# The Biomechanical Evaluation of Four Fixation Techniques for Proximal Biceps Tenodesis

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**Purpose:** The purpose of this study was to compare the cyclic displacement and ultimate failure strength of 4 proximal biceps tendon tenodesis fixation methods: the open subpectoral bone tunnel (SBT) biceps tenodesis, the arthroscopic suture anchor (SA) tenodesis, the open subpectoral interference screw (SIS) fixation technique, and the arthroscopic interference screw (AIS) technique. **Type of Study:** Biomechanical experimental control. **Methods:** Twenty fresh-frozen cadaver shoulders were dissected free of soft tissues, leaving the proximal humerus and the proximal biceps tendon as a free graft. Specimens were randomized to 1 of 4 groups with 5 total specimens in each group. A proximal biceps tenodesis was performed according to the techniques listed above. The specimens were mounted for an axial pull of the biceps tendon on a servohydraulic materials testing system with a 100-N load cycled at 1 Hz for 5,000 cycles, followed by an axial load to failure test. Cyclic displacement, ultimate load to failure, and site of failure were recorded for each specimen. **Results:** The mean cyclic displacement recorded for each experimental group was as follows: SBT group, 9.39 ± 2.82 mm; AIS group, 5.26 ± 2.60 mm; SIS group, 1.53 ± 0.60 mm; and SA group, 3.87 ± 2.11 mm. The mean ultimate failure loads after 5,000 cycles were as follows: SBT group, 242.4 ± 51.33 N; AIS group, 237.6 ± 27.58 N; SIS group, 252.4 ± 68.63 N; and SA group, 164.8 ± 37.47 N. Each specimen failed at the tenodesis site. **Conclusions:** The SBT group showed statistically significant greater displacement than the other tenodesis methods. There were no statistically significant differences in ultimate failure strength between any of the biceps tenodesis methods tested. **Clinical Relevance:** The data serve as a guide to the surgeon performing a proximal biceps tenodesis in choosing a fixation method. **Key Words:** Biceps tenodesis—Interference screw—Subpectoral.

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The biceps tendon has long been recognized as a possible source of shoulder pain. As the "pain generator" of the shoulder, it has been associated with everything from arthritis to impingement syndrome, without a full understanding its true pathology and function. Our understanding of its role in shoulder pathology has ranged from describing it as a vestigial structure,[1] to a vital structure of shoulder function with distinct disease pathology.

In this light, procedures to address disease of the proximal biceps tendon date back to the early 20th century. Techniques have been described that range from benign neglect to tenotomy and/or tenodesis of the biceps tendon.[2-10] Currently, we believe that biceps tenodesis is recommended over biceps tenotomy for the following 3 reasons[11]: (1) Maintenance of the length-tension relationship of the biceps muscle by establishing a new origin of biceps attachment at the appropriate length to prevent muscle atrophy, (2) maintenance of elbow flexion and supination strength for maximum elbow function, and (3) better cosmetic appearance.

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Current thought regarding proximal biceps tenodesis techniques can be divided into open[5,6,8,11-15] or arthroscopic procedures,[12,14,16-21] with some procedures incorporating interference screw fixation. Although many of these techniques are worthwhile and are in use today, there has been little information published on the biomechanical strength of the various biceps tenodesis techniques.[22]

A pilot study was initially performed to evaluate the concept of interference screw fixation for proximal biceps tenodesis with a novel device, the Biotenodesis screw driver (Arthrex, Naples, FL). This Biotenodesis screw driver allows the surgeon the ability to place the biceps tendon within a bone tunnel and then hold that tendon in place at the base of the bone tunnel while placing an interference screw over the top of the tendon. The Biotenodesis screw driver also allows the pulling sutures placed in the tendon to be tied around the interference screw, thus securing the tenodesed tendon using 2 methods. The primary method is the interference screw, with secondary fixation accomplished by tying the suture to the anchor (i.e., suture anchor fixation).

The initial pilot study looked at comparing 30 fresh-frozen cadaver shoulder biceps tenodeses divided among a subpectoral bone tunnel tenodesis technique[11] group (control) and 4 experimental groups based on the arthroscopic interference screw tenodesis technique.[23] Load to failure studies on the pullout strength of the tenodesis showed that an 8-mm bone tunnel with an 8 × 23 mm Arthrex biotenodesis interference screw had the strongest fixation and that all of the biotenodesis interference screw fixation groups were at least as strong as the subpectoral bone tunnel tenodesis technique. In addition, the concept of using the same size biotenodesis screw as the reamer size used was appreciated.

Further pilot work on an additional 16 fresh-frozen cadaver shoulders looked at an experimental setup similar to that described above, but in this case, tendon displacement followed by a load to failure test after cyclic loading (5,000 cycles at 1 Hz) was studied. The results showed that there were no differences in precyclic load to failure versus postcyclic load to failure strengths among any of the interference screw biotenodesis groups. Furthermore, there were no differences in tendon displacement after 5,000 cycles between either the biotenodesis groups or the biotenodesis groups compared with the control group (i.e., subpectoral bone tunnel technique).

