Biomechanical Head-to-Head Comparison of 2 Sutures and the Giftbox vs Bunnell Techniques for Midsubstance Achilles Tendon Ruptures

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Conflicts to Disclose

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Presenter: Rufus Van Dyke MD

The following authors have conflicts to disclose:

Rufus Van Dyke MD
Role: Principle Investigator
My disclosure is in the final AOFAS mobile app.
Received materials at no cost for specimen fixation from Arthrex, LCC.

No other forms of compensation were received in the conduction of this analysis
Introduction

- Midsubstance Achilles tendon repairs commonly have issues with overlengthening and wound healing. Previous studies have aimed to minimize these complications, testing many combinations of different surgical techniques and suture types. Thus far results have been inconclusive.

- Our study compares two non-absorbable braided sutures head-to-head, employing a recently introduced stitch, the Giftbox-modified Krackow.

- Secondly, we also test the Giftbox head-to-head against another more established stitch, the Bunnell.
Methods: Trial 1 Fiberwire vs. Ultrabraid

- 10 pairs of fresh frozen cadaver gastrocnemius/Achilles/calcanei were harvested and the Achilles transected with a scalpel 4 cm proximal to its insertion. Each left Achilles was randomized to receive #2 Ultrabraid or #2 Fiberwire for a Giftbox modified Krackow repair. All Achilles also received an epitendonous repair with 3-0 polypropylene suture to appose the tendon ends.

- After a single surgeon performed all 20 repairs, the calcanei were mounted onto an EnduraTec test frame with the Achilles placed at a 30° angle to simulate the physiologic stress of early heel rise.

- After preconditioning the tendon at 10 N, cyclic loading was then performed from 10 to 100 N at 2 Hz for 1000 cycles in a sinusoidal waveform. Calipers were used to measure any gapping between the tendon ends after 500 and 1000 cycles. Any specimen that exhibited over 5 mm of gapping was considered a “gapping failure” and immediately removed from any further testing.

- All remaining specimens underwent load-to-failure testing at a rate of 0.2 mm/sec. A clinical failure point was recorded with any slippage of the construct and maximum load to failure recorded at the point of catastrophic failure.
• 10 pairs of fresh frozen cadaver gastrocnemius/Achilles/Calcanei were harvested and an incision was made 4 cm proximal to the Achilles insertion on the calcaneus. Each left Achilles was randomized to receive a Giftbox-modified Krackow or Bunnell repair. #2 Fiberwire was used to for all repairs. All Achilles also received an epitendonous repair with 3-0 polypropylene suture to appose the tendon ends.

• After the same single surgeon performed all 20 repairs, the testing set up and procedure was the same as in trial 1.

• 2 specimens showed over 5 mm of tendon gapping after 1000 cycles. Those specimens along with the contralateral specimen were not included in load-to-failure testing.

• All remaining specimens underwent load-to-failure testing at a rate of 0.2 mm/sec, noting when the gap between the tendon ends reached 5 mm and finally the maximum load at catastrophic failure.
Trial 1 Results

- No "gapping failures" occurred during cyclic loading
- Fiberwire withstood significantly higher loads than Ultrabraid before clinical load-to-failure was reached (361 N vs 239 N)
- No significant difference in maximum load-to-failure

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Fiberwire</th>
<th>Ultrabraid</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Specimens</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Mean Clinical Load-to-Failure (N)</td>
<td>361 +/- 118.3</td>
<td>239 +/- 58.3</td>
<td>0.005</td>
</tr>
<tr>
<td>Mean Max Load to Failure (N)</td>
<td>415 +/- 124.2</td>
<td>356 +/- 99.5</td>
<td>0.16</td>
</tr>
<tr>
<td>Mean Linear Displacement after 1000 cycles (mm)</td>
<td>1.18 +/- 0.31</td>
<td>1.36 +/- 0.33</td>
<td>0.2</td>
</tr>
</tbody>
</table>
Two “gapping failures” were observed during cyclic loading, both from the Bunnell group. Two other specimens in the Bunnell group recorded tendon gapping over 2 mm.

