Interference Screw Versus Suture Anchor Fixation for Subpectoral Tenodesis of the Proximal Biceps Tendon: A Cadaveric Study

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Purpose: The purpose of this study was to compare the biomechanical properties of 2 fixation methods for subpectoral proximal biceps tenodesis. **Methods:** In 9 matched pairs of cadaveric shoulders, an open subpectoral tenodesis was performed 1 cm proximal to the inferior border of the pectoralis major tendon by use of either an 8 × 12–mm Bio-Tenodesis screw (Arthrex, Naples, FL) with No. 2 FiberWire sutures (Arthrex) or a 5.5-mm Bio-Corkscrew double-loaded suture anchor (Arthrex) with No. 2 FiberWire sutures. The specimens were dissected and mounted in a material testing machine. Cyclic loading (20 to 60 N, 100 cycles, 0.5 mm/s, 5-N preload) was performed, followed by an unloaded 30-minute rest, a 5-N preload, and a load-to-failure protocol (1.25 mm/s) with a 100-lb load cell. Ultimate load (in Newtons), stiffness (in Newtons per millimeter), and modes of failure were recorded. Data were analyzed by use of paired *t* tests and Wilcoxon signed rank tests. **Results:** Proximal biceps tenodeses with Bio-Tenodesis screws had a significantly higher mean load to failure (169.6 ± 50.5 N; range, 99.6 to 244.7 N) than those with Bio-Corkscrew suture anchors (68.5 ± 33.0 N; range, 24.2 to 119.4 N) ($P = .002$). Bio-Tenodesis screws also had a significantly higher stiffness (34.1 ± 9.0 N/mm; range, 20.6 to 48.9 N/mm) than Bio-Corkscrews (19.3 ± 10.5; range, 5.9 to 32.9 N/mm) ($P = .038$). **Conclusions:** In this cadaveric study the Bio-Tenodesis screw showed a statistically significantly higher load to failure and significantly higher stiffness than the Bio-Corkscrew anchor when used for tenodesis of the proximal biceps tendon in a subpectoral location. **Clinical Relevance:** Biomechanical comparison of these 2 fixation techniques provides information on stiffness and load to failure of alternate fixation methods.

Key Words: Biceps brachii—Tenodesis—Subpectoral—Bone screw—Suture anchors—Proximal.

Pathology of the proximal tendon of the long head of the biceps brachii is a common finding in the painful shoulder.[1] Biceps pathology can include tendonitis, tendinosis, subluxation, and partial- or full-thickness tears. Symptomatic biceps disease may be isolated or accompanied by rotator cuff disease and labral pathology.

Tenodesis is a surgical option for biceps pathology that aims to preserve flexion and supination strength with good cosmesis in patients with active lifestyles.[1-3] Tenodesis may be performed arthroscopically or in an open manner, and it may be done proximally (within the glenohumeral joint or bicipital groove) or distally (adjacent to the inferior border of the pectoralis major insertion).[4]

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The biomechanical properties of a tenodesis construct may be particularly important for early range of motion in patients with isolated biceps pathology. A variety of fixation devices have been used to achieve tenodesis of the biceps, and biomechanical studies have compared various techniques in human[3,5,6] and sheep[7,8] specimens. Richards and Burkhart[6] compared suture anchor fixation with interference screw fixation in a proximal tenodesis within the intertubercular groove in human cadavers and found that screw fixation had a significantly higher load to failure. Mazzocca et al.[3] compared fixation by use of arthroscopic suture anchors and arthroscopic interference screws in a proximal tenodesis within the intertubercular groove with open subpectoral interference screw fixation as well as open subpectoral bone-tunnel fixation; there were no significant differences in load to failure, despite mean loads similar to Richards and Burkhart.

The purpose of this study was to compare the biomechanical characteristics of a bioabsorbable interference screw (Bio-Tenodesis screw; Arthrex, Naples, FL) with those of a single bioabsorbable suture anchor loaded with composite polyethylene suture (Bio-Corkscrew; Arthrex) for subpectoral biceps tenodesis. We hypothesized that the screw construct would have a significantly higher load to failure and stiffness than the anchor construct.

