Radioulnar space available at the level of the biceps tuberosity for repaired biceps tendon: a comparison of 4 techniques

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Hypothesis: It is unknown whether certain methods of distal biceps tendon repair lead to an increased propensity of impingement of the repaired tendon. The purpose of this study was to evaluate various repair techniques in a cadaveric model to determine the radioulnar space available for the repaired biceps tendons.

Methods: Nine matched pairs of quartered, fresh-frozen cadaveric arms were transected at the level of the humeral mid shaft and the distal radiocarpal joint. Distance measurements and the angular relation of the bicipital tuberosity were measured at 5 forearm pronation-supination positions. These measurements were taken under each of the following conditions: intact native biceps, resected native tendon, suture anchor fixation of the biceps, suspensory suture device fixation of the biceps, tendon repair using a tenodesis technique, and fixation of the tendon using a trough technique.

Results: There were no significant differences in radioulnar space available after biceps tendon repair with the forearm in a supinated position. However, when the forearm was in a neutral or pronated position, the suture anchor method consistently had the lowest biceps insertion–to–ulna distance (0.6 to 2.1 cm). All forearm positions, except full supination, showed significant differences in terms of radioulnar space available for the repaired biceps.

Discussion: This study shows that the space available for the biceps tendon decreases with forearm pronation after reconstruction for all repair techniques. It appears that using suture anchors to repair the biceps tendon may predispose the repaired tendon to impingement when compared with other fixation techniques.

Level of evidence: Basic Science Study, Anatomy, Surgical Technique.

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Distal biceps tendon rupture/avulsion has a reported incidence of 1.2 per 100,000 patients yearly. Recent anatomic studies have reported on the biceps insertion to the bicipital tuberosity and the morphologic characteristics of the bicipital
Two studies have evaluated or quantified the effect of the reinsertion point of the ruptured tendon into the bicpital tuberosity. Seiler et al. reported on potential mechanisms for distal biceps tendon rupture. As a part of this study, they reported that the space occupied by the distal biceps tendon was only 15% larger than the tendon itself and decreased by 58% from supination to pronation. The computed tomographic scans showed that the radioulnar space at full pronation was 3.97 mm (range, 2.1-7.9 mm) and the mean change from supination to pronation was 3.85 mm (range, 2.5-7.2 mm). Schmidt et al. noted a visual increase in the thickness of the repaired biceps tendon on postoperative magnetic resonance imaging, although this increase in size was not quantified. Anatomic studies have noted the insertion dimensions of the biceps tendon to be 14 to 22 mm by 2 to 9.7 mm. Current surgical techniques tend to force the tendon into a more tubular configuration or into a smaller footprint insertion of 5 to 8 mm. Impingement of the repaired tendon could theoretically cause repair failure, decreased forearm rotation, or pain.

It is currently not known whether any of the popular methods of distal biceps tendon repair used today—reattachment of the tendon with suture anchors, insertion into an excavated tuberosity, soft tissue button technique, or interference screw fixation—lead to an increased propensity of impingement at the insertion site. The purpose of this study was to evaluate the various repair techniques in a cadaveric model, specifically addressing the radioulnar space available for the repaired tendon. Our null hypothesis was that there would be no difference in radioulnar space available for the reconstructed biceps tendon after reconstruction with 4 different techniques.

Materials and methods

Nine matched pairs of fresh-frozen cadaveric forequarters extending from the medial border of the scapula to the fingertips were obtained. All the specimens were from white men, aged 27 to 58 years, with a mean age of 49 years. None of the specimens had prior trauma or had undergone previous upper extremity surgery. They were thawed at room temperature overnight before anatomic dissection.

The arms were transected (bone and all soft tissue) at the level of the humeral mid shaft. The wrists were disarticulated at the radiocarpal joint. All muscle and soft tissue were stripped off the humerus and forearm with the exception of the distal biceps tendon, biceps muscle, distal radioulnar joint ligaments, interosseous ligament, elbow ligaments, and elbow capsule. The distal humeri were secured to the measurement table with a 6-mm threaded pin positioning the posterior flat aspect of the distal humerus parallel to the ground.

