

Biomechanical Evaluation of Two Arthroscopic Biceps Tenodesis Techniques: Proximal Interference Screw and Modified Percutaneous Intra-Articular Transtendon

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Abstract

The percutaneous intra-articular transtendon (PITT) technique has recently been shown to have results comparable to those of more accepted techniques. Its mode of failure was secondary to the suture pulling through the tendon substance. A modification was made whereby the tendon is locked within the suture configuration in an attempt to avoid pullout. We compared this new technique with a well-accepted technique of all-arthroscopic interference screw.

In each of 8 pairs of cadaveric shoulders (mean age, 55 years; range, 51-59 years), one shoulder was randomized to be treated with either modified PITT or interference screw (Biceptor; Smith & Nephew) biceps tenodesis, and the other shoulder was treat-

ed with the other technique. The tendons were preloaded at 10 N and then cycled at 0 to 50 N for 100 cycles at 1 Hz. Load to failure was calculated at a rate of 1.0 mm per second until peak load was observed.

Mean (SD) ultimate load to failure was 157 (41) N for the modified PITT technique and 107 (29) N for the interference screw technique ($P = .003$). In 7 of 8 specimens, the interference screw technique failed at the junction of the tendon, the screw, and the bone interface. In 7 of 8 specimens, the PITT technique failed by the tendon slipping through the suture or pulling through transverse ligament/rotator interval tissue.

Study results showed the modified PITT technique was a biomechanically superior construct.

Over the years, operative treatment of biceps pathology has escalated, likely secondary to increased identification and successful clinical outcomes. Although its true function remains controversial, the biceps tendon has been well accepted as a primary pain generator in the anterior aspect of the shoulder.^{1,2} Biceps pathology involves a spectrum of often overlapping findings—varying degrees of tearing, tendinitis, and instability. Pathology may be isolated or may present in association with other shoulder conditions, including impingement, bursitis, rotator cuff

tears, SLAP (superior labral tear anterior to posterior) lesions, and acromioclavicular disorders.³

Operative treatment of disease of the long head of the biceps mandates an initial choice of tenotomy or tenodesis. Which approach is superior is controversial.⁴⁻⁶ Although tenotomy and tenodesis have comparably favorable clinical results, tenodesis is often recommended, particularly for younger, active patients, mostly because cosmetic deformity is possible with tenotomy.

Tenodesis may be performed arthroscopically or through an open incision, and the biceps tendon

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may be placed anywhere from in the joint to under the tendon of the pectoralis major tendon. In many recent biomechanical studies, interference screws had higher load to failure and improved stiffness in comparison with other fixation methods.⁷⁻¹⁹ Most of those studies focused on fixation in a subacromial location. To our knowledge, only 2 studies of soft-tissue fixation have compared the percutaneous intra-articular transtendon (PITT) technique with other popular tenodesis techniques.^{20,21} The PITT technique demonstrated a common failure point, with sutures pulling through the tendon substance. It was hypothesized that adding a locking loop to the PITT suture configuration would further improve fixation.

We conducted a study to compare the biomechanical characteristics of 2 techniques for all-arthroscopic proximal biceps tenodesis: bioabsorbable interference screw (Biceptor; Smith & Nephew) and a locking-loop PITT modification developed at our institution.

Methods

Sixteen nonembalmed fresh-frozen human cadaveric shoulders (8 pairs: 3 male, 5 female) were used in this study. Mean specimen age was 55 years (range,

51-59 years). The specimens showed no evidence of high-grade osteoarthritic changes, biceps tendon fraying or tearing, biceps pulley lesions, or full-thickness rotator cuff tears. They were thawed at room temperature for 24 hours before the procedure.

In each pair, 1 shoulder was randomized to be treated with 1 of 2 arthroscopic biceps tenodesis techniques—modified PITT or Biceptor interference screw—and the other shoulder was treated with the other technique. Surgery was performed in an open fashion, and every attempt was made to simulate the arthroscopic approach. In all shoulders, biomechanical testing was completed immediately after tenodesis.

