL STUDY

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Introduction: Despite operative and non-operative treatment of acute fractures, the incidence of nonunion after an acute humeral shaft fracture has been reported to be as high as 13%.[1] Unstable humeral shaft non-unions are responsible for a great deal of functional disability. They are thus generally treated operatively.

Biomechanical analyses of many techniques for treating humeral shaft fractures have been described; however only one study focused on evaluating which type of construct could provide the stiffest fixation of humeral shaft fractures in a non-union model. In this study, Rubel et al found a significant increase in the stiffness of a double plate construct when compared to a single plate construct in torsion as well as four-point bending.

The use of the Synthes locking plate for the treatment of humeral shaft non-unions allows or plate osteosynthesis limiting the need for soft-tissue dissection necessary for the placement of long plates or double plates. This construct has been found to have excellent clinical results when compared to LC-DCP, however the biomechanical advantage ha not been demonstrated.

Purpose: The purpose of this study was to measure the rigidity of fixation and torsional strength of 4 different plate and screw configurations in a mid-shaft humeral defect model, simulating an unstable humeral non-union to determine whether 4.5mm locking compression plating (with unicortical or bicortical screws) displays a biomechanical advantage when compared to standard 4.5mm compression plating (both single and double plating techniques).

Methods: Twelve left composite Sawbones® humeri were used to test four constructs: (Group 1) a posteriorly placed 9-hole 4.5 mm narrow LC-DCP, (Group 2) double plate technique using a posteriorly placed 9-hole 4.5 mm narrow LC-DCP with a lateral 3.5 mm 10-hole pelvic reconstruction plate, (Group 3) a posteriorly placed 9-hole large-fragmentary locking plate with bicortical purchase of screws, and (Group 4) a posteriorly placed 9-hole large-fragmentary locking plate with unicortical purchase of screws

Six composite bones (Group 2) were plated using the double plating technique as described by Murray, with a nine-hole 4.5 mm narrow LC-DCP as well as a lateral ten-hole 3.5 mm pelvic reconstruction plate. The LC-DCP plate was placed on the posterior aspect, and fixed with four 4.5 mm self-tapping cortical screws on each side of the future osteotomy site with bicortical purchase, leaving the center hole of the plate empty. A lateral 3.5 mm pelvic reconstruction plate was then placed on the lateral cortex and secured using four 3.5 mm bicortical screws in the number-1, 4, 7, and 10 holes. Six composite bones (Group 2) were plated using the double plating technique as described by Murray, with a nine-hole 4.5 mm narrow LC-DCP as well as a lateral ten-hole 3.5 mm pelvic reconstruction plate. The LC-DCP plate was placed on the posterior aspect, and fixed with four 4.5 mm self-tapping cortical screws on each side of the future osteotomy site with bicortical purchase, leaving the center hole of the plate empty. A lateral 3.5 mm pelvic reconstruction plate was then placed on the lateral cortex and secured using four 3.5 mm self-tapping screws with bicortical purchase in the number-1, 4, 7, and 10 holes. Six composite bones (Group 3) were plated using a nine-hole Synthes Large Fragment locking plate. The central hole was left empty, and the remaining holes were filled with bicortical screws in the locked position. The screws were tightened using a torque wrench set at 4 N□m to ensure uniform screw purchase into the plates. To maintain the original alignment of the humerus, a 1 cm transverse gap osteotomy was then performed at the midshaft level of the humerus. A block was attached to the bone with PMMA at the proximal end and the sides of the block were aligned to the sagittal (AP) and frontal (ML) planes. A lever arm was attached to the aluminum block in the ML plane both for varus and valgus loading, and then in the AP plane for flexion and extension loading. The offset on the lever arm was set at 3.5 cm to simulate the approximate lever arm of the typical muscle attachments which apply bending loads to the elbow. The block also was gripped by a self centering vise on the MTS machine for application of axial rotation loading. The distal end of each bone was clamped firmly in a vise with angular adjustment. The angle vise was mounted on 2 orthogonal, linear bearing tables to allow for free movement in both the ML and AP directions. In this manner the vertical loads applied by the MTS machine remained truly vertical throughout the tests and no side shear loads could develop. During axial torsion, the axis of rotation was aligned to the medullary canal of the bone After elastic testing in the locked plate bicortical screw configuration for all modes of loading, the same bone had each bicortical screw sequentially removed and replaced with a unicortical screw. The mechanical testing regimen was then repeated on each bone. After elastic testing in the double plated, unlocked configuration for all modes of loading, the same bone had the lateral plate removed and the bone was tested again with only the posterior plate in place. Finally, three of the four constructs (Groups 1-3) were tested to failure using axial torque loading. An MTS 858 Mini Bionix II was used for mechanical testing of all constructs. The loading was sinusoidal at 0.25 Hz. All tests were performed at room temperature. A force displacement curve was obtained for all constructs and analyzed for structural stiffness. In addition, Selspot LED's were placed on the anterior surface of the bone, one on each side of the 1 cm gap. The LED's measured 3 plane movement to an accuracy of 0.05 mm.

