Comparison Of The Mechanical Characteristics Of A Universal Small Bi-planar Plating Technique Without Compression Screw To Single Anatomic Plate With Compression Screw

Bret Smith DO, Robert Santrock MD, Daniel Hatch, DPM, Paul Dayton DPM
Comparison Of The Mechanical Characteristics Of A Universal Small Bi-planar Plating Technique Without Compression Screw To Single Anatomic Plate With Compression Screw

Bret Smith DO, Robert Santrock MD, Daniel Hatch, DPM, Paul Dayton DPM

My disclosure is in the Final AOFAS Mobile App.

- I have a potential conflict with this presentation due to:
  - 1, 2, 3B, 4, 5
Statement of Purpose

- To better understand the mechanical characteristics of biplanar locked plating with small flexible plates we conducted a mechanical testing study comparing stability under cyclic loading of a two plate, biplanar construct, to a commonly used construct which utilizes a single inter-fragmentary screw placed with compression technique and single more rigid anatomical locking plate. Our hypothesis was that the biplane construct would maintain stability over a wider range of loading cycles and therefore provide benefit for stable fixation in weight bearing applications.
Methodology

- The **biplanar plating construct (BPP)** consisted of two 1.2mm thick titanium four hole straight locking plates (LAPIDUS CONTROL™ System, Treace Medical Concepts, Ponte Vedra Beach, FL) placed at 90 degrees circumferentially to each other (dorsomedial and medial plantar) and fixated **unicortically** with 2.5x14mm locking screws to produce a biplanar construct with no inter-fragmentary screw.

- The **single locking plate construct (SPS)** consisted of a 1.5mm thick anatomic Lapidus locking plate with four 3.5mm locking screws engaged bicortically and a single 4.0mm inter-fragmentary screw also engaged **bicortically** (DARCO LPS™ 0-step plate and DART-FIRE™ headed screw, Wright Medical, Memphis, TN). Test specimens were constructed using standardized surrogate bone models (Sawbones, Pacific Research Laboratories, Vashon, WA) on a servo hydraulic materials testing machine (MTS, Eden Prairie, MN).
Methodology

- A static cantilever test was first performed (BPP n=2; SPS n=2) to determine ultimate failure for each construct and set the loading parameters for the fatigue tests. For the cyclic testing, an initial cantilever load was applied for the first 50,000 cycles and then increased by 25N each successive 50,000 cycles until failure or 250,000 cycles were reached. Two sets of cyclic testing were performed at different starting load magnitudes. The first set of cyclic testing had an initial starting load of 180N (5.4N*m bending moment) in the plantar loading direction (BPP n=4; SPS n=4). Due to early observed failure of the SPS construct with the 180N plantar starting load, the second set of cyclic testing was performed with a starting load of 120N (3.6N*m bending moment) for the plantar loading direction (BPP n=5; SPS n=5) as well as at a 90 degree offset from the plantar load direction (BPP n=5; SPS n=5) to simulate alternative plate positions and surgical applications. A t-test was used to determine differences between the mechanical performance of the BPP and SPS constructs.
Results of Testing

- The results from static ultimate failure test for plantar bending was 556.2±37.1N (16.7±1.1N*m moment) for the BPP construct and 241.6±6.3N (7.3±0.2N*m moment) for the SPS construct (p=0.007).

- For cyclic failure testing in plantar bending at 180N starting load, the BPP construct failed at a mean of 158,322±50,609 cycles at a load of 242.5±25.0N (7.3±0.8N*m moment) and the SPS construct failed at a mean of 13,718±10,471 cycles at a load of 180.0±0.0N (5.4±0.0N*m moment) (p=0.002). For cyclic failure testing in plantar bending at 120N starting load, the BPP construct failed at a mean of 207,646±45,253 cycles at a load of 205.0±22.4N (6.2±0.7N*m moment) and the SPS construct failed at a mean of 159,334±69,430 cycles at a load of 185.0±33.5N (5.6±1.0N*m moment) (p=0.300). Two of the five BPP constructs and one of the five SPS constructs reached 250,000 cycles (220 N load, 6.6 N*m moment) without failure. For the cyclic testing with 90 degree offset loading (i.e. medial to lateral bending) at 120N starting load, all 5 BPP constructs (tension side) reached 250,000 cycles without failure. The SPS construct failed at a mean of 220,933±35,795 cycles at a load of 210.0±13.7N (6.3±0.4N*m moment) (p=0.14), with two of the five SPS constructs reaching 250,000 cycles (220 N load, 6.6 N*m moment) without failure.
The plating constructs were placed according to the associated manufacturer’s surgical technique guides; (top right) BPP construct, (bottom right) SPS construct
Results of fatigue testing of biplane 1.2 mm titanium plates with uni-cortical locking screws (BPP), against a 1.5 mm anatomic locking plate with bi-cortical locking screws and bi-cortical inter-fragmentary compression screw (SPS)