Modified PITT Technique

In an outside-in fashion, an 18-gauge spinal needle was used to pierce the transverse humeral ligament, the lateral aspect of the rotator interval tissue, and the biceps tendon. A second needle was then passed in similar fashion, piercing the biceps tendon just adjacent to the first needle (**Figure 1A**). A 0-polydioxanone monofilament suture (0-PDS; Ethicon, Johnson & Johnson) was threaded through the first needle and used to shuttle a single No. 2 braided nonabsorbable polyethylene suture (MaxBraid; Biomet Sports Medicine) back through the biceps tendon.

At this point, the free end of the nonabsorbable suture, which comes out of the anterior cannula during an arthroscopic procedure, was passed back into the glenohumeral joint (using a suture grasper), looped over the top of the biceps tendon, and brought back out of the joint anteriorly, thereby creating a locking loop around the tendon (**Figure 1B**). A shuttle suture (0-PDS) passed through the second needle was used to bring that anterior limb of nonabsorbable suture back through the biceps tendon, completing the stitch configuration (**Figure 1C**).

This process was repeated with another nonabsorbable suture. After suture passing was completed, the biceps was detached from its insertion at the superior labrum. The 2 nonabsorbable sutures, which would later be retrieved from the subacromial space, were then tied in standard fashion, securing the biceps tendon to the transverse humeral ligament/rotator interval tissue (**Figure 1D**).

Biceptor Interference Screw Technique

The interference screw technique was performed in accordance with the manufacturer's operative instructions.²² An 8 × 25-mm polyetheretherketone

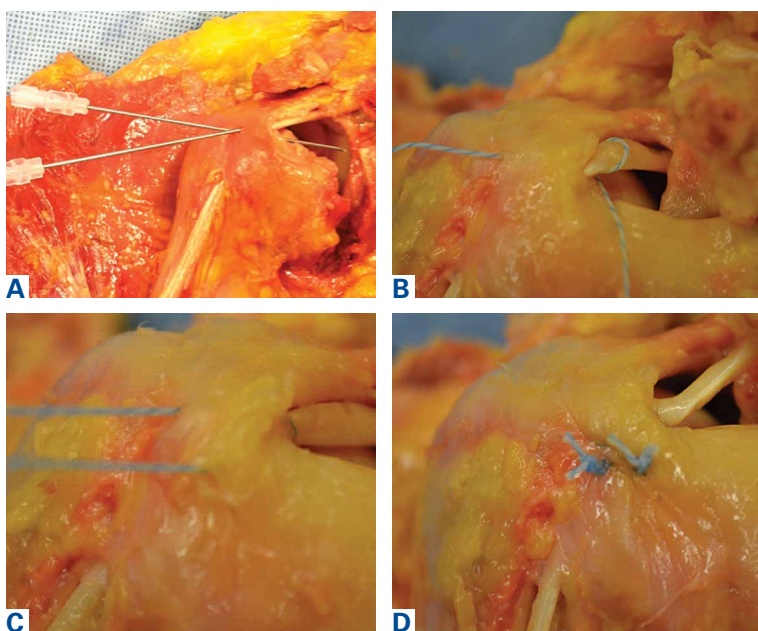


Figure 1. Modified percutaneous intra-articular transtendon technique. (A) Eighteen-gauge spinal needle is used to pierce transverse humeral ligament, lateral aspect of rotator interval tissue, and the biceps tendon. Second needle is then passed in similar fashion, piercing the biceps tendon just adjacent to the first needle. (B) A 0-Polydioxanone monofilament suture (0-PDS; Ethicon, Johnson & Johnson) is used to shuttle a MaxBraid suture (Biomet Sports Medicine) around the biceps tendon in locking loop configuration. (C) Free strands of MaxBraid suture come out of working portals and (D) are brought out of the same portal for tensioning and arthroscopic tying from subacromial space.

interference screw was used in all specimens, and the medium tendon fork was used to maintain tension on the biceps tendon during fixation (**Figure 2A**).

