The histologic and biomechanical response of two commercially available small glenoid anchors for use in labral repairs

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\textbf{Background:} This study examined histologic characteristics and biomechanical performance of 2 commercially available, small glenoid anchors.

\textbf{Methods:} Adult research dogs (n = 6) were used for histologic analysis. Anchors were inserted into the lateral rim of the glenoid using the manufacturer’s protocol. The dogs were humanely euthanatized 8 weeks after anchor implantation, and the glenoids were collected for histologic analysis. Bone socket width data were compared for statistically significant (P < .05) differences. In addition, 4 matched pairs (n = 8) of human cadaveric glenoids were instrumented with 1 BioComposite SutureTak (Arthrex, Naples, FL, USA) and 1 JuggerKnot (Biomet, Warsaw, IN, USA) suture anchor in the anterior-inferior quadrant. Anchor constructs were preloaded to 5 N, cycled from 5 to 25 N for 100 cycles, and then pulled to failure.

\textbf{Results:} All JuggerKnot anchor sites were cyst-like cavities with a rim of dense lamellar bone. All BioComposite SutureTak anchor sites contained intact anchors with close approximation of anastomosing trabeculae of lamellar bone. At 8 weeks after implantation, mean socket width of the JuggerKnot anchor sites was 6.3 ± 2.5 mm, which was significantly (P = .013) larger than the mean socket width of 2.7 ± 0.7 mm measured for the BioComposite SutureTak anchor sites. The JuggerKnot anchor demonstrated larger displacements during subfailure cyclic loading (2.9 ± 1.0 mm compared with 1.3 ± 0.4 mm) and load to failure tests (13.7 ± 6.6 mm compared with 3.2 ± 0.5 mm). Statistical differences (P < .01) existed in every category except ultimate load.

\textbf{Conclusions:} Based on the biomechanical in human bone and histologic findings in canine subjects, the all-suture anchor may be at risk for clinical failure.

\textbf{Level of evidence:} Basic Science Study, Biomechanics/Histology.

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\textbf{Keywords:} Rotator cuff; glenoid; suture anchor; labrum; pullout; histologic response

The shoulder is the most commonly dislocated joint in humans. Recurrence in young patients can be 90%.\textsuperscript{5,6,15} The injury involves a tear of the inferior capsuloligamentous complex and labrum from the anterior
inferior glenoid 97% of the time. Arthroscopic repair of the essential Bankart lesion has become an extremely effective technique for restoring stability and function.

Failure of arthroscopic labral repairs for instability has been attributed to the number of fixation points. The use of multiple sutures and anchor sites is less likely to have recurrence of instability or failure of the repair due to the increase in the number of attachment points and better distribution of loading. Concerns have been raised regarding anchor material, with cystic enlargement around anchors of varying materials.

Anchors generally must be placed in a linear fashion along the anterior glenoid. With multiple anchors, fracture has been reported through the anchor sites. In larger anchors could theoretically increase the likelihood of fracture by the need for drilling large holes closer together in the relatively small anterior glenoid. Smaller suture anchors would allow for multiple points of fixation in the glenoid with more bone between each anchor site, potentially decreasing the risk of glenoid fracture. Optimally, suture anchors for labral repairs should provide sufficient resistance to motion, such that native tissue is allowed to repair and normal joint function is restored while not increasing fracture risk of the anchoring bone. Thus, suture anchors should prevent displacements greater than 2 mm under physiologic loading using a prepared hole of minimal diameter to provide attachment.

Properties of suture anchors, including material, suture configuration, size, and technique are frequently updated. Biomechanical testing is regularly performed and cited in reports regarding new anchors. Most of the testing is in vitro and tests pullout strength. Other articles have described testing of cyclic loads and micromotion with respect to labral repairs. To our knowledge, in vivo testing of new anchor designs has not been reported.

We used an animal model to examine histologic characteristics during the initial healing period of 2 commercially available, small glenoid anchors: the Juggerknot (Biomet Inc, Warsaw, IN, USA), a soft, all-suture anchor, and the 2.4-mm BioComposite SutureTak (Arthrex Inc, Naples, FL, USA), a solid anchor. In addition, we compared immediate biomechanical characteristics of each in human cadaveric glenoid bone based on intended use. We hypothesize that the all-suture anchors will allow significantly greater motion during cyclic load to failure compared with a biocomposite anchor. We further hypothesize that qualitative histologic differences will be observed between the 2 anchors tested as judged by a pathologist blinded to anchor type.

**Methods**

This was an in vivo study of the histologic response and a biomechanical analysis of 2 commercially available small glenoid anchors.

Figure 1 Test setup for pullout testing of glenoid suture anchors. LED, light-emitting diode.

**In vivo testing in canine glenoids**

The study used adult (aged 2-4 years) purpose-bred research dogs (n = 6) weighing greater than 20 kg. On the day of surgery, each dog was premedicated, anesthetized, and prepared for aseptic surgery of 1 randomly assigned forelimb. With the dog in lateral recumbency, a minimal (3-cm incision) cranial approach to the assigned shoulder, with caudal (posterior) retraction of the acromial head of the deltoid muscle, was performed.