All measurements were taken 3 times by the same experimenter. The senior author, a shoulder and elbow fellowship-trained orthopaedic surgeon, took angular measurements using a standard goniometer (Smart Tool Technology, Oklahoma City, OK, USA) calibrated to the degree. Distance measurements were taken using a digital caliper (OEM, Mineola, NY, USA) with a range of 0 to 150 mm, calibrated to 0.01 mm. Elbow range of motion was recorded (flexion, extension, pronation, and supination). The angular relation of the bicpital tuberosity was measured using a goniometer with respect to a line drawn from the midpoint of the sigmoid notch to the midpoint of the radial styloid. Lastly, the measurement of the closest distance or gap between the native biceps tendon and the ulna was recorded. The distance was evaluated at 5 forearm positions: full supination, 45° of supination, neutral, 45° of pronation, and full pronation.

The biceps tendon was sharply released from its distal attachment. The distance between the biceps tendon insertion and the ulna was recorded at the same 5 forearm positions. Four methods of accepted repair were then performed. After each repair, the distance between the repaired tendon and the ulna was again recorded using the same 5 forearm positions.

Each tendon was secured with a whipstitch using No. 2-0 FiberWire (Arthrex, Naples, FL, USA). The suture was first placed through the suture loop on the anchor, and then a suture was used to attach the tendon terminally to each of the subsequent fixation devices. The suture was tied first to the suture anchor (Fig. 1). It was then untied and fixed to the EndoButton (Smith & Nephew, Andover, MA, USA), and the EndoButton was deployed through a 4.5-mm hole on the opposite cortex (Fig. 2). The suture was again untied and was delivered into the socket and fixed at the volar aperture with a tenodesis screw (Arthrex), keeping the tendon on the ulnar aspect (Fig. 3). It was lastly untied and sutured through bone tunnels to reproduce a traditional bone tunnel repair with tuberosity excavation (Fig. 4).

The first method used was suture anchor fixation with one 6.5-mm Arthrex Corkscrew suture anchor. The anchor was placed at the center of the biceps tendon insertion on the tuberosity. The biceps tendon was fixed to the suture anchor (Fig. 1), and measurements were taken at the 5 previously described positions. The loop of the anchor was then cut, releasing the tendon without affecting the FiberWire suture.
The biceps tendon diameter was measured, the dorsal cortex drilled at 4.5 mm, and the volar cortex drilled to the tendon diameter. An EndoButton was then attached to the biceps tendon using a surgeon’s knot with 3 throws and leaving a 2-mm gap between the tendon and the button. The button was passed through the bone and deployed on the far cortex (Fig. 2). Measurements were again repeated. The suture was untied to release the tendon from the radius and EndoButton.

The near cortex hole was over-drilled to accept a tenodesis screw using an 8-mm tunnel and a 7-mm tenodesis screw (Arthrex), and the tendon was fixed in place (Fig. 3). Standard measurements were then repeated.

Lastly, the volar cortex was widened to an oval, 3 drill holes were placed on the radial edge, the tendon was attached as described by Morrey et al., and the tendon was fixed using a No. 2-0 suture (Fig. 4). Measurements were again repeated.

The variables measured were summarized by use of means and standard errors for each treatment group. A mixed-model 2-way analysis of variance (ANOVA) was used to analyze the data with the fixed treatment effects represented by the arm used (left/right) and attachment method used (anchor, EndoButton, native, resected, tenodesis, and trough). Because subjects were used repeatedly for each treatment, the subjects were treated as a random effect in the model to take advantage of the within-subject variability. A Tukey adjustment was made for the pair-wise comparison of each treatment group if needed. Analysis of the data using the mixed-model 2-way ANOVA consistently showed significant contribution to the overall variability within each subject. This emphasized the need to treat the subjects as a random component of the model.

