Biomechanical evaluation of distal biceps reconstruction with cortical button and interference screw fixation

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**Hypothesis:** Tension slide repair maintains the strength of the standard cortical button repair but reduces gap formation at the repair. Distal biceps tendon repair with a suspensory cortical button has yielded the strongest published repair, despite observed gap formation and tendon pistoning. The tension slide technique (TST) was described to reduce gap formation while maintaining the strength of cortical button repair. This study evaluates the biomechanics of the TST compared with previously described EndoButton (Smith & Nephew, Memphis, TN) repair and the TST with and without an interference screw.

**Materials and methods:** The study used 20 matched specimens: 5 had a standard cortical button repair, and 5 had biceps repair with the TST. An additional 10 specimens underwent a TST, 5 with an interference screw and 5 without. All were cyclically loaded for 3600 cycles. Gap formation and load to failure were measured.

**Results:** The mean (SD) load to failure for standard technique was at 389 (148) N vs 432 (66) N for the TST ($P$ = .28). The mean (SD) gap formation was 2.79 (1.43) mm with the standard repair and 1.26 (0.61) mm with the TST ($P$ = .03). The mean (SD) load to failure with TST repair was 436 (103) N without the interference screw and 439 (94) N ($P$ = 0.48) with the screw. The mean gap formation was 1.63 (1.09) mm without the screw and 1.45 (0.67) mm with the screw ($P$ = .38).

**Conclusion:** This TST maintains the strength of the standard cortical button repair, but significantly reduces gap formation and motion at the repair site.

**Level of evidence:** Basic science study.

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**Keywords:** distal biceps; repair; gap formation; cortical button; interference screw

Rupture of the distal biceps brachii tendon has received significant attention in recent reports as a result of increased incidence and improvements in diagnosis.\textsuperscript{1,3} Conservative treatment has led to observed deficiencies in elbow supination and to a lesser degree elbow flexion, providing the rationale for anatomic repair in the active patient with a distal biceps tendon rupture.\textsuperscript{4,6,9,13,14,15,17,18} Biomechanical studies evaluating the mean failure strength have been reported; few of these studies also examined cyclical loading and gap formation of repair constructs.\textsuperscript{5,11} Cortical button fixation most frequently yielded the highest loads to failure, although suture anchor repairs also performed well.\textsuperscript{7,10,11,12,16} Unfortunately, the strongest methods of fixation have been associated with higher mean gap formation between the tendon and bone
after cyclical loading. In our previous studies, we observed pistoning and macromotion at the repair sites during biomechanical testing. This observation led us to develop the tension slide technique (TST) to reduce this motion.17

Our goal was to assess the biomechanical properties of the TST distal biceps repair, performed through a minimally invasive single anterior approach designed to minimize gap formation, restore the anatomic footprint, and maintain the superior strength of cortical button fixation. We present the biomechanical analysis of cortical button distal biceps repair comparing Bain’s standard technique2 with the TST, as well as the TST with and without interference screw.

Materials and methods

Investigational Review Board approval was not required for this study.

The study used 20 matched specimens. In the first arm of the experiment, 5 had a standard cortical button repair with 2 No. 2 sutures performed as described by Bain et al.,5 and 5 had biceps repair with the TST, with 1 No. 2 suture. In the second arm of the experiment, an additional 10 specimens underwent a TST repair. Five of these specimens were additionally repaired with an interference screw and 5 without.

Before reconstruction, a 0.1875-inch threaded rod was cemented into the distal radius and a second threaded rod was inserted into the distal humerus. The threaded rod in the radius created an adjustable moment allowing the applied weight to be positioned such that a 50-N force was seen at the insertion of the biceps tendon.

The repairs were performed according to the following descriptions.