Soft all-suture (1.4-mm Juggerknot) and solid biocomposite (2.4-mm BioComposite SutureTak) anchors were inserted into the lateral rim of the glenoid using the manufacturer’s instructions and instrumentation. One anchor of each type (n = 6/anchor) was placed in the glenoid of each dog in a location immediately cranial (anterior) or caudal (posterior) to the acromion, with the site altered so that each anchor was equally distributed between locations. The suture from each anchor was passed through adjacent labrum and capsule in a simple stitch configuration and tied.

Routine surgical wound closure was performed, and the dogs were recovered and treated with analgesics for 3 days. The dogs in both groups were allowed full ambulation in their runs (24 sq ft) for the duration of the study, which created a “worst case” scenario rather than using a sling or immobilization.

The dogs were humanely euthanized 8 weeks after anchor implantation. The glenoids were collected, fixed in formalin, and processed for nondecalcified sectioning and staining using Goldner’s trichrome staining. Separate sections were made for each anchor site. One pathologist, who was blinded to anchor type and location, subjectively assessed the histologic sections with respect to bone socket geometry, anchor integration, and responses of the surrounding bone. Maximum bone socket width was determined on calibrated images by using Image-Pro Plus7 software (Media
Chybernetics Inc, Bethesda, MD, USA). Bone socket width data were compared for statistically significant (\(P < .05\)) differences using a \(t\) test (SigmaPlot, San Jose, CA, USA).

**Biomechanical testing**

Four matched pairs (\(n = 8\)) of human cadaveric glenoids were obtained for biomechanical testing. Soft tissue was removed from the glenoids, and a hand saw was used to cut the scapula to facilitate attachment of the specimen to the test machine. Specimens were attached to the table of an Instron 8821s servohydraulic test machine (Instron, Norwood, MA, USA) using a compression-gripping clamp (Fig. 1). One BioComposite SutureTak and 1 JuggerKnot suture anchor were installed in the anterior-inferior quadrant of each glenoid. Anchor position was randomized to account for variations in bone density around the glenoid. Anchor position was randomized to account for variations in bone density around the glenoid. The 2.4-mm BioComposite SutureTak insertions were performed using an AR-1949 spear and AR-1934D-24 drill (both Arthrex Inc). JuggerKnot insertions were performed with the guide, drill, and obturator from the 912040 kit. All insertions were performed in accordance with manufacturer protocols. This included manual seating of the JuggerKnot anchors by tugging on the suture after insertion.

Anchor constructs were preloaded to 5 N (in line with the direction of anchor insertion), cycled from 5 to 25 N for 100 cycles, and then pulled to failure at a rate of 15 mm/min. Displacement was measured using Optotrak Certus 3-dimensional optical tracking (NDI, Waterloo, ON, Canada) with 1 light-emitting diode placed on the glenoid using a tissue tack and the other end attached to the suture grip clamp (Fig. 1). Yield load, ultimate load, displacement at ultimate load, cyclic displacement, load at 1-mm total displacement, and load at 2-mm displacement postcycling were calculated.

**Results**

**Histology**

All JuggerKnot anchor sites were cyst-like cavities with a rim of dense lamellar bone. All BioComposite SutureTak anchor sites contained intact anchors with close approximation of anastomosing trabeculae of lamellar bone (Fig. 2).

At 8 weeks after implantation, the mean socket width of the JuggerKnot anchor sites was \(6.3 \pm 2.5\) mm (drill bit diameter, 1.4 mm), which was significantly (\(P = .013\)) larger than the mean socket width of \(2.7 \pm 0.7\) mm measured for the BioComposite SutureTak anchor sites (original drill bit diameter, 2.4 mm).

**Biomechanical testing**

The results (mean ± standard deviation) along with \(P\) values from the statistical analysis are presented in Table I. Statistical differences (\(P < .01\)) existed in every category
except ultimate load. The JuggerKnot anchor demonstrated larger displacements during subfailure cyclic loading (2.9 ± 1.0 mm compared with 1.3 ± 0.4 mm) and load to failure tests (13.7 ± 6.6 mm compared with 3.2 ± 0.5 mm). Figure 3 shows a representative force vs displacement plot for the JuggerKnot and BioComposite SutureTak anchors tested in human cadaveric glenoids.

Figures 4 and 5 show the failure modes of the JuggerKnot and BioComposite SutureTak anchors, respectively, when tested to failure in tension along the direction of suture insertion.

### Discussion

#### Histologic analysis

Consistent cavity formation, including significant expansion of the drill tunnel, was associated with the JuggerKnot anchors in the canine glenoid. BioComposite SutureTak anchors maintained anchor–bone interface and tunnel size. All sutures incite foreign body reactions to varying degrees wherever they are placed in the body; as such, the response of bone observed in this study is completely expected. The amount and type of foreign material combined with the fixation type (JuggerKnot or BioComposite SutureTak) allows various amounts of early micromotion.