METHODS

Nine matched pairs of cadaveric shoulders were assigned to two procedure groups. For each pair, one shoulder underwent tenodesis of the long head of the biceps with the Bio-Tenodesis screw and the contralateral shoulder underwent tenodesis with the Bio-Corkscrew. The assignment of the left side or right side to each treatment group was random. After an initial arthroscopic tenotomy of the long head of the biceps, the arm was abducted and internally rotated, and a 3-cm incision was made on the medial aspect of the inferior border of the pectoralis major tendon. Following the technique of Wiley et al.,[9] we identified the tendon of the long head of the biceps at the upper border of the pectoralis major tendon. For placement of fixation hardware, a 2 × 1–cm area of bone was denuded of soft tissue, 1 cm above the inferior border of the pectoralis major tendon.

Following the technique of Mazzocca et al.,[10] we used a guidewire and an 8-mm reamer to create a 15-mm-deep bone tunnel in the Bio-Tenodesis screw group. The tenotomized biceps tendon was cut 25 mm proximal to the musculotendinous junction, and by use of a No. 2 FiberWire (Arthrex), a Krackow stitch was inserted into 15 mm of the stump of the tendon. One limb of the stitch was passed through the cannulated Bio-Tenodesis screw and screwdriver, and the other limb was left free. The end of the tendon was drawn into the tip of the Bio-Tenodesis screw. An 8 × 12–mm Bio-Tenodesis screw was used to fix the tendon in the previously drilled hole in the humerus. The 2 strands of No. 2 FiberWire sutures were tied to each other outside the screw with 3 pairs of square knots.

By use of the same approach as described previously, a hole was created with a punch in each humerus in the Bio-Corkscrew group for the 5.5 × 14.7–mm Bio-Corkscrew, which was double-loaded with No. 2 FiberWire. The 2 FiberWire sutures were passed through the biceps tendon, each in a horizontal mattress at right angles to the other in an arthroscopic Mason-Allen configuration, and each was secured with 3 pairs of squared knots. The humeri were dissected to remove all tissue other than that of the repair and were frozen until testing. Each specimen was thawed to room temperature for at least 24 hours before testing.

The shaft of each humerus was potted in a fast-setting resin and fixed to an inverted knee clamp to secure the resin to the base of a material testing machine (model TTS-25 series; Adelaide Testing Machines, Toronto, Ontario, Canada). The tendon was secured in a custom sinusoidal clamp such that the angle of pull was in line with the long axis of the tendon and the humerus (Fig 1). The construct was preloaded to 5 N and underwent cyclic loading from 20 N to 60 N for 100 cycles at 0.5 mm/s, monitored by a 100-lb load cell. Any specimens in which failure did not occur during the cyclic loading protocol underwent a load-to-failure protocol. After a 30-minute rest in the unloaded state, the constructs were loaded to failure at 1.25 mm/s. A 5-N preload was applied, and a 100-lb load cell was used to monitor the process. Ultimate load (in Newtons), stiffness (in Newtons per millimeter), and mode of failure were recorded. Data were analyzed by use of paired *t* tests and Kolmogorov-Smirnov tests (SPSS software, version 14; SPSS, Chicago, IL). The experiment was designed by an a priori power analysis. For 9 cadaveric shoulders, the power of *t* tests with an α value of 0.05 is 80% for a very large effect size (Cohen $d = 1.5$).

RESULTS

Table 1 lists the demographic and biomechanical testing data for matched shoulder pairs with a proxi-