Results

The mean angle at which the biceps tuberosity sat while the forearm was in complete supination was 47°. The mean
radioulnar space available at each forearm position tested is shown in Table I. Table I shows that in the position of full supination and 45° of supination, there was not a significant change in the space available when the native tendon was resected. However, when the forearm was in the neutral position, 45° of pronation, and full pronation, there was significantly more radioulnar space available when the native tendon was resected.

Figure 5 shows the mean distance between the biceps and ulna across the 5 different positions tested for each fixation group. These results show that the radioulnar space available for the biceps tendon varied significantly by the amount of pronation-supination experienced by the forearm while the biceps tendon was repaired. In addition, Figure 5 shows that the distance was not related to whether the left or right arm was used.

There were no significant differences between the attachment methods for the supination position (Fig. 5). At the position of 45° of supination, using a tenodesis method to repair the biceps tendon resulted in significantly less space between the biceps tendon insertion and ulna compared with the native tendon, the space available when the biceps tendon was resected, and the trough-based fixation method based on the post hoc Tukey-adjusted pair-wise comparison results. The neutral, 45° pronated, and fully pronated (Fig. 5) positions all showed fairly consistent results. The suture anchor method consistently had the lowest biceps insertion–ulna distance. It was significantly lower than all other methods except tenodesis at the 45° pronated position. The condition in which the biceps tendon was completely resected consistently had the greatest radioulnar space available for all positions except for supination.

Table II shows the results for the 2-way mixed-model ANOVA. Statistically significant differences between fixation devices and forearm positions are presented. All positions except for full supination showed significant differences with respect to fixation modality that are not accounted for based on variance of pronation-supination of the forearm alone. Table III shows the Tukey-adjusted P values for the pair-wise comparisons across the different fixation methods. There was significantly less radioulnar space available when using suture anchors compared with all other fixation devices with the forearm in the neutral and pronated positions.

Discussion

Although there are numerous studies that have compared different exposure and fixation techniques for distal biceps repair,6,8,11,12,20,25,31 we believe that this is the first study to compare the amount of radioulnar space available for the biceps tendon using different fixation techniques. This study showed that there were significant differences between fixation techniques in terms of the amount of space available for the biceps tendon at time zero after repair. These differences in space could increase the risk of tendon impingement after repair.

It is widely advocated to repair the biceps with the arm in full supination because doing so moves the posterior interosseous nerve away from the site of dissection and is believed to provide the maximal exposure for the repair.31 The findings of this study support this thought because the amount of radioulnar space available for the biceps repair was significantly greater when the forearm was in full supination or 45° of supination than when it was in any other position. Seiler et al30 determined that the biceps occupied 85% of the proximal radioulnar joint in full pronation, an amount that was 50% greater than when the forearm was held in supination. As Table I shows, this study found an even greater difference in the amount of space occupied by the biceps between the forearm in full supination (8.3 cm) and full pronation (3.3 cm). In addition, this study found that there was no significant increase in the radioulnar space when the biceps tendon was resected compared with its native attachment when the forearm was in supination. This is in contrast to when the forearm was in the neutral and pronated positions because there was significantly more radioulnar space after tendon resection in each of these positions.

Although Figure 5 shows that the amount of radioulnar space available for the biceps tendon varies greatly with pronation-supination of the forearm, Table II shows that the fixation techniques themselves, and not simply the forearm position, play a key role in the amount of space available. This is important because it has been suggested that one of the reasons for failure of a biceps repair is impingement of the distal biceps tendon in the proximal radioulnar space,25,30,31 and these fixation devices may influence the amount of radioulnar space available after a repair. The idea of impingement of a repaired biceps tendon is further supported in this study by the finding that the native insertion of the biceps tendon leaves considerably more radioulnar space available than fixation with either a suture anchor, Endo-Button, or tenodesis technique when the forearm is in a