<table>
<thead>
<tr>
<th>Loading Direction</th>
<th>Construct</th>
<th>Starting Load (N)</th>
<th># Cycles</th>
<th>Failure Load (N)</th>
<th>Failure Moment (N*m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plantar</td>
<td>SPS</td>
<td>180</td>
<td>13,718 ± 10,471</td>
<td>180.0 ± 0.0</td>
<td>5.4 ± 0.0</td>
</tr>
<tr>
<td></td>
<td>BPP</td>
<td>180</td>
<td>158,322 ± 50,609*</td>
<td>242.5 ± 25.0*</td>
<td>7.3 ± 0.8*</td>
</tr>
<tr>
<td></td>
<td>SPS</td>
<td>120</td>
<td>159,334 ± 69,430</td>
<td>185.0 ± 33.5</td>
<td>5.6 ± 1.0</td>
</tr>
<tr>
<td></td>
<td>BPP</td>
<td>120</td>
<td>207,646 ± 45,253</td>
<td>205.0 ± 22.4</td>
<td>6.2 ± 0.7</td>
</tr>
<tr>
<td>90° Offset (Med to Lat)</td>
<td>SPS</td>
<td>120</td>
<td>220,933 ± 35,795</td>
<td>210.0 ± 13.7</td>
<td>6.3 ± 0.4</td>
</tr>
<tr>
<td></td>
<td>BPP</td>
<td>120</td>
<td>250,000**</td>
<td>220**</td>
<td>6.6**</td>
</tr>
</tbody>
</table>

* p < 0.05 (BPP relative to SPS construct)

** All test specimens reached 250,000 cycles (220 N, 6.6 N*m moment) without failure

Mechanical test funded by Treace Medical Concepts, Ponte Vedra, FL.
Proposed clinical application of Biplanar locking plates with uni-cortical screw insertion and no compression screw for MTPJ and TMTJ arthrodesis
Analysis & Discussion

- Comparison of the mechanical characteristics of the BPP construct to the SPS construct shows superior or equivalent stability in multi-planar orientations of force application both in static and fatigue testing. The BPP concept shows promise for clinical application in small bone fixation as it provides consistent stability in multi-planar orientations using low profile plates and unicortical screw insertion, making it universally adaptable to many clinical situations. In addition, relative stability is maintained without an inter-fragmentary screw thereby eliminating surface preload and gap strain, potentially making this technique enable more biologic healing by callus formation.

- Plate thickness and size are key components that determine the rigidity or flexibility of a plate. Additionally, the number and technique for screw insertion has a bearing on stability and flexibility. Fewer screws, especially close to the fusion or fracture site reduce the stiffness of the construct. Also uni-cortical application of the screws can provide an advantage of less overall rigidity and more micro motion. However, the total amount of movement needs to be controlled to avoid instability. A biplane construct of two smaller flexible titanium plates has the advantage of multi-plane stability and some retained flexibility. Uni-cortical insertion requires less time for application because screw measuring is not needed and opens the opportunity for standardized plate systems not requiring multiple screw lengths in a large set. A simple straight flexible plate can be contoured to the surgical anatomy and predetermined length uni-cortical screws can be inserted. A second identical plate and screws is contoured to the anatomy approximately 90 degrees to the first plate to achieve multi-plane stability.
Analysis & Discussion

- When considering the strength and stability of a fixation construct, there are two engineering principles that are considered. Load Failure represents the absolute strength of the construct, which is the force, required to induce complete failure. Another concept is cyclic failure, which is failure after multiple cycles of forces much less that those resulting in load failure (fatigue). In the case of clinical bone fixation it stands to reason that a construct must have enough strength to prevent load failure but even more importantly if the patient is to walk early in the postoperative course, the construct must prevent cyclic failure with repeated loading seen with weight bearing. Considering these facts, and the recent literature that indicates controlled micro motion is beneficial for healing our priority is to find a construct that is strong enough to resist load failure, stable enough to prevent cyclic failure and flexible enough to allow micro motion.

- Although encouraging, the results from this study are limited to non clinical conclusions. The authors are continuing to collect prospective and retrospective clinical data to better understand the clinical application of this biplane concept.
References