The standard technique was performed as described by Bain et al.2 Biceps were repaired using a biceps button (Arthrex, Naples, FL) instead of an EndoButton (Smith & Nephew, Memphis, TN), and 2 No. 2 FiberWire sutures (Arthrex, Naples, FL). These were sutured in a Krakow fashion, leaving 2 mm of suture between button and tendon. A Beath pin was used to pull the tendon into an 8-mm socket in the radial tuberosity, and the button was flipped.

The TST technique was performed as described by Sethi et al.17 The TST used 1 No. 2 polyester (Fiberloop, Arthrex, Naples, FL) suture to secure the distal 2.5 cm of the biceps tendon in locking-loop fashion. The suture was then threaded through the biceps button. The first strand was fed through the right hole then back through the left hole. Then the opposite was performed with the other tail of the same suture, with the strand being fed through the left hole then back through the right hole. The end result is to have the strands facing toward the distal biceps tendon.

In both arms of the experiment, a 3.0-mm guide pin was then drilled through the central aspect of the radial tuberosity from anterior to posterior, aiming 15° in the ulnar direction. The anterior cortex and intramedullary canal were then reamed with an 8.0-mm cannulated reamer to allow for flush seating of the end of the distal biceps tendon.

The standard repair was then passed through the radial tuberosity with a Beath pin, and a toggle suture was used to “flip” the button. In contrast with the TST, a button inserter, which holds the button, was then used to pass the button through the tuberosity. The button was released from the holder and a tactile release of the button was appreciated. The button was tested at this point by pulling back on the suture limbs. One limb of each suture was then grasped in each hand and slowly tensioned. As this was performed, the biceps docked itself in the prepared bone socket. One limb of the suture was then brought through the tendon and then tied. In the specimens where an interference screw was used, 1 limb of the suture was passed into the Biotenodesis Screw Driver (Arthrex, Naples, FL), a 7- × 10-mm screw (Arthrex, Naples, FL) was then inserted on the radial side of the tuberosity to push the tendon against the ulnar aspect of the cortex, and the suture limbs were tied over the screw.

Specimens were randomly reconstructed and tested using an MTS (MTS Systems Corp, Eden Prairie, MN). The elbow was mounted anatomically with the humerus held in a rigid clamp in line with the actuator. The biceps reconstruction was secured to the actuator by a custom sinusoidal clamp attaching to the biceps tendon at the muscular tendinous junction. Once this specimen was mounted, the forearm was positioned at 90° of flexion and a 2-lb weight was adjusted by using the threaded rod in the radius to create a 50-N force at the biceps insertion. The force of 50 N was based on the expected passive contraction force of the biceps tendon in the early postoperative period. This load was registered through a 2500-N load cell. A 5- × 5-mm block of foam bone substitute was glued to the radial tuberosity just distal to the reconstruction.

A 9-mm differential variable reluctance transformer (DVRT; MicroStrain, Burlington, VT) was used with one end of the DVRT inserted into the foreign bone substitute and the other end inserted into the biceps tendon reconstruction. Once the load was properly configured, the specimen was cycled dynamically from full extension to 90° of flexion at a rate of 0.5 hertz. This method of nonrestricted loading allowed the forearm to go from pronation to supination as the arm is flexed. The DVRT measured displacement through 3600 cycles at a rate of 0.5 hertz.

After cyclic loading was complete, specimens were loaded to failure. This was accomplished by restraining the arm at 90° of flexion and loading at a rate of 120 mm/min until reconstruction failure. Displacement data were recorded with accuracy of ± 0.5 mm, and load of failure data were recorded to ± 0.5 N. Mechanism of failure was recorded as well as final load and maximum displacement over 3000 cycles. Displacement and load to failure data were compared and analyzed (Figures 1–4).

Results

In the first arm of the experiment, the mean (standard deviation [SD]) load to failure for the standard technique was at 389 (148) N vs 432 (66) N for the TST (P = .282; Table I). The mean gap formation was 2.79 mm with standard repair and 1.26 mm with the TST. This difference was significant (P = .03; Table II). Stiffness of the constructs was 14 N/mm and 20 N/mm, respectively.

