Abstract
There are a variety of arthroscopic devices used to pass sutures through the rotator cuff for its repair. Because they vary in size and shape, it is possible that they could damage the cuff and affect the integrity of the repair. We chose four devices for assessment—SutureLasso™ (Arthrex, Naples, FL), straight BirdBeak™ (Arthrex, Naples, FL), Viper™ (Arthrex, Naples, FL), and a #7 tapered Mayo needle—and performed cuff reattachments in four paired shoulders using suture anchors. These repairs were cycled and tested to failure. The SutureLasso™ and Mayo needle repairs failed at approximately 285 N whereas the BirdBeak™ and Viper™ failed during cycling at 150 N. It appears that the devices, which made the bigger holes in the cuff, can compromise the integrity of the repair.

Materials and Methods
Four matched pairs of fresh frozen cadaveric shoulders were utilized. After thawing, the supraspinatus was removed at its origin along with the humerus. A rotator cuff tear was created by dissecting the supraspinatus from its insertion on the greater tuberosity. The supraspinatus tendon was then split longitudinally to allow two repairs per shoulder.

Rotator cuff repairs were performed with two 5-mm Bio-Corkscrew™ suture anchors (Arthrex, Naples, FL) preloaded with #2 Ethibond. For the first repair, suture anchors were inserted 5 mm from the articular cartilage margin and 1 cm apart at 45° to the long axis of the humeral shaft. For the second repair on the same humerus, the anchors were inserted 0.5 cm from the first anchors. Four suture passers were tested with each pair of shoulders: SutureLasso™ suture passer (Fig. 1), straight BirdBeak™ suture passer (Fig. 2), Viper™ suture passer (Fig. 3), and a #7 tapered Mayo needle.

The tendon was held taut by the ends using a clamp specifically designed for this purpose and one leg of the sutures from each anchor was passed 1 cm from the edge of the tendon and tied with an arthroscopic, Roeder sliding knot using a standard knot pusher and followed by 3 alternating half-hitches with alternating posts; the other suture legs were then passed and similarly tied.

The humerus was cut at a level 7 cm below the greater tuberosity and secured to the actuator of a servohydraulic mechanical testing machine (MTS, Eden Prairie, MN) in an angle vise simulating 45° of abduction as previously described. This corresponds to the angle at which the greatest force is placed across the tendon in vivo.
free end of the tendon was attached to the load cell using a serrated clamp. Each specimen was cyclically loaded to 150 N at a rate of 33 mm/s. A load of 180 N represents approximately two-thirds of the static maximum load that the supraspinatus can generate.8 Also, the loading rate of the supraspinatus in normal daily activities is 33 mm/s.8 Thus, the test conditions were in a physiologic range. Specimens were loaded to 5,000 cycles. Failure was defined as 0.5 cm of displacement at the repair site. If the specimen did not fail at 5,000 cycles, load was applied at a rate of 50 N/sec until failure occurred. The mode of failure was also recorded. In order to ascertain the cross-sectional area and shape of the holes these instruments create, the middle portion of one tested tendon was pierced by all of the suture passage devices while being held taut. This specimen was fixed and sectioned parallel to its surface to produce histological slides showing the defects created by the passers. NIH Image software was used to measure their cross-sectional areas.

Because of the small sample size, the strengths of the repairs for the various passers were compared by a nonparametric Mann-Whitney test. For the specimens that failed during cycling, 150 N was used as the failure strength.

<table>
<thead>
<tr>
<th>Type of suture passer</th>
<th>Number of cycles at 150 N (s.d.)</th>
<th>Strength-N (s.d.)</th>
<th>Size of passer end (mm)</th>
<th>Area of hole in tendon (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SutureLasso™</td>
<td>5000</td>
<td>285(120)</td>
<td>2.4 dia</td>
<td>0.96</td>
</tr>
<tr>
<td>BirdBeak™</td>
<td>48(32)</td>
<td>150</td>
<td>2.75 x 2.75</td>
<td>2.20</td>
</tr>
<tr>
<td>Viper™</td>
<td>460(430)</td>
<td>150</td>
<td>1.6x1.0</td>
<td>0.92</td>
</tr>
<tr>
<td>Mayo needle</td>
<td>5000</td>
<td>287(130)</td>
<td>1.3 dia</td>
<td>0.37</td>
</tr>
</tbody>
</table>

Table 1 Comparison of the Four Test Suture Passers

Figure 1 SutureLasso™ suture passer.

Figure 2 BirdBeak™ suture passer.

Figure 3 Viper™ suture passer.
**Results**

The SutureLasso™ and tapered needle passer repairs were the strongest, failing at loads of 285 N and 287 N, respectively, which were significantly greater (p < 0.05) than the other two passers (Table 1). The BirdBeak™ and Viper™ passer repairs failed during cycling at 48 and 460 cycles, respectively. The primary mode of failure was suture cutting through the tendon. Several specimens failed by suture breakage and in one case, the anchor pulled out of the bone.

The cross-sectional areas of the holes created by the suture passers were: tapered needle = 0.37 mm$^2$, SutureLasso™ = 0.96 mm$^2$, BirdBeak™ = 2.20 mm$^2$, and Viper™ = 0.92 mm$^2$ (Table 1). The shapes of the holes they created varied from circular for the tapered needle to square or rhomboid for the other devices (Fig. 4).

**Discussion**

This study demonstrates that the durability of rotator cuff repair under cyclic loading is dependent upon the method used for suture passage through the tendon. Sutures cutting out through the tendon has been shown both clinically and biomechanically to be the most common mode of failure for suture anchor-based rotator cuff repairs. Suture passing instruments with smoother tips, such as the SutureLasso™ passer and the tapered needle, create smaller and more symmetric holes in the tendon. This may result in the suture cutting out of the tendon at a greater number of cycles. Both the BirdBeak™ and Viper™ suture passers have sharper contours in their distal ends that pierce the tendon. These contours may contribute to a decreased ability of the tendon to endure cyclic and static loads. If this results in increasing suture cutout during the critical first 3 months of healing, greater failure rates for arthroscopic rotator cuff repairs could result.

The limitation of this study is the small sample size. Although this resulted in large standard deviations, the differences we found between the devices tested were of statistical significance.

We recommend that smaller devices with symmetrical tips be used for arthroscopic passage of sutures through the rotator cuff tendon.

**References**