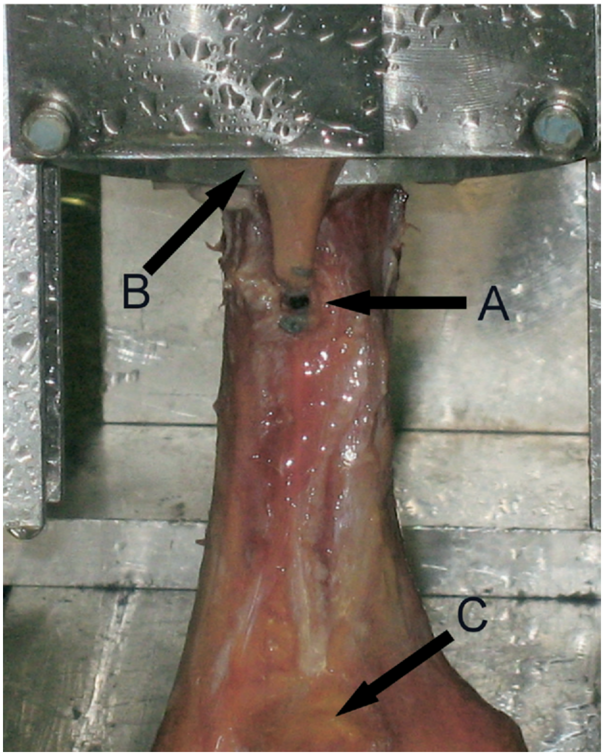

Figure 1. Experimental jig for biomechanical testing of cadaveric shoulders. (A) Site of tenodesis approximately 1 cm proximal to inferior border of pectoralis major tendon. (B) More distal end of tenodesed proximal biceps tendon being held by custom clamp. (C) Proximal humerus, noteworthy for absence of biceps tendon within intertubercular groove. The figure illustrates the setup for an interference screw construct, but the setup is similar for the suture anchor construct.

mal biceps tenodesis by suture anchor construct versus interference screw construct. The screw construct had a significantly higher ultimate load than the suture anchor construct (mean ± SD, 169.6 ± 50.5 N *v* 68.5 ± 33.0 N) by paired *t* test ($P = .002$). The screw construct also had a significantly higher mean stiffness than the suture anchor construct (mean ± SD, 34.1 ± 9.0 N/mm *v* 19.3 ± 10.5 N/mm) by paired *t* test ($P = .038$). All data were consistent with a normal distribution by Kolmogorov-Smirnov tests ($P > .05$).

Of the tenodeses, 9 failed by the suture cutting or tearing through the tendon (4 Bio-Tenodesis screws and 5 Bio-Corkscrews), 7 had failure of the biceps tendon itself (4 Bio-Tenodesis screws and 3 Bio-Corkscrews), and 2 failed at the suture-tendon interface (1 Bio-Tenodesis screw and 1 Bio-Corkscrew). Of 9 suture anchor constructs, 5 failed at or below 60 N during the cyclic-loading portion of the protocol, and 4 of 9 completed the cyclic-loading portion and then completed the load-to-failure portion of the protocol. All 9 interference screw constructs completed the cyclic-loading portion of the protocol without failure up to 60 N and then completed the load-to-failure portion of the protocol.

DISCUSSION

A potential benefit of tenodesis over tenotomy is superior biomechanical properties[11]; therefore the biomechanical properties of the tenodesis construct are important, especially for early range of motion or in patients with isolated biceps pathology. This is the motivation behind our study and previous biomechanical studies.

Our study compared a bioabsorbable interference screw with a single bioabsorbable suture anchor loaded with composite polyethylene suture in human cadavers. Previous biomechanical studies used multiple anchors, metallic anchors, simple braided sutures, metallic screws, or ovine cadavers. The main advantages of our study are a side-by-side comparison of devices not previously compared in a subpectoral location. The conclusions correlate with some prior studies[6] and help reconcile others that showed similar loads to failure but fell short of showing statistical significance.[3] The main disadvantages of our study are the comparison of 2 newer methods of tenodesis without comparison to a well-known open method[10,12] and the cadaveric biomechanical design, which shares the limitations in extrapolation to clinical care of prior published biomechanical studies including the possibility of side-to-side differences in matched shoulder pairs.