In the second arm of the experiment, the TST repair without the interference screw had a mean (SD) load to failure of 436 (103) N vs 439 (94) N repair with the screw (P = .477; Table I). The mean gap formation was 1.63 mm without the screw and 1.45 mm with the screw (P = .384; Table II); stiffness was
20 N/mm and 25 N/mm, respectively. There were no statistically significant differences.

Power calculations of these findings on gap formation revealed that with an \( \alpha \) level of .05, \( P = .64 \) and \( P = .09 \) in the first and second arms of the experiments respectively. To detect if there is a significant difference present between the TST with and without the interference screw in the second arm of the experiment, with an \( \alpha \) level of .05 and power of .80, 330 specimens would be needed in each group. For the load to failure, power calculations revealed that to determine if a significant difference were present,

\[
\begin{align*}
P &= \frac{\text{power}}{\text{significance level}} \\
&= \frac{.80}{.05} \\
&= 16
\end{align*}
\]

with an \( \alpha \) level of .05 and power of .80, 87 and 8926 specimens would be needed in each group of both arms of the experiment, respectively.

The mode of failure for specimens with dual fixation (button and screw) was tendon failure. None of the interference screws pulled out, and the cortical button actually tore through the bone failure method in 1 specimen. Specimens fixed without interference screw failed by a combination suture and knot slippage as well as tendon failure.

Discussion

In our previous studies, we observed pistoning and macromotion at the distal biceps repair sites during biomechanical testing. This present study and technique were specifically designed to address the repair site motion and technical issues associated with suspensory cortical button repair of the distal biceps tendon.
Biomechanical studies evaluating the mean failure strength have been reported; however, few of these studies also examined cyclical loading and gap formation of the repairs. These studies have suggested that cortical button fixation and suture anchor fixation both have high yield strengths, but that interference screw fixation had the least gap formation.5,7,8,11 Mazzocca et al11 compared 4 techniques of distal biceps repair. A biomechanical model was used to compare bone tunnel, EndoButton, suture anchor, and interference screw techniques. The EndoButton technique had a statistically significant highest load to failure (440 N) compared with the suture anchor (381 N), bone tunnel (310 N), and the interference screw (232 N).11 The EndoButton had the highest load to failure in other studies as well.8

The load to failure for the TST was consistent with our previous findings, and not significantly different from a standard technique.4 Values indicate that the mean load/strength differences between the groups in the 2 samples are not statistically significant (P < .05).

Displacement after cyclical loading may have important consequences in the setting of early postoperative range of motion and on healing. Standard techniques with cortical button fixation (ie, not using a tension slide) have reported 2.59 mm after only 1000 cycles.5 Mazzocca et al11 reported that EndoButton had the second highest displacement (3.42 mm) compared with the bone tunnel (3.55 mm), suture anchor (2.33 mm), and interference screw (2.14 mm). Despite the minimized gap formation, almost 30% of suture anchor and interference screw repairs in this series failed during cyclical loading.11 Bisson et al5 reported that 2 different suture types fixed to a bone tunnel yield 6.8 to 6.9 mm of tendon displacement before failure.5

All of these methods suggest that pistoning of the tendon occurs with elbow motion. This macromotion could certainly delay or inhibit direct tendon healing and provide a basis for identifying a method to decrease this motion. These data also suggest that early motion with the suture anchor technique should be used with caution.

In the TST repair, gap formation between the biceps tendon and radial tuberosity is minimized. Gapping was measured between 1.26 and 1.45 mm after 3600 cycles. This result is favorable compared with any study that has evaluated gap formation. The ability to tension the distal biceps tendon/button complex through the anterior incision and dock the tendon flush against the posterior aspect of the radial tuberosity is unique to this procedure and may be important.