A 2.4-mm guide wire was inserted perpendicular to the humeral shaft, at the planned site of tenodesis, 10 mm distal to the entrance of the bicipital groove. An 8-mm cannulated reamer was passed over the wire, and a 30-mm tunnel was drilled (**Figure 2B**). The proximal part of the tendon was advanced into the center of the tunnel using the tendon fork (**Figure 2C**), and the tendon was held at the bottom of the tunnel with a 1.5-mm guide pin. The tendon fork was removed, and the cannulated interference screw was inserted over the guide pin between the 2 limbs of the biceps tendon (**Figure 2D**). The tendon was closely monitored to ensure it was not wrapped up when the screw was placed.

Biomechanical Testing

After each tenodesis, the humerus was amputated 5 inches distal to the fixation site. All extraneous soft tissue was dissected away, leaving the distal aspect of the biceps tendon as a free graft. Each proximal humerus–biceps tendon construct was then mounted on a materials testing machine. A custom-designed soft-tissue clamp was used to secure the distal aspect of the biceps tendon to the test actuator and load cell (**Figure 3A**). A custom-designed jig was used to stabilize the proximal humerus to the platform of the materials testing machine (**Figure 3B**). The specimens were mounted so that the line of pull throughout the testing protocol was applied parallel to the long axis of the humerus, thereby approximating the *in vivo* biceps force vector (**Figure 3C**). Digital cameras recorded each test for analysis of the mechanism of failure for each specimen. Marker dots were drawn on each tendon to assess tendon stretch before construct failure.

The tendons were preloaded to 10 N and then cycled at 0 to 50 N for 100 cycles at 1 Hz. After cyclic loading, axial load to failure was performed at a rate of 1.0 mm per second until a peak load was observed and subsequent loading led to tendon elongation with no further increase in load. Displacement and force applied during cyclic loading and load to failure were recorded. Stiffness was then calculated as the slope of the linear portion of the force-displacement curve using the least mean squares approach. Mechanism of failure was documented for each specimen.

Statistical Analysis

Analyzing our preliminary data with G*Power, we determined that a total sample size of 8 would be required (effect size [Cohen *d*] was 1, α error probability was .05, power was .8). We hypothesized that the ultimate strength and stiffness of one group would be less than 1 SD above those of the other group. Paired *t* test with significance set at $P < .05$ was used to compare the techniques.

Results

Both repair constructs exhibited standard load-displacement curves, with a linear increase in load with displacement until the point of failure, at which time further displacement occurred with no discernible increase in load (**Figure 4**). Ultimate load to failure is determined as the highest point of the curve, and stiffness is calculated as the slope of the load-displacement curve.