Richards and Burkhart[6] used human specimens to test a 7 × 25–mm Bio-Tenodesis screw loaded with No. 2 Ethibond (Ethicon, Somerville, NJ) (mean load, 233.5 N) against a double–suture anchor technique using 2 Mitek GII anchors (DePuy Mitek, Raynham, MA) (2.4 × 8.8–mm titanium with nitinol arcs) loaded with No. 2 Ethibond (mean load, 135.5 N). Two screws failed by pulling out of the bone socket, and one failed with a fracture of the proximal humerus through the socket. The most common mode of failure for the suture anchor group was suture breakage at the eyelet, a well-recognized problem.[13] We did not encounter these modes of failure in our study; instead, the failure modes we report are all at the suture-tendon interface and within the substance of the tendon. Richards and Burkhart emphasized that the design of the Bio-Corkscrew anchor may protect against failure of suture at the eyelet. In addition, metaphyseal bone

Table 1. *Biomechanical Testing Data for Matched Pairs of Cadaveric Shoulders With Proximal Biceps Tendon Tenodesis by Suture Anchor Construct Versus Interference Screw Construct*

				Ultimate Load (N)		Stiffness (N/mm)	
	Age (yrs)	Gender	Anchor Side/Screw Side	Suture Anchor	Screw	Suture Anchor	Screw
Matched Shoulder Pair							
1	86	F	L/R	26.8	127.4	5.9	32.9
2	86	F	R/L	49.9	244.7	12.1	48.9
3	87	F	L/R	119.4	99.6	26.5	28.9
4	68	M	R/L	92.6	160.7	32.9	20.6
5	88	F	L/R	74.6	205.0	25.9	35.2
6	82	F	R/L	24.2	126.8	5.9	39.4
7	80	M	L/R	86.8	175.1	28.7	31.2
8	76	M	R/L	47.5	236.7	11.0	44.5
9	81	M	L/R	94.5	150.4	24.6	25.7
Mean ± SD	81.6 ± 6.4			68.5 ± 33.0	169.6 ± 50.5	19.3 ± 10.5	34.1 ± 9.0

NOTE. Ultimate load is in units of Newtons (N). Stiffness is in units of Newtons per millimeter (N/mm). The final row shows the mean and standard deviation (SD) of the data columns.

quality at the proximal location used in that study differs from the diaphyseal quality in a more distal subpectoral location. Finally, the difference in mode of failure might reflect disparities in cadaveric tendons. Because the fixation devices in our study did not reach failure load, we surmised that their loads to failure would be much higher in healthier tendons.

Mazzocca et al.[3] tested the loads to failure of 4 methods in human cadavers—arthroscopic interference screws (237.6 N), subpectoral bone tunnels (242.4 N), open subpectoral Bio-Tenodesis screws (252.4 N), and arthroscopic suture anchors (164.8 N)—and found no significant differences in the loads to failure. Two Mitek GII anchors were used, each single loaded with No. 2 FiberWire. The tendon was secured by use of sutures from each anchor in a modified Mason-Allen configuration. The specimens failed at the tendon-bone interface, and there were no intratendinous failures. We used a similar technique, but the Bio-Tenodesis screw in our study failed at a lower mean load. An important feature of this study is that the mean loads to failure for interference screws and anchors are similar to those in our study and to those in the study by Richards and Burkhart; however, statistical significance was not achieved, perhaps because of the larger SDs despite relatively small sample sizes, resulting in modest power in both studies. In addition, we used a single double-loaded anchor as opposed to 2 single-loaded anchors and found no failures at the bone-anchor interface. Another important feature of this study is the comparison of more proximal tenodeses with a more distal subpectoral tenodesis.

Jayamoorthy et al.[5] used human specimens to compare the keyhole technique, which uses osseous tunnels to achieve both metallic and bioabsorbable interference screw fixation. They concluded that there was no significant difference between the keyhole reference standard and the bioabsorbable screw in terms of load to failure. Failure occurred by slipping of the tendon at the bone-screw interface or by tendon splitting and pullout from the keyhole. This study differed from our approach in that all tenodeses were performed proximally in the intertubercular groove versus more distally in the subpectoral location. In addition, comparison was made between interference screws and the keyhole technique, a well-known open method.[12]

Ozalay et al.[7] compared several methods of fixation in sheep specimens under load to failure. The strongest construct was the tenodesis screw (8 × 25–mm titanium screw) (243 N), followed by Snyder's tunnel technique (229 N), metallic suture anchors (two 2.8-mm Mitek Superanchors) (129 N), and the keyhole technique (101 N). These results are only partially consistent with the human biomechanical testing by Jayamoorthy et al.[5] with respect to the strength of the keyhole versus tenodesis, perhaps because of the species difference or other specimen factors. In our study we found the Bio-Tenodesis screw to have a higher mean load to failure than the Bio-Corkscrew (169.6 N *v* 68.5 N), similar to the rank ordering of strengths determined by Ozalay et al.

