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Biomechanical evaluation of subpectoral biceps tenodesis: dual suture anchor versus interference screw fixation

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Background: Subpectoral biceps tenodesis has been reliably used to treat a variety of biceps tendon pathologies. Interference screws have been shown to have superior biomechanical properties compared to suture anchors; although, only single anchor constructs have been evaluated in the subpectoral region. The purpose of this study was to compare interference screw fixation with a suture anchor construct, using 2 anchors for a subpectoral tenodesis.
Methods: A subpectoral biceps tenodesis was performed using either an interference screw (8 × 12 mm; Arthrex) or 2 suture anchors (Mitek G4) with #2 FiberWire (Arthrex) in a Krackow and Bunnell configuration in seven pairs of human cadavers. The humerus was inverted in an Instron and the biceps tendon was loaded vertically. Displacement driven cyclic loading was performed followed by failure loading.
Results: Suture anchor constructs had lower stiffness upon initial loading ($P = .013$). After 100 cycles, the stiffness of the suture anchor construct "softened" (decreased 9%, $P < .001$), whereas the screw construct was unchanged (0.4%, $P = .078$). Suture anchors had significantly higher ultimate failure strain than the screws ($P = .003$), but ultimate failure loads were similar between constructs: 280 ± 95 N (screw) vs 310 ± 91 N (anchors) ($P = .438$).
Conclusion: The interference screw was significantly stiffer than the suture anchor construct. Ultimate failure loads were similar between constructs, unlike previous reports indicating interference screws had higher ultimate failure loads compared to suture anchors. Neither construct was superior with regards to stress; although, suture anchors could withstand greater elongation prior to failure.
Level of evidence: Basic Science, Biomechanics, Cadaver Model.

Keywords: Biceps tendon; interference screw; suture anchor; biomechanics

Proximal biceps tenodesis is a reliable treatment for tears, subluxation, and synovitis of the long head of the biceps (LHB). Several studies have evaluated techniques for LHB tenodesis including arthroscopic and open techniques in the suprapectoral or subpectoral regions. Subpectoral tenodesis (below the pectoralis major tendon) provides excellent pain relief and functional improvement with limited residual biceps tendon symptoms.[4,6] Various techniques have been described for subpectoral fixation including interference screws, suture anchors, and bone tunnels.[1,5]

Several authors have compared interference screw fixation and suture anchor fixation for proximal biceps

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tenodesis in both the suprapectoral and subpectoral region. No significant difference in initial fixation strength has been reported comparing a subpectoral interference screw fixation and a suprapectoral double suture anchor tenodesis.[3] Suprapectoral interference screw fixation has been shown to have inferior initial biomechanical properties compared to a suprapectoral double suture anchor tenodesis.[7] Finally, several studies have reported superior initial biomechanical properties of a subpectoral interference screw tenodesis compared to a subpectoral single suture anchor tenodesis.[1,8] No authors have directly compared a subpectoral interference screw tenodesis with a subpectoral double suture anchor tenodesis.

The purpose of this study was to compare the initial biomechanical properties of a subpectoral biceps tenodesis using interference screw fixation and a subpectoral double suture anchor biceps tenodesis in cadaveric shoulders. We hypothesize that there is no difference in the initial biomechanical properties between interference screw fixation and subpectoral double suture anchor proximal biceps tenodesis constructs. Construct stiffness under cyclic load as well as yield and ultimate stress and strain were compared between constructs.

Methods and materials

Seven pairs of fresh human cadaveric shoulders with no history of shoulder pathology were utilized for testing (3 male and 4 female cadaveric pairs with an average age of 56 $\pm$ 14 years). All specimens were dissected free of all soft tissue, preserving only the humeral shaft and biceps muscle belly and tendon which were utilized for testing. Shoulders within a pair were randomized to 2 different biceps tenodesis techniques: interference screw or dual suture anchors. Specimens were randomized utilizing the random permuted blocks method.

The interference screw technique was performed as previously described by Mazzocca et al.[5] An 8 $\times$ 15-mm bone tunnel was created utilizing the Arthrex Biotenodesis Screw Set (Arthrex, Naples, FL, USA), 15 mm proximal to the inferior border of the pectoralis major tendon insertion. The biceps tendon was cut 25 mm proximal to the musculotendinous junction and a No. 2 FiberWire (Arthrex) was placed in the distal 15 mm of the proximal biceps using a Krackow stitch. An 8 $\times$ 12-mm PEEK Arthrex Tenodesis Screw (Arthrex) was used to fix the tendon into the previously drilled hole, while 1 limb of the previously passed stitch was placed through the interference screw. The 2 stitch limbs were then tied after the screw was placed, using 2 half hitches followed by a reverse half hitch, followed by 3 half hitches on opposite posts thrown in opposite directions after each hitch (Fig. 1).