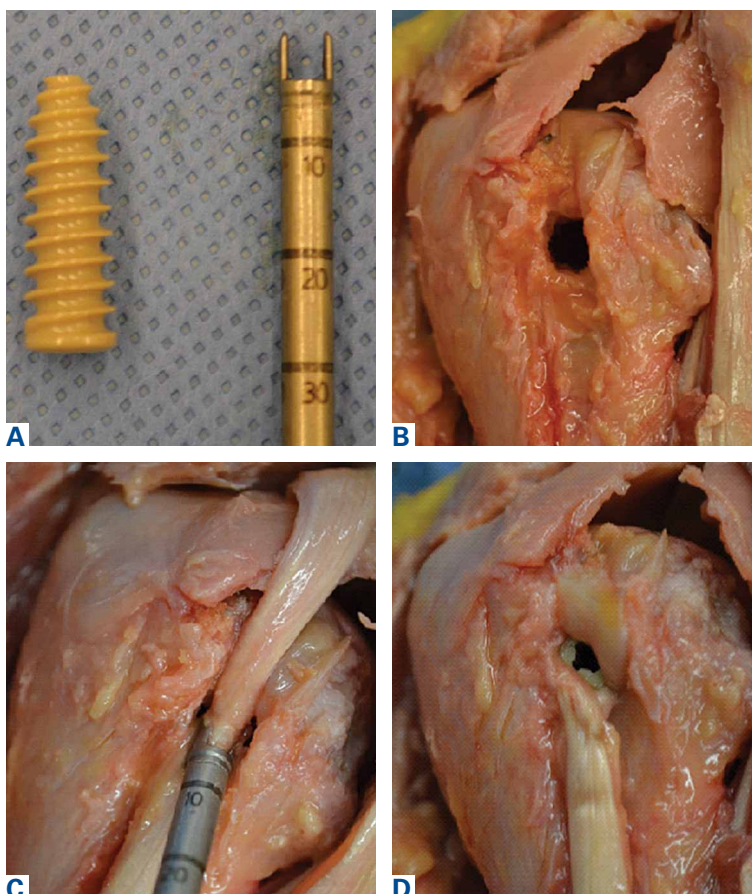


Figure 2. Biodegradable interference screw technique. (A) Polyetheretherketone screw (8 × 25 mm) with medium tendon fork. (B) After a guide wire is inserted perpendicular to the humerus 10 mm down from the exit of the bicipital groove, an 8-mm reamer is used to core out bone for the tendon and screw. (C) Medium tendon fork is then used to push the tendon to the floor of the created tunnel. (D) The screw is then placed between 2 limbs of tendon, with pulling slight tension on the proximal tendon to ensure the tendon is not wrapped around the screw.

Mean axial displacement parallel to the shaft of the humerus with cyclic loading was 7.1 mm with the modified PITT technique and 7.9 mm with the interference screw technique. There was no macroscopically visible high-grade tearing or slippage of the biceps tendon in any specimen with cyclic loading for either repair construct.

Mean (SD) ultimate load to failure was significantly ($P = .003$) higher with the modified PITT technique, 157 (41) N, than with the interference screw technique, 107 (29) N; actual effect size (Cohen d) was 1.19, difference of means was 50 N, and pooled SD was 42 N. The interference screw technique yielded significantly ($P = .010$) more mean (SD) stiffness, 38.7 (14.7) N/mm, than the modified PITT technique, 15.8 (9.1) N/mm; actual effect size (Cohen d) was 1.37, difference of means was 22.9 N/mm, and pooled SD was 16.7 N/mm.

In the interference screw technique, the mode of failure was consistent. Of the 8 specimens, 7 failed at the screw–tendon interface at the distal aspect of the tunnel; in the eighth specimen, the entire tendon pulled out from under the screw construct. In the modified PITT technique, there was more variability in failure: tendon slipped through suture (4 specimens), tendon/suture construct as unit pulled through transverse ligament/rotator interval tissue (3), and suture failure (1).

Discussion

This study was the first to directly compare a bony interference screw technique with a soft-tissue technique (modified PITT). Fixation strength is crucial. A load of 112 N is applied to the long head of the biceps tendon when a person holds 1 kg of weight in the hand with the elbow at 90° flexion.²² As mean (SD) ultimate load to failure was 157 (41) N with the modified PITT technique and 107 (29) N with the interference screw technique in this study, the interference screw can be recommended only with some hesitation.

The interference screw was stiffer with cyclic loading—an expected outcome, as it was secured to rigid bone—vs soft tissue, as in the modified PITT technique. Although the clinical implications for the modified PITT technique are unknown, more than likely, with the tendon being secured to soft tissue, there will be scarring over time.