#### Biomechanics

The observation in all test results was that the BioComposite SutureTak demonstrated much lower displacement before anchor failure than the JuggerKnot (3.2 ± 0.5 mm compared with 13.7 ± 6.6 mm). In addition, there is evidence in the force vs displacement plots (Fig. 3) that the JuggerKnot anchor was slipping within

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### Table 1  Test results for JuggerKnot and BioComposite SutureTak

<table>
<thead>
<tr>
<th>Variable</th>
<th>JuggerKnot (Mean ± SD)</th>
<th>2.4-mm BioComposite SutureTak (Mean ± SD)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate load, N</td>
<td>141.0 ± 38.2</td>
<td>136.7 ± 23.9</td>
<td>.7890</td>
</tr>
<tr>
<td>Displacement at ultimate load, mm</td>
<td>13.7 ± 6.6</td>
<td>3.2 ± 0.5</td>
<td>.0009</td>
</tr>
<tr>
<td>Cyclic displacement, mm</td>
<td>2.9 ± 1.0</td>
<td>1.3 ± 0.4</td>
<td>.0001</td>
</tr>
<tr>
<td>Load at 1-mm displacement, N</td>
<td>10.1 ± 3.2</td>
<td>31.3 ± 18.0</td>
<td>.0050</td>
</tr>
<tr>
<td>Load at 2-mm displacement after cycling, N</td>
<td>53.5 ± 8.7</td>
<td>99.7 ± 12.8</td>
<td>.0062</td>
</tr>
</tbody>
</table>

SD, standard deviation.
the prepared hole before failure, as shown by the multiple peaks in pullout force vs displacement plots. Clinically, such slipping leads to a loss of reduction and can hinder healing. Conversely, the BioComposite SutureTak anchors typically demonstrated a single peak in pullout force at anchor failure.

The observed failure mode of all but 1 of the JuggerKnot anchors was pullout of the suture from the glenoid (Fig. 3). One JuggerKnot anchor tested broke the suture near the suture V-grip clamp. The observed failure mode of the BioComposite SutureTak included pullout of the anchor (5 anchors) and breakage of the top portion of the anchor (3 anchors). Both failure modes are shown in Figure 4.

The biomechanical objective of a suture anchor is to maintain sufficient tension in the repaired tissue to reestablish function and allow healing. This is done through anchoring of the device to the bone and the stiffness of the construct. The 2 anchors presented in this study use different methods to achieve such fixation. The JuggerKnot anchor achieves fixation by increasing the cross-sectional area of the device after installation. This is done through setting of the inserted suture after deployment, thus requiring increased force for removal. The BioComposite SutureTak anchor achieves fixation through interdigitation of the anchor with the native bone.

The ability of suture anchors to maintain fixation depends on 2 primary factors. First, the compliance of the device will determine its ability to resist tension. Second, any micromotion between the device and the native bone will increase displacement under loading. In this study, the JuggerKnot anchor demonstrated more micromotion between the device and the bone before ultimate failure than the BioComposite SutureTak anchor. This micromotion is likely due to the increased cavity size created by setting of the anchor or the soft nature of the device, or both. Conversely, the BioComposite SutureTak anchor maintained a comparatively rigid interface between the anchor and native bone.

Clinical relevance

In vitro testing of the JuggerKnot and BioComposite SutureTak has been reported. Mazzocca et al found no difference in ultimate load to failure (146.0 N compared with 171.9 N) but significantly lower loads at 2 mm of displacement (39 N for JuggerKnot compared with 84 N for SutureTak). To our knowledge, clinical outcomes using these particular anchors have not yet been published in peer reviewed literature; however, acceptable clinical results have been reported for each implant type.

Previously published results have suggested between 1 and 3 mm of displacement correlates with clinical failure. In that regard, the all-suture anchors has the potential to allow failure-levels of displacement in the early postoperative period. The biomechanical testing supports such displacement, and the histologic results offer a possible explanation. Micromotion may be secondary to the less rigid anchor point and a deformable material at the bone interface. Enlargement of a cavity surrounding the all suture anchor correlates with early micromotion and such a response of bone is predictable.

The JuggerKnot anchor demonstrated larger cavities and increased compliance in the canine study and human cadaveric human study, respectively, which led to greater than desired displacements during cyclic and load-to-failure testing. The BioComposite SutureTak anchor maintained a comparatively smaller cavity with interdigitation of the device and the bone. The BioComposite SutureTak anchor demonstrated significantly smaller displacements under tensile subfailure cyclic loading (1.3 ± 0.4 mm compared with 2.9 ± 1.0 mm) and load-to-failure tests (3.2 ± 0.5 mm compared with 13.7 ± 6.6 mm).

Limitations

This study has several limitations. The biologic response was measured in a canine model. Host response to the
anchor material may be different in human bone. However, canine models have shown tremendous translational applications in the orthopedic literature. The biomechanical testing was limited in the number and types of anchors tested; however, results for other anchors have been published, and our results are similar.

Conclusions

As with any animal or biomechanical model, direct translation of the results should be done with caution. However, based on the biomechanical findings in human bone and histologic findings in canine subjects, the all-suture anchor may be at risk for clinical failure.

Disclaimer

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