The suture anchor technique utilized 2 Mitek G4 Suture Anchors (Mitek, Norwood, MA, USA). Each anchor was loaded with a single No 2. FiberWire stitch. The biceps tendon was cut 25 mm proximal to the musculotendinous junction and a No. 2 FiberWire stitch from one anchor was passed through the 15 mm of biceps tendon just proximal to the musculotendinous junction using a Krackow stitch. The second stitch from the other anchor was placed as a Bunnell stitch in the same region of the biceps

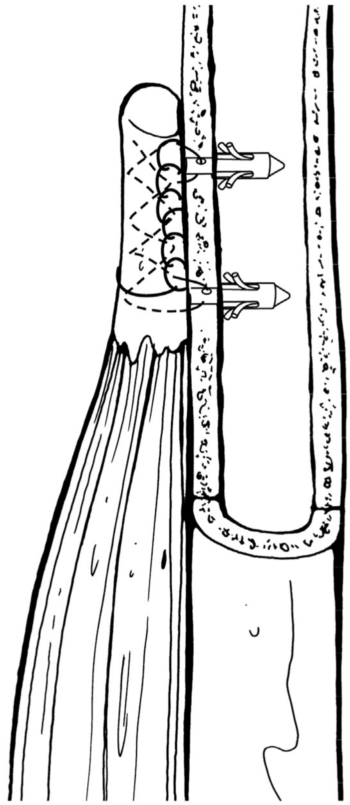

Figure 1 Interference screw biceps tenodesis construct (PEEK 8 $\times$ 12-mm Tenodesis screw with a No. 2 FiberWire suture in a Krackow stitch pattern).

tendon. The Krackow stitch was passed from the end of the cut tendon to the musculotendinous junction and then back to the cut end. The Bunnell stitch was passed in the opposite direction starting at the musculotendinous junction, passed up to the cut end, and then back to the musculotendinous junction. Two holes were drilled with the Mitek G4 anchor drill (Mitek, Norwood, MA, USA) in the bicipital groove, one 15 mm proximal to the inferior border of the pectoralis muscle and a second at the level of the inferior border. The Krackow stitch anchor was then impacted into the proximal hole and the Bunnell stitch anchor was impacted into the distal hole and then both were tied using the knot previously tied for the interference screw repair (Fig. 2).

A uniaxial, servo-hydraulic materials testing machine (Instron 1331 Load Frame, Model 8800 controller; Instron Corp., Norwood, MA, USA) equipped with a 5 kN tension/compression load cell (Model 2518-103, Instron Corp., Norwood, MA, USA) was used for the biomechanical testing. The shaft of each humerus was then inverted, potted, and fixed to the test platform of the Instron. A portion of the biceps muscle was left attached to the repaired tendon, and a thermoelectric cryoclamp was then secured to the muscle belly just distal to the musculotendinous junction (Fig. 3). The biceps tendon was loaded vertically with the angle of pull in line with the long axis of the tendon and humerus, as described by Golish et al.[1]

Based on the cross-sectional area of the tendon, 0.5 MPa tare stress was applied to normalize initial loading of the constructs. For preconditioning, the tissue and construct stress relaxed under constant deformation for 1 minute at the displacement required to

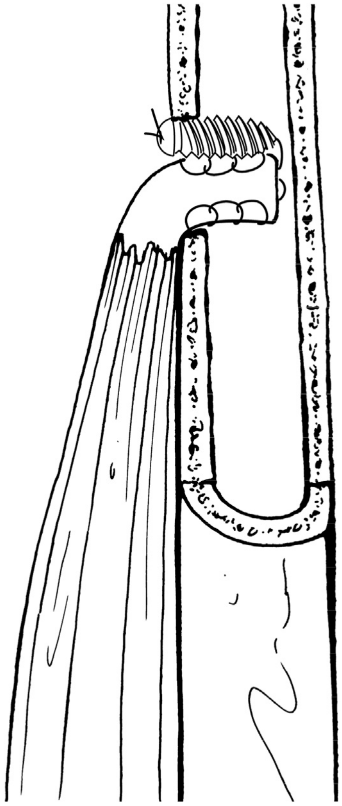

Figure 2 Dual suture anchor biceps tenodesis construct (2 Mitek G4 suture anchors each loaded with a No. 2 Fiberwire suture with 1 in Krackow stitch pattern and the other in a Bunnell stitch pattern).