In laboratory testing of biceps tenodesis constructs, interference screw fixation has had superior load-to-failure characteristics in comparisons with other fixation methods. Golish and colleagues¹³ found significantly higher load to failure with a biotenodesis screw than with a double-loaded suture anchor for subpectoral tenodesis. Testing similar implants, in a location more proximal in the bicipital groove, Richards and Burkhart¹⁴ likewise found superior fixation strength with an interference screw. Ozalay and colleagues¹⁶ found superior strength in an interference screw compared with suture anchor, keyhole, and bone tunnel in sheep. In a pig model, the highest ultimate load to failure was found in an interference screw—vs keyhole, bone tunnel, suture anchor, and ligament washer.¹⁹ Load to failure for the interference screw in these studies ranged from 170 N to over 400 N.^{13,14,16,19}

A few other investigators have studied the Biceptor interference screw. Slabaugh and colleagues¹⁵ found a mean (SD) load to failure of 173.9 (27.2) N for all specimens tested. Patzer and

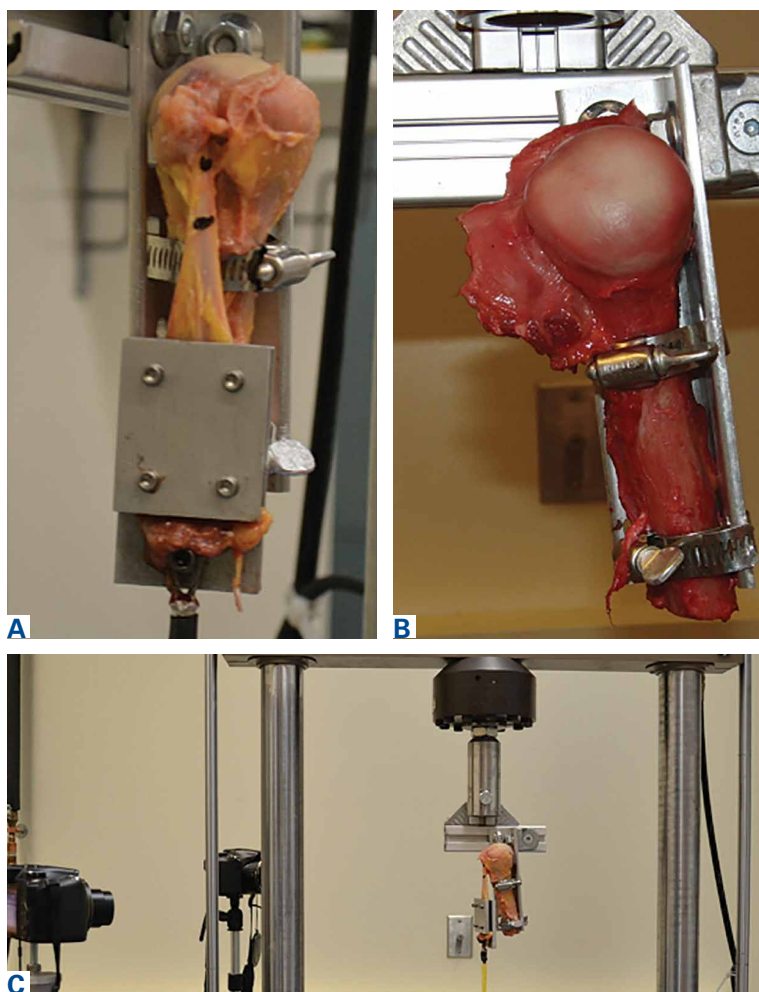


Figure 3. Biomechanical testing setup. Custom-designed soft-tissue clamp used to (A) secure distal aspect of biceps tendon to test actuator and load cell, (B) secure proximal humerus during testing, and (C) pull parallel to humeral shaft during testing.

colleagues^{9,17} found that the mean (SD) ultimate load to failure with the Biceptor proximal interference screw, 173.9 (27.2) N, was superior to that of a suture anchor.

The mean (SD) ultimate load to failure reported for the Biceptor interference screw in the present study, 107 (29) N, is lower than the values reported in the other studies—not only for the Biceptor screw but for interference screws in general. Nevertheless, we performed the technique as the manufacturer recommended.²² Our results were consistent across all specimens studied. Interestingly, in the study by Slabaugh and colleagues,¹⁵ 7 specimens failed at the tendon–screw interface during cyclic testing and were not included in the analysis of ultimate load to failure. As these specimens failed at a load between 5 N and 70 N, including their data would have significantly lowered the mean load to failure.