### Table I

<table>
<thead>
<tr>
<th>Variable</th>
<th>Samples, No.</th>
<th>Peak load/strength, N*</th>
<th>95% CI</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard technique</td>
<td>5</td>
<td>388.67 ± 148.01</td>
<td>204.89-572.45</td>
<td>.282</td>
</tr>
<tr>
<td>TST</td>
<td>5</td>
<td>432.24 ± 66.12</td>
<td>350.14-514.34</td>
<td></td>
</tr>
<tr>
<td>TST, no screw</td>
<td>5</td>
<td>435.61 ± 103.39</td>
<td>307.23-563.99</td>
<td>.477</td>
</tr>
<tr>
<td>TST, with interference screw</td>
<td>5</td>
<td>439.29 ± 94.12</td>
<td>322.43-556.16</td>
<td></td>
</tr>
</tbody>
</table>

CI, Confidence interval; SD, standard deviation; TST, tension slide technique.

* Values indicate that the mean load/strength differences between the groups in the 2 samples are not statistically significant (P < .05).

† Difference between the means, 1-sided.

### Table II

<table>
<thead>
<tr>
<th>Samples, No.</th>
<th>Displacement, mm</th>
<th>Displacement difference, mm</th>
<th>95% CI</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard technique</td>
<td>5</td>
<td>2.788 ± 1.432</td>
<td>1.532 ± 1.100</td>
<td>-0.072 to 3.137</td>
</tr>
<tr>
<td>TST</td>
<td>1.256 ± 0.609</td>
<td>0.175 ± 0.901</td>
<td>-1.140 to 1.489</td>
<td>.384</td>
</tr>
<tr>
<td>TST, no screw</td>
<td>5</td>
<td>1.627 ± 1.086</td>
<td>1.452 ± 0.668</td>
<td></td>
</tr>
<tr>
<td>TST, with interference screw</td>
<td>5</td>
<td>1.452 ± 0.668</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

CI, Confidence interval; SD, standard deviation; TST, tension slide technique.

* Value for the difference (1-sided).

† Significant value (P < .05).
in minimizing gap formation. None of the specimens tested failed during cyclical loading. These data suggest that this repair is durable under cyclical conditions, designed to mimic early postoperative range of motion.

The addition of the interference screw did not significantly affect the ultimate tensile load, reduce the gap formation, or improve the stiffness of the construct. From a biomechanical standpoint, the screw does not improve the repair mechanics and clinically would add both time and cost to the procedure. We believe that the screw also helps to restore preinjury anatomy with particular respect to the ulnar position of the tendon. The supination moment of the biceps may be improved by accurate footprint recreation, although this requires further study.

The primary weakness of this study is the small number of specimens and the low power associated with the load to failure. This is a dilemma in many biomechanical tests, and obtaining the correct number of specimens is cost prohibitive. Nonetheless, the TST was certainly not weaker than the strongest known repair (standard EndoButton technique) and has statistically less macromotion at the tendon-bone interface during cyclical loading. We also advocate the use of 2 implants, which is more costly than other surgical alternatives, and we believe that cost containment, when possible, is an important part of our role in health care delivery. Furthermore, this is an industry-supported study, with inherent (not intentional) conflicts of interest. Despite these limitations, we believe that we are able to show that the TST maintains the strength of previously reported cortical button repairs and reduces the gap formation.

In conclusion, the TST is a useful modification of existing techniques to repair distal biceps tendon ruptures. The advantages of the technique include a small 1-incision anterior approach, the ability to tension the repair from the anterior incision, and the strength of cortical button fixation. There is no need to predetermine the length of suture between the button and the biceps, and minimal concern about the button flipping. The TST is supraphysiologic with respect to strength and approaches the native stiffness with the addition of a screw. This, when combined with the favorable biomechanical performance of this repair, have encouraged us to use this technique on acute distal biceps repairs. These data have further allowed us to move our clinical repairs immediately postoperatively with immediate activities of daily living, without a brace, and without complication.

References


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