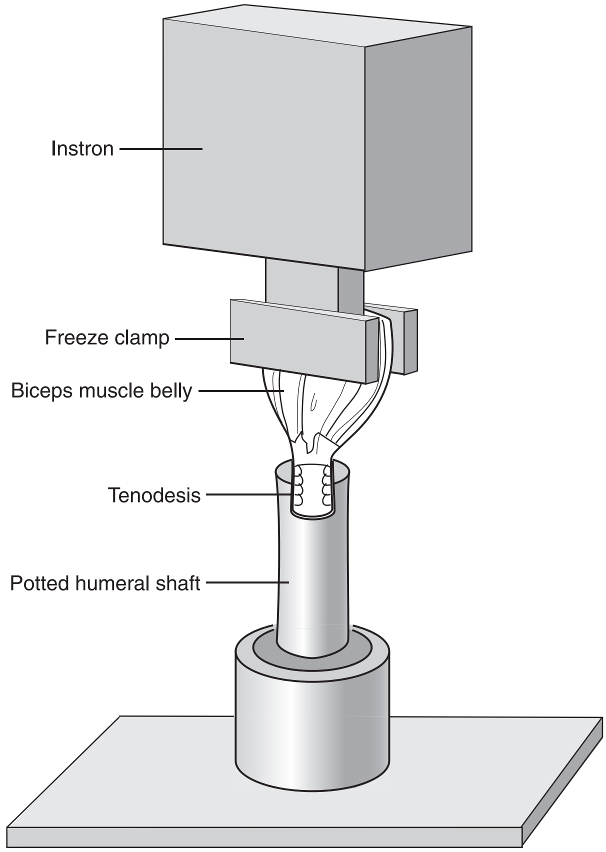

Figure 3 Specimens were inverted with the humeral head fixed to the testing table and a freeze clamp fixed to the biceps muscle belly. Vertical cyclic and failure loads were applied utilizing a materials testing machine.

induce 8 MPa stress. The tissue was then unloaded and recovered for 5 minutes. The tare stress was reapplied, then displacement driven cyclic loading (100 cycles, 0.5 mm/s) was performed with a triangle waveform between the points defined by 0.5 and 8 MPa tare stress. The tissue again relaxed for 5 minutes and then pulled to failure at 1.25 mm/s. Initial stiffness as well as stiffness of the construct after the first 100 cycles were determined. Stress and strain were determined for yield and ultimate failure of the construct. Yield was defined as the point on the stress/strain curve that departed from an elastic response, or deviation from the linear region of the loading curve. Ultimate failure was defined as the peak stress and strain achieved before significant loss of the construct integrity.

Paired *t* tests were performed to compare results between constructs with significance at $P \leq .05$. An a priori power analysis utilizing the data from Mazzocca et al was performed with an alpha of 0.05, and showed a sample size of 14 specimens (7 in each group) to provide a power of 85%.[3] The Mazzocca data were utilized as they best replicated the constructs tested in the present study, specifically a dual suture anchor and an interference screw constructs.

Results

The average tendon cross sectional area was 11.6 ± 4.7 mm^2 (range, 6.2-19.0; $P = .981$ between construct groups). Suture anchor constructs had lower stiffness upon initial loading: 160 ± 33 MPa (anchors) and 280 ± 92 MPa (screw) ($P = .013$). After 100 cycles, the suture anchor construct "softened" (decreased 9%, $P < .001$), whereas the screw construct was relatively unchanged (0.4%, $P = .675$). The stiffness of the interference screw and suture anchor constructs after 100 cycles was 279 ± 93 MPa (screw) and 146 ± 31 MPa (anchors) ($P = .009$).

Yield stress, defined as the point departure from a linear stress/strain response (initiation of plastic deformation), was similar between constructs: 13 ± 6 MPa (screw) and 10 ± 2 MPa (anchors) ($P = .314$). Yield strain was significantly lower for the screw: 7.2 ± 3% (screw) and 11.9 ± 2.3% (anchors) ($P = .028$). Suture anchors had significantly higher ultimate failure strain than the screws: 20.4 ± 7.4% (screw) and 45.7 ± 13.3% (anchors) ($P = .003$); but failure stress was not statistically different: 26 ± 8 MPa (screw) and 30 ± 12 MPa (anchors) ($P = .416$). Conversion of ultimate failure stress to load (Newtons) reveals no significant differences in ultimate failure loads between screw and suture anchor constructs: 280 ± 95 N (screw) vs 310 ± 91 N (anchors) ($P = .438$).