Concern over the Biceptor interference screw's lower failure load relative to that of other interference screws has been raised before.^{9,17} A major issue is possible overstuffing of the humeral tunnel, as the hole is reamed the same size as the screw. With the Biceptor, the proximal and distal portions of the tendon are placed in the tunnel in a U-shaped configuration with the screw between these limbs. The idea is that the 2 biceps tendon limbs might become abraded and consecutively weaken as the screw is inserted between the tendon limbs, more so than with a single loop. This idea was suggested by the typical longitudinal tendon splitting that occurs at the screw–tendon interface at the distal aspect of the tunnel.²³ In the present study, consistent failure (**Figures 5A-5C**) at the distal aspect of the screw–tendon junction supported the idea that the tendon is abraded during placement of the interference screw or during the friction-causing 90° turn the tendon takes into the bone on loading. There is no way to quantitatively examine tendon quality before interference screw placement, but on gross inspection all the tendons were of good quality. Slabaugh and colleagues¹⁵ also found consistent failure at the screw–tunnel interface.

The PITT technique has been described as a simple all-arthroscopic soft-tissue technique for biceps tenodesis.^{23,24} Subsequently developed soft-tissue techniques have demonstrated clinical benefits.²⁵⁻²⁷ Proposed advantages of these techniques are lower cost associated with decreased implant needs, no reliance on quality of bone for fixation, suturing while biceps tendon is still

attached to anchor (anatomical tension is closely reproduced), and less interference with any subsequent use of magnetic resonance imaging for diagnostic purposes in the shoulder.

There have been only 2 biomechanical studies of the PITT technique. Lopez-Vidriero and colleagues²⁰ compared the biomechanical properties of the PITT and suture anchor techniques in a human cadaveric laboratory study and found that the PITT technique had mean (SD) ultimate load to failure of 142.7 (30.9) N and mean (SD) stiffness of 13.3 (3) N/mm. They observed consistent suture pullout through the tendon substance during fail-

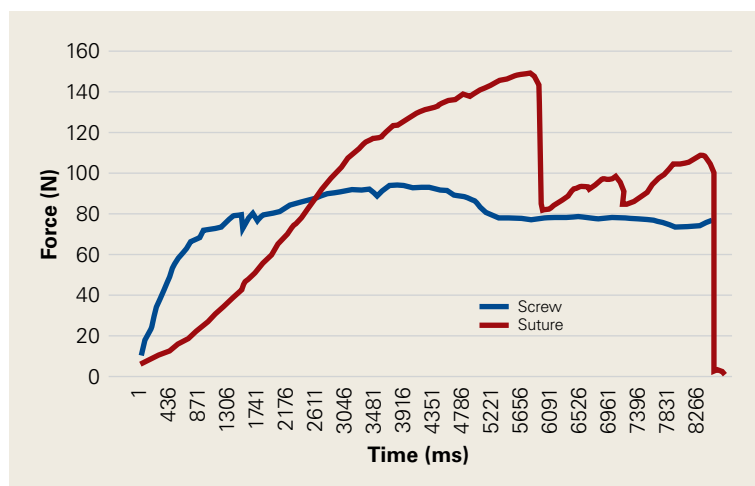


Figure 4. Typical force-versus-time curve of loading for suture and screw techniques.