<table>
<thead>
<tr>
<th>Trial 2 - Cyclic Loading</th>
<th>Giftbox</th>
<th>Bunnell</th>
<th>P - Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Specimens</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Failed Specimens During Cyclic Loading</td>
<td>0</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Specimens with gapping over 2 mm</td>
<td>0</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Mean Linear Displacement after 1000 cycles (mm)</td>
<td>0.17</td>
<td>2.29</td>
<td>0.065</td>
</tr>
</tbody>
</table>

Mean clinical load-to-failures were 353 N for Giftbox and 285 N for Bunnell.

<table>
<thead>
<tr>
<th>Trial 2 - Load to Failure</th>
<th>Giftbox</th>
<th>Bunnell</th>
<th>P - Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Specimens</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Mean Clinical Load-to-Failure (N)</td>
<td>353 +/- 114.4</td>
<td>285 +/- 81.6</td>
<td>0.16</td>
</tr>
<tr>
<td>Mean Max Load-to-Failure (N)</td>
<td>361 +/- 105.9</td>
<td>336 +/- 83.2</td>
<td>0.61</td>
</tr>
</tbody>
</table>

Bone failures occurred at the mounting Steinman pin during cyclic loading in both calcanei from a single cadaver. These specimen were removed from the study without data inclusion.
Results: Trial 1 vs. Trial 2

- The was no significant difference between the clinical load-to-failure values when comparing the two Giftbox + Fiberwire groups in Trials 1 and 2.

<table>
<thead>
<tr>
<th>Cadaver Demographics</th>
<th>Trial 1</th>
<th>Trial 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Sample Size</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Mean Age (P = 0.98)</td>
<td>73.9</td>
<td>73.8</td>
</tr>
<tr>
<td>Age Range</td>
<td>48-91</td>
<td>53-94</td>
</tr>
<tr>
<td>Males</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Females</td>
<td>5</td>
<td>4</td>
</tr>
</tbody>
</table>
Discussion: Fiberwire vs. Ultrabraid

- Achilles tendons repaired with the Giftbox technique and #2 Fiberwire suture exhibited superior biomechanical characteristics with significantly higher clinical load failure as well as linear displacement (stiffness), in comparison to repairs performed using Ultrabraid ($p = 0.005$). Linear displacement was less with Fiberwire; however, it did not reach statistical significance ($p = 0.20$ and $p = 0.33$). These results are likely due to material and structural differences between the two sutures.

- Ultrabraid seemed to pull through tissues more easily, potentially leading to the lower observed clinical load-to-failure values.

- Maximum load-to-failure did not appear to be clinically relevant. We observed that it typically occurred well after the knot slid through the tissue and many times after over 1 cm of gapping had occurred.
The two instances of “gapping failures” during cyclic load with the Bunnell technique were likely due to the non-locking nature of the stitch and having only 2 of the core sutures crossing the repair site vs. the 4 sutures of the Giftbox.

- The Bunnell does not loop through the tendon as many times or lock. Therefore, the Bunnell may not “grasp” the tendon as well and force is not distributed as evenly throughout the construct.

Removing the “gapping failures” before load-to-failure testing likely decreased the difference between the load-to-failure values for the Giftbox and Bunnell because the repairs that “gapped” during cyclic loading would likely have registered lower clinical load-to-failure values than their Giftbox counterparts that “survived” cyclic loading.

Given our observations of gapping during cyclic loading and current post-operative rehab protocols that allow early weight bearing, future testing should use a more intensive and extended cyclic loading model. Single displacement driven load-to-failure testing does not reflect the repetitive nature of rehab and did not adequately capture the biomechanical differences noted with cyclic loading in this study. This is especially true for maximum load-to-failure, as many of the values obtained were recorded when tendon ends were gapped over 1 cm.
Conclusion

• The Giftbox-modified Krackow outperformed the Bunnell in a head-to-head biomechanical comparison, behaving as a stiffer construct during cyclic loading. There was also a trend toward higher clinical load-to-failure values, but it was not statistically significant.

• Fiberwire suture is associated with significantly stronger Achilles tendon repairs than Ultrabraid in biomechanically tested cadaver tendons.

• This study’s experimental design produced consistent results
  – Giftbox + Fiberwire repairs from Trial 1 and Trial 2 behaved almost identically under biomechanical testing.

• More head-to-head comparisons of fixation combinations in human specimens are needed to determine a single, optimal repair construct.

• Maximum load-to-failure values appeared to lack clinical relevance.