Failure modes differed between constructs. Screw failure occurred at the bone/screw/tendon interface with disruption of the tendon tearing away from the junction. Suture anchor failure occurred as a result of the tendon pulling through the sutures after tightening of the suture bundle.

Discussion

The purpose of this study was to compare the mechanical properties of interference screw and dual suture anchor constructs in the setting of subpectoral biceps tenodesis. Suture anchors provided a ‘‘softer’’ response than screws to cyclic loading by deforming more under the same applied stress. Likewise, suture anchors allowed over double the deformation of interference screws while maintaining similar failure stress.

Each technique for biceps tenodesis has benefits and drawbacks. Interference screws require no suture passage through the humerus; therefore, it is technically simple and allows intramedullary healing of the tendon. Drawbacks include the requirement for a relatively large hole in the humerus up to 8 mm. The humeral socket can create a stress riser and has been reported with humeral fractures even in healthy young patients.[10] Additionally, a perfect interference fit can be challenging with varying tendon sizes and thicknesses. While interference screw fixation was shown in the present study to provide superior (ie, less) construct deformation, which may promote healing, interference screw fixation of a tendon into cortical bone may actually weaken the tendon, potentially leading to a stress riser and rupture after tenodesis.[2]

Suture anchor fixation only requires very small holes (2-3 mm) to be drilled, improving integrity of the bone, but the tendon is required to heal to the surface of the humeral cortex instead of within the canal. Additionally, variability in tendon sizes and thicknesses has little impact on the reproducibility of the procedure. The higher deformation under load in the present study may indicate some lengthening of the construct during the healing process. Nevertheless, the data for ultimate failure in the present study indicate the dual suture anchors perform as well as the interference screws with respect to failure loading.

The ultimate failure loads in the present study were in good agreement with prior studies of interference screw fixation (∼200-300 N).[3,9] The ultimate failure load of the dual suture anchor construct in the present study is higher than those of single anchor constructs tested in previous reports.[1,3,6,7] The increase in failure load is likely a result of a second anchor and a locking stitch pattern providing additional stability. In contrast, Richards et al tested a dual suture anchor arrangement and found it to be significantly weaker than the interference screw.[9] While interference screw construct loads were in good agreement, their suture anchor construct obtained only half the ultimate load found in our study. The suture anchor repairs in the study by Richards et al failed by 2 mechanisms: suture pull-through (2/6) and suture breakage (4/6).[9] Richards et al utilized a mattress stitch for their anchors as opposed to locking stitches in the present study.[9] The locking stitches in the present study likely resulted in reduced suture pull-through leading to higher ultimate failure loads. The locking stitches also likely led to superior ultimate strength compared to interference screws because of increased stress distribution over the tenodesed tendon, compared to the discrete interface between the interference screw and bone. Richards et al used No. 2 Ethibond (Ethicon, Somerville, NJ, USA) as opposed to No. 2 Fiberwire (Arthrex, Naples, FL, USA) used in the current study.[9] The high strength suture, Fiberwire (Arthrex), utilized in the current study resulted no suture breakage, while the Ethibond (Ethicon) resulted in 67% suture breakage in the study by Richards et al. Consequently, we recommend utilizing a high strength suture for the repair.

Limitations of the current study include that the data only represent a measure of time-zero construct stability. Scar formation, healing and preoperative tendinopathy can all affect the final integrity of the construct. Clinical trials are required to determine the efficacy of one technique over the other. The insignificant results of the comparison of failure loads may be a result of inferior power although an a priori power analysis was performed using the best equivalent data in the literature suggesting 7 pairs of shoulders will achieve over 80% power.

Conclusion

The interference screw construct was significantly stiffer than the dual suture anchor construct for a biceps tenodesis in the subpectoral region. Yield and failure stresses were similar between constructs unlike previous reports indicating interference screws have higher ultimate failure loads compared to suture anchors. These results are likely due to the use of 2 anchors, high strength suture and the locking stitch configuration utilized in the present study compared with prior studies. Finally, the interference screws had lower failure strains (half that of suture anchors) indicating suture anchor constructs could withstand greater elongation prior to failure.

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Disclaimer

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