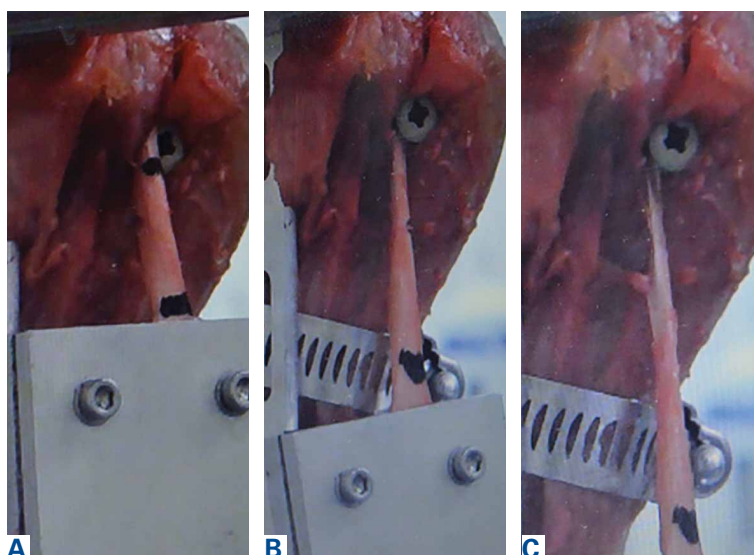


Figure 5. Typical mode of failure for interference screw. (A) Screw placed into previously reamed tunnel. (B) Force applied with ultimate failure testing. (C) Typical screw construct failure mechanism: tendon severed at screw, tendon, and bone interface at distal aspect of tunnel.

ure, which suggests the most important factor for strength is the quality of the biceps tendon. Su and colleagues²¹ found biomechanically inferior results of the classic PITT technique as compared with the interference screw technique.

This article provides the first description of the modified PITT technique. Our mean (SD) load to failure of the modified PITT technique was 157 (41) N, slightly higher than that reported for the classic PITT technique, albeit under a different setup.²⁰ There was more variation in ultimate load to failure in our study than in previous studies, which could be secondary to tissue quality. As the modified PITT technique relies on surrounding tissue holding the biceps in place, this tissue would need to be of good quality and strength to obtain strong fixation. A possible concern is that placing stitches in the rotator interval could increase the risk of shoulder stiffness, but this has not been encountered clinically.

A more variable mechanism of failure was also found in the present study. Although half the specimens failed by suture pullout through the tendon, similar to what Lopez-Vidriero and colleagues²⁰ described, 3 of our 8 specimens failed with the entire biceps tendon–suture construct pulling through the transverse ligament tissue, and 1 specimen failed by suture breakage. Although these numbers are too small for making definitive statements, our modified PITT technique may add some security to the tendon–suture construct. Such added security may be of particular value in the setting of poor-quality, diseased tendon tissue, and the construct may be more limited by the strength of surrounding tissues. In addition, if failure occurs at the suture transverse humeral ligament–rotator interval interface, more surrounding rotator interval tissue can be incorporated into the tenodesis to decrease the likelihood of failure through this mechanism.

This study had several limitations. First, it was a time zero study in a cadaveric model with simulated biomechanical loading. As such, it provided information only on initial fixation strength and could not prove any superior clinical outcomes or account for any biological changes with healing that occurred over time. Second, the study may have been underpowered, though sample size was chosen in accordance with other cadaveric biomechanical studies. Third, all procedures were performed in an open manner, simulating the arthroscopic approach. Particularly in the setting of the modified PITT technique, this represented

a best case scenario. Spinal needles and subsequent sutures were easily passed under direct visualization through the transverse humeral ligament, rotator interval, and biceps tendon. There is likely marked variability in this step during arthroscopy in which visualization is more limited, as in the setting of concomitant procedures, such as subacromial decompression or rotator cuff repair. In addition, all tendons tested were normal in appearance and gave no indication of chronic degenerative changes.

Another study limitation is that we did not quantify bone mineral density, which if poor would have affected interference screw strength. However, mean specimen age was 55 years, minimizing chances of poor bone quality. In addition, 7 of the 8 failures in the interference screw group occurred not with pullout but at the screw–tendon junction, suggesting poor bone quality was not a significant factor. As tendon diameter was not measured before the procedures were performed, there is the possibility it could have been better in the modified PITT group and worse in the interference screw group because of tunnel crowding, as noted.

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