A Cortical Suspension Technique for Distal Pole Patella Tendon Repair: Biomechanical Evaluation Versus Transosseous Tunnel Suture Repair and Suture Anchor Repair Techniques

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Introduction: Patella tendon ruptures are disabling injuries that generally occur in active individuals under the age of forty. The mechanism of injury is typically a rapid, eccentric contraction of the quadriceps against full body weight with the knee in a position of partial flexion. The injury most commonly occurs at the distal pole of the patella and surgical repair is necessary to ensure return of a functional extensor mechanism. The most commonly described repair technique involves 4-stranded suture fixation of the patella tendon with a Krachow locking stitch and repair through transpatellar drill holes. This technique often requires some form of augmentation to enable early mobilization. In recent years, several authors have promoted the use of suture anchors for patella tendon repairs. There is no consensus regarding optimal augmented repair technique, subsequent duration of immobilization and/or rehabilitation protocol. Cortical button (CB) fixation is a secure method for anchoring tendons/ligaments, but it has not previously been used in patella tendon repair. This study evaluates a novel patella tendon repair technique using cortical suspension fixation.

Methods: Twenty-four fresh-frozen cadaveric knees were used to compare three techniques of patella tendon repair following patella tendon rupture. Specimens were divided into three groups such that mean donor age, weight and height were closely matched for the three groups. In each specimen the patella tendon was sectioned at the distal pole of the patella.

Three repair groups were prepared for mechanical testing:
1) SR (Standard transpatellar tunnel suture repair) - performed using a 2 suture, 4 strand repair originally described by Krachow, using No. 2 FiberWire (Arthrex, Naples, FL). Three parallel transpatellar tunnels are drilled from inferior to superior in the patella, dividing the patella into quarters. Two separate sutures are placed in the patella tendon via the Krackow whipstitch method, and the ends of each suture are then passed superiorly through the transosseous tunnels and tied.
2) SA (Suture anchor repair) - Two 5.5 mm corkscrew PEEK suture anchors, each fitted with No. 2 FiberWire sutures are placed med/lat from the distal pole dividing the patella into thirds. Each suture is secured into the patella tendon using a modified Mason-Allen technique for a total of 4 suture loops placed in the tendon.
3) CB (Cortical button (Tightrope, Arthrex) repair) - two strands of FiberTape suture (Arthrex) were passed vertically through the midsubstance of both sides of the tendon exiting proximally at the sectioned end of the tendon. The free proximal ends of the FiberTape were each passed through the looped end of an ACL Tightrope device (Arthrex) and then worked back down distally through the tendon. The FiberTape repair was augmented by running No. 2 FiberWire in a baseball type stitch from distal to proximal on either side of the tendon, weaving through the FiberTape. Two 4.5mm vertical transpatellar tunnels were drilled from inferior to superior in the patella dividing the patella into equal thirds. The Tightrope oblong buttons were passed through the tunnels allowing the buttons to lie flush
with the antero-proximal surface of the patella near the pole. The Tightrope buttons were then tightened until adequate apposition of the cut tendon ends has been achieved. All repairs were performed at 45° of knee flexion.

Specimens were tested using a custom apparatus (Fig.1) based on biomechanical testing protocols established by Bushnell et al and Ravalin et al. A 22.25N weight was positioned on each distal tibia to produce a 735N-cm moment on each knee at full extension per the Bushnell/Ravalin protocols. Knees were first cycled from 90° flexion to full extension up to 250 cycles and gap formation at the repair site was monitored at 1, 10, 100 and 250 cycles. Gap opening was measured using a 9mm M-DVRT sensor (LORD Microstrain, Williston, VT) straddling the repair site. Specimens surviving cyclic loading were then loaded to catastrophic failure with maximum load and failure mode recorded. Standard ANOVA means comparisons (Graphpad Instat, San Diego, CA) were used in comparing gap formation and maximum load to failure data for each of the three groups.

Results: Two specimens were lost to testing (one SA and one SR) during the specimen preparation and initial testing phase of the project, leaving SA (n=7), SR (n=7) and CB (n=8). CB repair had significantly less gap formation than SA repair after 1 cycle (p <0.001) and 20 cycles (p<0.01) and significantly less gap formation than SR (Krackow) repair after 1, 20, 100 and 250 cycles at p<0.05. See Fig. 2.

All SA repairs failed through the suture. SA repairs failed at the suture-anchor eyelet interface (n= 4) or by anchor pullout (n=3). In 7/8 specimens, maximum achievable load in CB specimens was limited by fraying of the quad tendon at the sutured tendon to load strap interface rather than repair construct failure. One CB repair demonstrated limited subsidence along a superior-anterior fissure in the patella in addition to quadriceps fraying. Additional load to failure tests were performed on CB constructs applying tensile load directly to the patella (i.e. with quad tendon removed) to determine repair construct ultimate load. CB repairs sustained significantly higher loads to failure (1530N ± 59N SEM) than anchor repair (648N ± 53N SEM) and suture repair (662N ± 31N SEM) at p<0.001. See Fig. 3.

Subsequent to mechanical tests all patellae were CT-scanned and mean Hounsfield units (HU) and total bone volume in the HU threshold range of 148-1600 HU was determined for each patella using MIMICS Software (Materialise, Leuven, Belgium). In each of the three test groups, there was no significant correlation between failure load and mean HU or bone volume. Anchor pullout in the SA group did occur, however, at three of the four lowest bone volumes for that group.

Discussion: Patella tendon repair using cortical suspension fixation demonstrated mechanical advantages over suture and anchor repair in cadaveric specimens both in terms of reduced cyclic load gap formation and in a greater than 2x increase in construct catastrophic load to failure versus the current standard repair method (SR) and the suture anchor repair method. The increased safety factor in maximum load capacity and reduced gap formation with cyclic loading are definite advantages with respect to potentially accelerated rehabilitation protocols. The approximate cost difference between anchors and cortical suspension instrumentation is approximately 15-20%.

Significance: The demonstrated mechanical advantages of distal pole patella tendon repair using cortical button fixation support the consideration of this technique for use in clinical practice subsequent to appropriate clinical assessment.
Figure 1: Flex/Ext Cyclic Test Set-up
Figure 2: Gap Formation By Repair Construct

<table>
<thead>
<tr>
<th></th>
<th>Cortical Button Repair</th>
<th>Suture Anchor Repair</th>
<th>Suture Repair</th>
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</thead>
<tbody>
<tr>
<td>1 Cycle</td>
<td>2.3 ± 0.4mm</td>
<td>5.9 ± 0.6mm</td>
<td>4.2 ± 0.4mm</td>
</tr>
<tr>
<td>20 Cycles</td>
<td>4.1 ± 0.6mm</td>
<td>7.6 ± 0.5mm</td>
<td>6.4 ± 0.7mm</td>
</tr>
<tr>
<td>100 Cycles</td>
<td>5.7 ± 0.7mm</td>
<td>7.7 ± 0.7mm</td>
<td>8.5 ± 0.3mm</td>
</tr>
<tr>
<td>250 Cycles</td>
<td>6.6 ± 0.8mm</td>
<td>8.4 ± 0.7mm</td>
<td>9.2 ± 0.2mm</td>
</tr>
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* Indicates significant difference from cortical button repair (p<0.05).
Figure 3: Maximum Load to Failure

* Cortical button repair significantly different from suture anchor and suture repairs (p<0.001).

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