Reconstruction Plate Fixation For Mid-Shaft Clavicle Fractures: How Is Fracture Stability Affected by Plate Position or Locking Screws?

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Introduction: Internal plate fixation for clavicle fractures is a common treatment for complex fractures or nonunions. Reconstruction plates are lower profile and easier to contour than standard low contact dynamic compression plates and have been used in small clinical studies with good results. Biomechanical data comparing plate positions and locking technology is limited. One study suggested that the superior plate position had a mechanical advantage in torsion and compression,[1] but no study has examined cantilever bending in recon plates or the effects of locking technology. The purpose of this study was to compare two different plate positions both with and without locking screws for maximizing fracture stability of simulated mid-shaft clavicle fractures.

Materials and Methods: Twenty-four synthetic clavicles with an transverse midshaft osteotomy were repaired with either a 3.5 mm 8 hole small fragment locking or non locking controllable dual reconstruction compression plate (LCDRCP or CDRCP) (Zimmer Inc, Warsaw, Indiana). Plates were positioned in either the superior or anterior inferior plate position (n=6/group). Clavicles were then fixed in a biaxial servohydraulic MTS858 load frame (MTS Co., Eden Prairie, MN) with the piston in line with the mechanical axis of the clavicle. (Figure 1A) 100 cycles of axial compression were performed at 5 N/s between 10 and 500 N, followed by 100 cycles of axial torsion at 0.5 deg/s between ±5 Nmm for 100 cycles. Clavicles were then repositioned horizontally for cantilever bending: the proximal end was rigidly clamped and a support was placed under the screw closest to the fracture on the proximal side of the fracture. The actuator piston was centered on the distal end. (Figure 1B) Failure tests were performed at 0.5 mm/s until 30 mm of displacement or gross mechanical failure. Data for force and displacement were sampled at 10Hz. Stiffness data were calculated and compared across the four groups with 2-way ANOVA (p<0.05) and a Tukey’s post hoc test for individual comparisons.

Results: In compression, anterior inferior plates were significantly stiffer (p<0.0001) than superior plates and LCDRC plates significantly stiffer (p<0.04) than CDRC plates. (Table 1) In torsion, anterior-inferior plates were significantly stiffer than superior plates (p<0.02), though plate type had no significant effect. There was a significant (p<0.03) interaction term favoring anterior reconstruction and superior LCDRC plates. In cantilever failure, superior plates were significantly stiffer (p<0.0001) than anterior-inferior plates but plate type had no significant effect. Failure mechanism also differed, with all anterior plated constructs failing by plate bending and all superior constructs failing by clavicle breakage through the most distal screw hole. (Figure 2)

Discussion: Anterior inferior plates were significantly stiffer than superior plates in axial compression and torsion. Previous work has suggested that the superior plate position was stiffer than the anterior plate position.[1] The anterior-inferior position is closer to the mechanical axis than either the anterior or superior positions. Furthermore this previous study used gimbaled fixtures which allowed clavicles to buckle. They also used cadaveric specimens rather than synthetic models. We opted to use fixtures that did not allow buckling to test resistance to compression and bending separately and to use synthetic specimens for their uniformity.

When the anterior-inferior constructs are loaded in cantilever bending the fracture distracted and the plate bends, so the resistance to loading is completely dependent on the plate bending moment (thickness). The same load for the superior plated constructs caused the clavicle fragments to compress against each other and the plate to act in tension. As the tensile strength of these plates far exceeds their resistance to bending, a plate in the superior position has a mechanical advantage. This finding is only true when bony apposition exists: a severely comminuted fracture repaired with a superior recon plate would fail at loads similar to the anterior inferior constructs. Recon plates may spur earlier healing compared to stiffer plates due to increased load sharing between plate and bony fragments, as seen in a previous clinical study[2]. However, if bony fragment abutment cannot be assured or if there is a need for increased hardware stiffness, such as with osteopenic patients or with a noncompliant patient, stiffer plates should be used.

Table 1

<table>
<thead>
<tr>
<th>Stiffness Measurement</th>
<th>Anterior Inferior LCDRC</th>
<th>Anterior Inferior CDRC</th>
<th>Superior LCDRC</th>
<th>Superior CDRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compression (N/mm)</td>
<td>799±11</td>
<td>512±55</td>
<td>661±62</td>
<td>546±50</td>
</tr>
<tr>
<td>Torsion (N/mm)</td>
<td>32±16</td>
<td>35±16</td>
<td>35±16</td>
<td>35±16</td>
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</tbody>
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Figure 1A/B: A-Torsion/compression setup (left), B-Cantilever failure setup (right)

Figure 2: Failed Clavicles: Anterior above, Superior below


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