FAILURE MODE OF SUTURE ANCHORS AS A FUNCTION OF INSERTION DEPTH

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INTRODUCTION
A high proportion of successful rotator cuff repairs are left with residual deficiencies in the cuff. Previous biomechanical studies reported failures via suture cutting through bone tunnels, suture breakage, knot slippage, suture anchor pull out, and soft tissue failure at the suture-tendon junction. Due to the clinical failures discussed above, surgeons often “bury” the anchor or place the anchor at twice the normal depth to improve pullout strength. It is unclear, however, if the depth of anchor insertion may have an influence on failure characteristics. New modes of failure could be either weakening of the suture at the tunnel entrance or anchor eyelet during cyclic loading with abrasion and mechanical degradation of the suture, or suture cut out through the bone. The purpose of this study was to determine if anchor insertion depth has an effect on the failure characteristics of sutures and suture anchors used in rotator cuff repairs.

METHODS
Thirty metallic OBL (Smith and Nephew, Memphis, TN) 5.0 mm screw-in suture anchors loaded with a single number 2 braided nonabsorbable polyester suture were randomly inserted at 3 depths (proud, standard, and deep) in four, 12 week old bovine humeri. Immature bovine bone has reported a bone density of 0.8g/cm³, similar to the value reported for young humans¹, making the bovine model a viable biomechanical testing option.

Anchors were placed in the rotator cuff insertion site of the infraspinatus tendon after soft tissue resection. Anchors were placed 1 cm away from an adjoining anchor in a random pattern. The “proud” anchors were inserted with the shallowest part of the threaded portion of the anchor flush with the bone surface in the middle of the hole. The “standard” anchors were inserted according to the manufacturer’s guidelines with the first laser line flush with the bone surface (threads 3mm counter sunk). The “deep” anchors were inserted at twice the depth of the standard anchors (6 mm) (Figure 1).

Figure 1: Anchor insertion techniques.

The anchor was placed into the bone at an angle of 45 degrees to maximize purchase. Each shoulder was tested with an equal number of proud, standard, and deep anchors (n=3). Surgical knots were used to create a closed loop and concentrate the failure mechanism at the suture-bone-anchor interface. The loop was then attached to a MTS 858 machine (Eden Prairie, Minnesota) over a smooth metallic rod. The humerus was held in place with a custom fixation rig. Sutures were marked at the
eyelet and within the rig to accurately determine the location of failure. The direction of suture pull was perpendicular to the angle of insertion of the suture anchor. The sutures were then placed under 10 N of pre-load and cyclically loaded from 10 to 90N at 0.5 Hz to a maximum of 500 cycles. If still intact after 500 cycles, the sutures were loaded at 0.5mm/sec to failure. The number of cycles, mode of failure and maximal failure load were recorded for each specimen. All data were compared with a one-way ANOVA (p<0.05), employing a Tukey’s post-hoc test for multiple comparisons.

RESULTS
There was a significant difference in the number of cycles to catastrophic failure between the deep and both the standard and proud sutures (p<0.0004) (Table 1). No deep construct failed early via suture breakage. Four out of eleven standard depth and 6/9 proud depth anchors failed early during cyclic testing. All early failures in these groups occurred by suture failure at the anchor eyelet. There was no statistical difference in cyclic failure between the proud and standard anchors (Table 1). Using 3 mm of displacement as a standard for clinical failure, the sutures in the deep anchor group failed earlier than the standard and proud anchor groups. In 9/10 of the deep specimens, failure via gross cutting through the cortical margin of the bone was observed and occurred at an average of 8 ± 6 cycles. The standard anchors failed to the 3 mm level at an average of 12 ± 2 cycles with a variable degree of bone cut through. The proud anchor sutures failed at the 3mm clinical level at an average of 30 ± 31 cycles. There was no statistical difference between the deep and standard anchors in number of cycles to 3mm of failure. In evaluating ultimate load failure, the deep anchor had a statistically greater failure load than either the even anchors or the proud anchors. In all deep construct specimens, ultimate failure occurred at the knot at a mean of 165 ± 18N. For the even constructs the mean ultimate failure was 133 ± 38N, while the proud anchors had the lowest failure load of 112 ± 36N.

SUMMARY
Based upon these data, burying suture anchors beyond the specified insertion depth is inadvisable. Excessive anchor depth may lead to early clinical failure by the suture cutting through bone, and is of specific concern for osteoporotic bone. It is clear that suture abrasion at the anchor eyelet may result in catastrophic failure of the repair construct. There are two potential solutions for this phenomenon. Anchor eyelets should be designed to lessen the possibility of abrasive degradation of the suture, and abrasion-resistant materials should be developed in order to decrease the risk of suture fretting.

REFERENCES

ACKNOWLEDGEMENTS
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<table>
<thead>
<tr>
<th>Anchor Depth</th>
<th>Cycles to Catastrophic Failure *</th>
<th>Cycles to 3mm of Failure **</th>
<th>Max Failure Load (N)***</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep</td>
<td>500 ± 0 *</td>
<td>8 ± 6</td>
<td>165 ± 18 ***</td>
</tr>
<tr>
<td>Even</td>
<td>377 ± 197</td>
<td>12 ± 2</td>
<td>133 ± 38</td>
</tr>
<tr>
<td>Proud</td>
<td>259 ± 207</td>
<td>30 ± 31 **</td>
<td>112 ± 36</td>
</tr>
</tbody>
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* p <0.0004  ** p <0.02  *** p <0.005