The design of the Bio-Corkscrew incorporates an eyelet fabricated from suture, which has been advocated for minimizing suture breakage at the eyelet.[6] However, Deakin et al.[14] compared the properties of 3 different suture anchors on the bench top, without the use of cadavers—Mitek GII anchors (metallic), Corkscrew anchors (metallic), and Bio-Corkscrew anchors (PLDLA)—with No. 2 Ethibond and No. 2 FiberWire sutures and found that No. 2 Ethibond failed first in all anchors. Ethibond failed at the eyelets of the metal anchors. FiberWire also failed at the eyelets but at a higher load (range, 214 to 270 N *v* 175 to 193.9 N). The Bio-Corkscrew anchor had a No. 5 braided polyester loop as an eyelet that failed first when used with No. 2 FiberWire and at a lower load than the metal anchors. Unlike Deakin et al., we did not encounter eyelet failure in our study, possibly because the load to failure of the suture-tendon interface was lower than that of the eyelet. This is in contrast to the results of Richards and Burkhart,[6] who found failure at the eyelet in anchors with metallic eyelets. Both the implants in our study used No. 2 FiberWire to capture the tendon. Regardless of the anchor design, interference screws showed superior load to failure in our study, mitigating the importance of the eyelet design in the Bio-Corkscrew.

The Bio-Tenodesis screw is designed to hold the tendon in a bone tunnel with an interference fit. For the construct to fail, the interference fit between the tendon, screw, and bone must fail, resulting in screw pullout from the bone tunnel[3]; however, in our study the suture-tendon interface failed at a lower load relative to screw pullout. Overall, the Bio-Corkscrew failed at a much lower load (68.5 N) than the Bio-Tenodesis screw (169.6 N). Pereira et al.[15] estimated the force necessary to maintain the elbow at 90° of flexion to be 52 N and the force needed to support a 1-kg weight to be 110 N. Rodosky et al.[16] estimated the maximum force that can be applied by the long head of the biceps tendon at the shoulder to be 130 to 160 N. With these parameters in mind, our study suggests that the Bio-Tenodesis screw may enable early mobilization of the elbow compatible with an early return to activity.

The modes of failure in our study (i.e., suture cutting through the tendon, intrasubstance failure of the tendon, and failure at the suture-tendon interface) suggest that they were a function of the state of the cadaveric tendon itself, perhaps promoted by the relatively high stiffness of both constructs, which may not be physiologic. There were no failures of the suture material or the knots. None of the implants pulled out of bone. For this latter reason, bone mineral density and cortical thickness of bone, which play an important part in the pullout strength of anchors,[17] were deemed less important. Fracture of the humerus was a mode of failure of the tenodesis screw in some studies[6]; however, we did not encounter fracture as a mode of failure. We believe that when these 2 techniques are used in live tendons, they will be able to tolerate higher loads. Initial strength seems to depend more on the quality of tendon than on mode of fixation. Even though the mean load to failure of the Bio-Tenodesis screw in our study was lower than that of the tenodesis screw and the bone tunnel in previous studies,[3,7] it falls within the physiologic limit of the estimated load on the proximal biceps attachment.[15]

These considerations highlight a weakness of this study, which is a biomechanical investigation in human cadavers. As a result, the data from this and other prior studies may not apply exactly in patients. However, we believe that the relative merits of the 2 devices will hold true in patients even though the actual numbers may differ. By testing the devices in pairs of upper extremities from the same cadavers, we were able to moderate the possible impact of these factors. The assessment of load to failure is affected by the fact that we test failure after testing cyclic loading. Despite this, we believe that the loads to ultimate failure obtained after cyclic loading give an estimate of what to expect during mobilization of patients after tenodesis.

CONCLUSIONS

In this cadaveric study, the Bio-Tenodesis screw showed a statistically significantly higher load to failure and significantly higher stiffness than the Bio-Corkscrew anchor when used for tenodesis of the proximal biceps tendon in a subpectoral location.

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