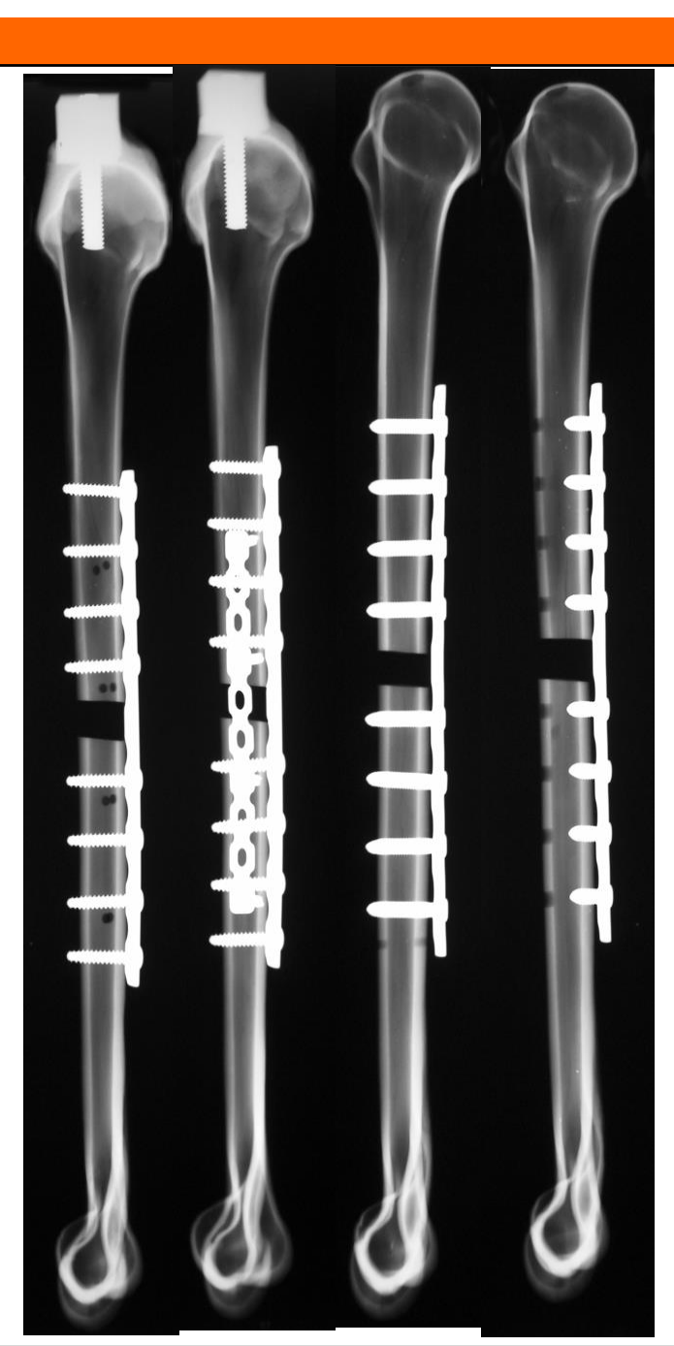

Figure 1 – The 4 groups tested, in the order described.

Figure 2 – setup for flexion and axial torque loading. Note LED's for measuring movement across the gap.

Results: The double plated constructs were significantly more rigid than single posterior plates using either locked or unlocked screws for structural stiffness in flexion (270% greater, $P < 0.00001$ and 294% greater, $P < 0.00003$, respectively), extension (60% greater, $P < 0.00007$ and 136% greater, $P < 0.004$, respectively) and torque (43% greater, $P < 0.0001$ and 24% greater, $P < 0.01$, respectively), but not in varus or valgus loading. Additionally, the double plated construct was significantly stronger when tested to torsional failure, as compared to the bicortical locked construct (40% greater, $P < 0.0008$) and bicortical unlocked (32% greater, $P < 0.004$) single posterior plating. All specimens failed either proximal or distal to the construct with failure seen to originate at the most proximal or distal screw hole, respectively. No constructs failed through the hardware. One unlocked single posterior plate construct bent through the plate, but the failure occurred through the bone at the distal most screw.