### Table I Mean values for radioulnar space available at level of biceps tuberosity

<table>
<thead>
<tr>
<th></th>
<th>Native*</th>
<th>Resected†</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (cm)</td>
<td>SEM (cm)</td>
<td>Mean (cm)</td>
</tr>
<tr>
<td>Full supination</td>
<td>8.3</td>
<td>0.45</td>
<td>8.1</td>
</tr>
<tr>
<td>45° of supination</td>
<td>6.4</td>
<td>0.43</td>
<td>6.2</td>
</tr>
<tr>
<td>Neutral</td>
<td>4.1</td>
<td>0.33</td>
<td>5.3</td>
</tr>
<tr>
<td>45° of pronation</td>
<td>2.7</td>
<td>0.36</td>
<td>5.2</td>
</tr>
<tr>
<td>Full pronation</td>
<td>3.3</td>
<td>0.30</td>
<td>5.2</td>
</tr>
</tbody>
</table>

* Space available with native tendon in place.
† Space available when the native tendon was resected from the insertion.
neutral position, 45° of pronation, and 45° of supination. This is an important finding because it is commonly believed that most daily activities are completed with the forearm in positions from 20° of pronation to 100° of supination. Therefore, if fixation is occurring with a device that is decreasing the amount of radioulnar space available for the biceps tendon within the neutral and pronated positions, it could be worsening the potentially pathologic impingement of the repaired tendon occurring in those positions.

Marnitz et al recently evaluated 25 distal biceps tendons that had been repaired with bioabsorbable suture anchors using magnetic resonance imaging. They found that there was a close to 3-fold increase in the cross-sectional area of the repaired tendons compared with the contralateral, native tendon and suggested that this increased size may cause impingement of the biceps tendon when the forearm is pronated. Our study suggests that using suture anchors to repair the biceps tendon may result in significantly less radioulnar space available when the forearm is in a pronated position after repair than using other fixation techniques (Fig. 5). Similarly, Schmidt et al reported on a series of a single surgeon using a single–anterior incision EndoButton technique and noted that the repaired tendons were, on average, 73° more anterior than the native insertion site and had a 58% incidence of intrasubstance heterogeneity/heterotopic ossification in the repaired tendon. The magnetic resonance imaging evaluation was performed in the flexed-abducted-supinated position and therefore did not address any evidence of impingement in the radioulnar space with pronation, but Schmidt et al did note that there was a “visual increase in the size of the repaired tendon,” despite not taking measurements. It is unknown whether using fixation techniques besides suture anchors will cause a similar increase in the cross-sectional size of the repaired tendon. However, it seems reasonable to suggest that a repaired tendon is likely to have an increased girth compared with the native tendon and that using a fixation method that appears to allow the most radioulnar space would aid in decreasing any potential impingement experienced by the tendon.

The weaknesses of our study include many that are typical of cadaveric studies. It is difficult to accurately assess the dynamic relationship between the biceps muscle and the proximal radioulnar space in a laboratory setting; moreover, using 2-dimensional measurement of a forearm

![Figure 5](image-url)
stripped of all surrounding musculature does not fully capture the intricate, 3-dimensional anatomy of the proximal radioulnar joint. In addition, we did not measure the thickness of the native biceps tendons. It may be possible that native tendon girth itself is a significant variable in the amount of radioulnar space present. However, by using repeated measures and mean values, we attempted to minimize any potential biases that tendon size could cause. Lastly, our technique for suture anchor fixation does not represent the bulk of the current literature in that we used only a single anchor. Although single-anchor fixation is supplanted by double-anchor fixation with regard to biomechanical strength, it allowed measurements of each method to be completed using native tendon and native bone with minimal modifications. This allowed the effective reproduction of tendon fixation characteristics.

**Conclusion**

The position of the forearm, along with the fixation device used, has a significant impact on the amount of radioulnar space available for the repaired distal biceps tendon. Suture anchors appear to leave the least amount of space available, whereas the trough technique appears to provide the most space available to the repaired tendon. Knowing which repair technique allows for the most proximal radioulnar space is important when completing preoperative planning in an effort to avoid post-repair impingement.

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Space available for repaired biceps tendon


