THE EFFECT OF HUMERAL ELEVATION ANGLE ON THE PULLOUT STRENGTH OF SUTURE ANCHORS

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ABSTRACT INTRODUCTION:
Rotator cuff injuries account for more than 4.5 million physician visits annually in the U.S. Injuries to the rotator cuff are typically treated arthroscopically by using implanted suture anchors for the repair. Common suture anchor designs include variations in thread design and the material used. The primary objective of this study was to understand and model the effects of frontal plane humeral elevation and anchor type on the pullout strength of common suture anchors. We examined both titanium and resorbable suture anchors in this study. Our hypothesis was that the humeral elevation angle in the frontal plane will have a greater effect on pullout strength compared to the thread design or material choice.

METHODS:
This study was performed on polyurethane foam proximal humeral models (Model 1051, Pacific Research Labs, Vashon Island, WA) for the elevation angle study and 5 lb-ft² and 10 lb-ft² polyurethane foam blocks (Model 1522-23, and 1522-01. Pacific Research Labs, Vashon Island, WA) for the thread form study. To evaluate suture anchor thread form and material choice, we used a 5mm PLA (poly lactic acid) biodegradable anchor (Mitek Spiralok™) and 6.5mm titanium anchor (Smith & Nephew Twinfix™). Ten tests were performed for each anchor type for a total of twenty tests. The anchor was threaded such that the axis of the screw was perpendicular to the block surface and top of the anchor was flush with the polyurethane block. The anchor was pulled out along the axis of the screw until failure in a materials testing system at 0.15 mm/s (Instron 2200,Instron Corp, Norwood, MA). To evaluate the affect of elevation angle and thread form, we used the 6.5mm Smith & Nephew Twinfix™, 5mm Mitek Fastin™, and 3.5mm Smith & Nephew Twinfix suture anchors to examine the effect of humeral angle on the pullout strength. Custom fixturing was designed to allow for the tendon pull to be set to various angles in a materials testing system (Bose SmartTest SP, Eden Prairie, MN). Three humeral angles were 120°, 150°, and 180° measured with respect to the horizontal. For the case where the angle is 180°, the line of action of the force is aligned with the humeral shaft. A design of experiments was performed to populate a runs order of three different anchors and three different frontal elevation angles. The suture anchor was inserted into the humeral head greater tuberosity at an angle of 45° to the axis of the humerus and threaded to a depth such that the top of the anchor was flush with the surface of the humerus. The JMP Statistical software (SAS Institute, Cary, NC) was used for the analysis of data for this study. For the uniaxial tests, the suture anchors were grouped according to type and the polyurethane blocks were grouped according to density. A student’s t test was performed to see significant pullout differences between block density and suture anchors. An F test was used to see the probability that the two distributions being examined are statistically similar. F ratios were calculated to examine the contribution of each source (anchor, angle, density, and interactions) on the variance seen in the model. Tukey’s HSD (Honest Significance Difference) analysis was also used to compare all possible pairs of means for the three anchors of the angle evaluation.

RESULTS SECTION:
The simple pullout analysis of the Mitek and Smith and Nephew screws led to a model for pullout force as a function of thread diameter in mm and polyurethane foam (Table 1). The regression model R² was 0.98 with both coefficients p-values <0.0001. A regression analysis was performed for the pullout force as a function of the humeral angle and the anchor diameter (Figure 1). The model R² was 0.92 and the coefficients p-values <0.0001.

DISCUSSION:
It was our hypothesis that thread design and material would not significantly affect the pullout strength of suture anchors. Table 1 confirms that the density of block and diameter of the anchor are significant. Surprisingly, our model predictions fit the data very well and agree with the literature values. The model even agrees with the ¼ -20 screws data from Nien and coworkers. This shows that the holding power of a suture anchor is really dependent on the overall size, rather than the thread design or material.

Table 1. Pullout data for three screws in different polyurethane foams. The data on the ¼ - 20 screws were taken from the literature¹.

<table>
<thead>
<tr>
<th>Screw Type</th>
<th>Pullout Force (N)</th>
<th>Model Pullout Force (N)</th>
<th>Thread Diameter (mm)</th>
<th>Foam Density (pcf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0 Mitek</td>
<td>68.6±2.9</td>
<td>65.1</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>181.1±15.2</td>
<td>184.5</td>
<td>5.0</td>
<td>10.0</td>
</tr>
<tr>
<td>6.5 S&amp;N</td>
<td>84.8±4.6</td>
<td>88.2</td>
<td>6.5</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>211.1±5.4</td>
<td>207.5</td>
<td>6.5</td>
<td>10.0</td>
</tr>
<tr>
<td>1/4-20 Screw</td>
<td>155.5±5</td>
<td>156.7</td>
<td>6.4</td>
<td>8.0</td>
</tr>
</tbody>
</table>

Figure 1. Model predictions of pullout for compared to experimental data.

Since we have shown that the anchor size is really the only important factor, we used the diameter as a variable in the model and obtained a very good model fit which confirms our hypothesis that as the humeral angle increases, the force to pull out the anchor decreases.

While the humeral model demonstrates that as the humeral angle increases, the pullout force decreases, the simple pullout demonstrates that the density of the foam has a much more profound affect on the pullout strength of the anchor. From Table 1, it can be seen that the pullout strength for an anchor decreases by nearly a factor of three if the density is reduced by a factor of two.

The size of suture anchor also contributed to the traumatic failure of the interface. It was observed that the pullout of the 6.5mm Smith & Nephew anchor produced large areas of bone damage. In comparison, the smallest 3.5mm Smith & Nephew anchor, produced a clean and less traumatic pullout. There is a clear tradeoff between the pullout strength and traumatic failure. The larger anchors provide higher pullout forces, but also larger areas of damage when failure occurs.

A limitation of this study is that it does not account for anchor placement and the effects of the cortical thickness on the humeral head. Those types of data are better obtained using cadaveric tissue. However, the problem with a cadaveric tissue study is that the intrinsic variability of the tissue leads to a much larger sample size requirement.

We conclude that as the humeral angle increases, the anchor holding force decreases; and that suture anchor diameter and bone density are the most important factors for estimating holding force for a suture anchor.

REFERENCES:

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