The vertical movement at the osteotomy gap was significantly greater in the single plated constructs compared to the double plated constructs only for flexion ($P < 0.00001$ and 0.01), but not for extension. In axial rotation (torque), the structural stiffness was significantly greater for the double plated constructs than either of the single plated, bicortical screw constructs ($P < 0.02$ and 0.0001, respectively). The shearing movement also was significantly greater at the osteotomy site in axial torque for the single locked plate vs. the double unlocked plated construct ($P < 0.0005$).

Comparing the locked to the unlocked plated constructs with a single posterior plate and bicortical screws, the locked plated constructs were significantly more rigid in torque (16% greater, $P < 0.004$). However, when tested to torsional failure, there was no statistical difference (4.9% greater, $p = 0.5$).

Comparing the use of unicortical and bicortical locked screws using a single posterior plate, bicortical screws were significantly more rigid in torque (90% greater, $p < 0.004$). Notably, the unicortical screw construct loosened in each specimen when torsional stress reached 4 N·m.

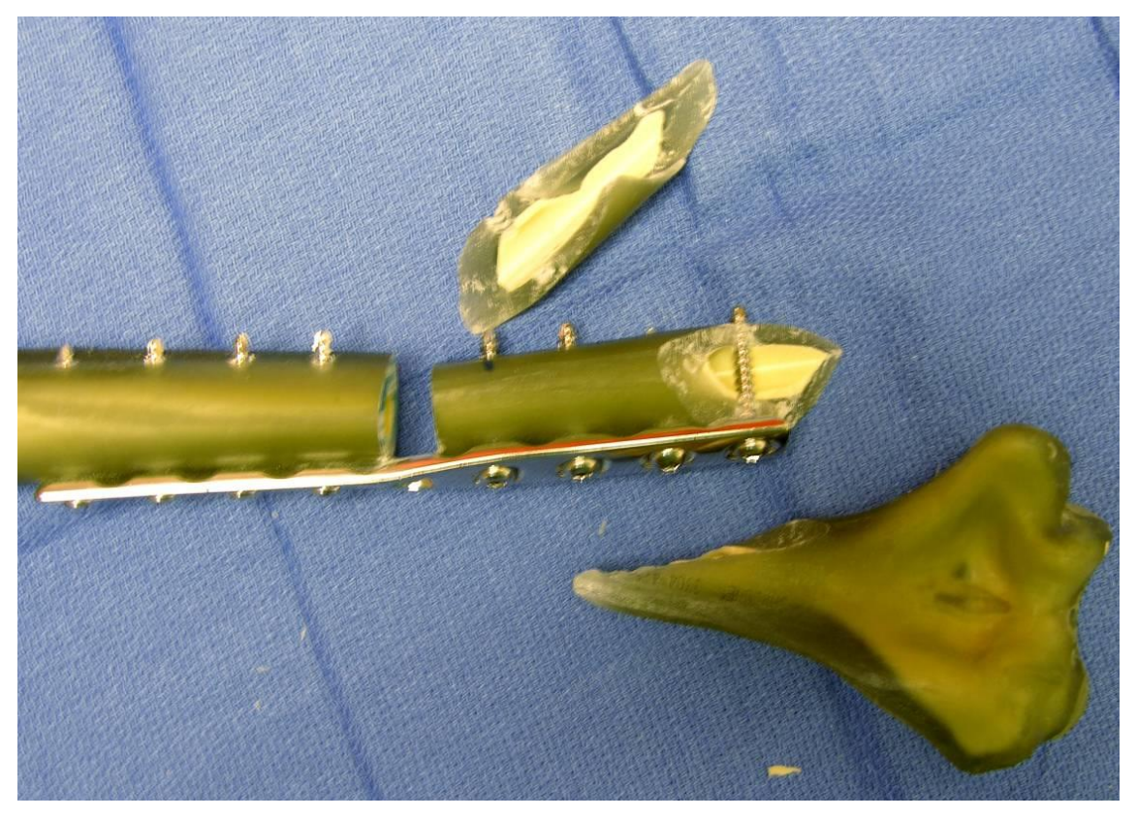

Figure 3 – 4 of 6 group 1 & 2. and 5 of 6 of group 3 bones failed with a spiral, oblique fracture through the distal screw hole.

Conclusion: The double plating technique showed significantly greater stiffness and strength than any single plating technique, including bicortical locked plating. Bicortical locked plates provide additional torsional stiffness, which may be important in treating humeral shaft non-unions.

References: 1)Ring D et. al. *JBJS* 1999; 81(2): 177-190. 2) Rubel IF et. al. *JBJS* 2002; 84: 1315-1322

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