Parallel Locked Plating of Simulated Distal Humerus Fractures Exhibit Superior Biomechanical Properties to Locked Orthogonal Plating

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Introduction: Distal humerus fractures continue to be some of the most challenging fractures to manage. They commonly occur in osteopenic bone and have complex anatomy with limited options for internal fixation [1]. Optimal treatment of these fractures in the adult population has proven difficult to standardize, even with advances in fracture fixation methods. Recent research has focused on the ideal plate configuration for internal fixation of bicolumnar distal humerus fractures, so far with varied results [2-5]. This study aimed to determine the biomechanical stiffness of parallel and orthogonal locking plate configurations in torsion, bending, and load to failure.

Methods: Tests were conducted on nine matched pairs of cadaveric humeri. They were stripped of all soft tissues, and a 10mm block of bone was partially excised from the distal humerus metaphysis to simulate an AO type 13-A3 extra-articular fracture with comminution. Each simulated fracture was repaired using Biomet ALPS distal humerus locking plates in either a parallel or orthogonal configuration, with nine humeri in each group. After plate fixation, the osteotomies were completed to remove the 10mm bone block while maintaining an anatomic reduction. The proximal 4.5cm of the humeri were mounted in PVC cylinders using two 3.2mm transfixing pins, and potted with PMMA. The distal fragment was held in a custom-designed fixture with sharpened screws and epoxy putty (Ace Hardware Corp., Oak Brook, IL). Each specimen was mounted on an Instron 1321 biaxial servohydraulic test machine (Instron Corp., Canton MA) retrofitted with MTS TestStar™ II digital controller (MTS Corp., Eden Prairie MN) and tested at 0.5°/s up to ±2N-m of torque in external and internal rotation for 20 cycles. (Figure 1) The specimen was then mounted horizontally and tested in cantilevered bending at 1mm/s of displacement up to ±50N in extension and flexion for 100 cycles. Finally, each specimen was loaded at 1mm/s to failure in extension. Student’s paired t-test was used to analyze cyclic displacement (i.e. rotational and bending) as well as initial stiffness in failure defined as the slope of the linear region up to 200N of load.

Results: During torsion testing, the parallel plate configuration required significantly less rotational displacement than the orthogonal configuration to reach 2N-m of torque in either direction of rotation throughout cycling (p<0.0001). (Table 1) An effect of cycling was not detected between the first and last cycle of rotation in either direction for the parallel (p>0.55) or orthogonal plate configurations (p>0.21). Bending tests demonstrated that the parallel plate configuration required significantly less displacement to reach 50N of load in either direction of bending (p<0.001). As in torsional testing, an effect of cycling was not detected between displacement of the first and last cycle in either direction of bending for the parallel (p>0.51) or orthogonal plate configurations (p>0.35). During bending failure tests, initial stiffness of the parallel plate configuration was significantly higher than the orthogonal plate configuration (p<0.005). (Figure 2)

Discussion: Parallel versus orthogonal plating in the fixation of distal humerus fractures has undergone much recent scrutiny, and the ideal method continues to remain controversial. Biomechanical studies by several different authors have demonstrated varied results, with some favoring parallel plating due to increased stiffness under various testing conditions in both cadaveric and synthetic bone models, while others show no statistically significant difference [2-4]. The most recent study has examined the use of locking screw technology in distal humerus fractures using a cadaveric model, and showed no difference between the two plate configurations [4]. It is possible that no clear answer has emerged in the past because of varied testing protocols, the use of multiple plate types, and different substrates used for testing. We were able to demonstrate significant differences in torsion and bending, favoring the parallel plate configuration as a stiffer construct. The use of locked plating has been shown to have a substantial advantage in poor bone quality or metaphyseal comminution [5]. And given the increasing incidence of distal humerus fractures in the elderly, it is important to determine the biomechanical function of locked plates in different configurations.

Significance: The parallel plate configuration demonstrated significantly greater stiffness than the orthogonal plate configuration in torsion and bending with the use of locked distal humerus plates. This greater stiffness may prove desirable in the postoperative management of patients with comminuted distal humerus fractures, providing a stable anatomic reconstruction of the joint to allow early range of motion.

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Table 1: External and internal rotation (degrees) at 2N-m of torque during the first and last of 20 torsion cycles. Extension and flexion displacement (mm) at 50N of load during the first and last of 100 bending cycles. Values reported as mean (sd).

<table>
<thead>
<tr>
<th>Direction (deg)</th>
<th>Rotation</th>
<th>First</th>
<th>Last</th>
<th>Orthogonal</th>
<th>First</th>
<th>Last</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>External</td>
<td>0.7(0.1)</td>
<td>0.6(0.1)</td>
<td>0.9(0.2)</td>
<td>0.8(0.2)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Internal</td>
<td>0.7(0.2)</td>
<td>0.7(0.2)</td>
<td>0.9(0.2)</td>
<td>1.0(0.2)</td>
<td></td>
</tr>
<tr>
<td>Bending (mm)</td>
<td>Extension</td>
<td>3.6(0.5)</td>
<td>3.6(0.6)</td>
<td>5.0(0.8)</td>
<td>5.2(1.5)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flexion</td>
<td>3.6(0.6)</td>
<td>3.9(0.7)</td>
<td>4.9(0.8)</td>
<td>5.3(1.2)</td>
<td></td>
</tr>
</tbody>
</table>
**Figure 1**: (left) Typical set up for external/ internal torsion tests prior to (right) cyclic extension/ flexion bending tests followed by load to failure in extension.

![Diagram of testing setup](image)

**Figure 2**: Construct stiffness evaluated from 0 to 200N of load during load to failure in extension. Statistical difference denoted by • for p<0.005.

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