The purpose of our study was to compare the cyclic displacement and ultimate failure strength of 4 proximal biceps tendon tenodesis fixation methods: the open subpectoral bone tunnel biceps tenodesis, the arthroscopic interference screw technique, the open subpectoral interference screw fixation technique, and the arthroscopic suture anchor tenodesis. Our hypothesis was that the SIS technique has less cyclic displacement at 5,000 cycles and shows no difference in peak load to failure when compared with the other biceps tenodesis techniques.

## METHODS

Twenty fresh-frozen human cadaver shoulders were studied. The mean age of the specimens was 78 ± 18 years. Each specimen was thawed at room temperature over a 24-hour period before dissection and tenodesis. Each shoulder was dissected free of soft tissues, leaving the proximal humerus and the proximal biceps tendon as a free graft (i.e., the biceps tendon was cut from its attachment to the superior labrum).

DEXA scans (DEXA Lunar, Madison, WI) for evaluation of bone mineral density and bone mineral content were performed at the bicipital groove and humeral diaphysis on all specimens before any further testing. This was done to eliminate any bias that bone mineral density could have in regard to pullout strength of the interference screw fixation among specimens.

The specimens were randomly divided into 4 groups with 5 specimens in each group. Group 1 was defined as the subpectoral bone tunnel (SBT) tenodesis technique. Group 2 was defined as the arthroscopic interference screw (AIS) technique. Group 3 was defined as the subpectoral interference screw (SIS) technique. Group 4 was defined as the arthroscopic suture anchor (SA) technique. The following sections describe how each technique was performed.

### Group 1: SBT Biceps Tenodesis Technique

The tenodesis performed was based on a technique published by Mazzocca et al.[11] using bone tunnels for suture passage and intracortical biceps fixation. The approximate location of the inferior border of the pectoralis major tendon (which was dissected away in the cadaver specimens) is where the musculotendinous portion of the native biceps tendon should lie. To ensure similarity between our experimental technique and the in vivo tenodesis technique, the proximal portion of the biceps tendon was resected to leave 20 to 25 mm of tendon proximal to the musculotendinous portion of the biceps. A No. 2 Fiberwire suture (Ar-

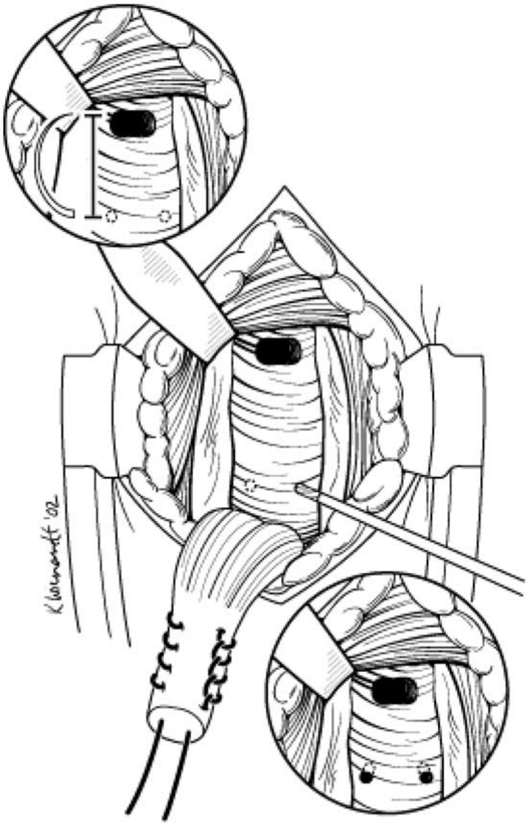

**FIGURE 1.** Two smaller holes are drilled inferior to the major bone tunnel—the sizing of this should be done with the needle that will be used as the passing suture. The inferior holes are used for suture shuttling.

threx) was placed in a whipstitch fashion for 1.5 cm in the remaining proximal biceps tendon.

A 4.5-mm drill was used to drill 3 holes in a horizontal fashion at the proximal portion of the bicipital groove that anatomically lies under the pectoralis major tendon. The holes were made through the anterior cortex of the humerus and then connected with a rongeur to allow space for the biceps tendon to pass. A 3.2-mm drill was then used to make 2 holes distal in the bicipital groove, which functioned as the suture shuttle holes to pull the tendon into the bone tunnel (Fig 1). The holes were drilled far enough distal so that a No. 2 nonabsorbable suture with its corresponding needle could be threaded in a retrograde fashion. The needles were then retrieved through the bone trough proximally and then removed. The No. 2 nonabsorbable suture was tied in a square knot around the No. 2 Fiberwire and pulled through its corresponding hole distally (Fig 2). In this way, the biceps tendon was pulled into the bony trough, and the 2 suture ends

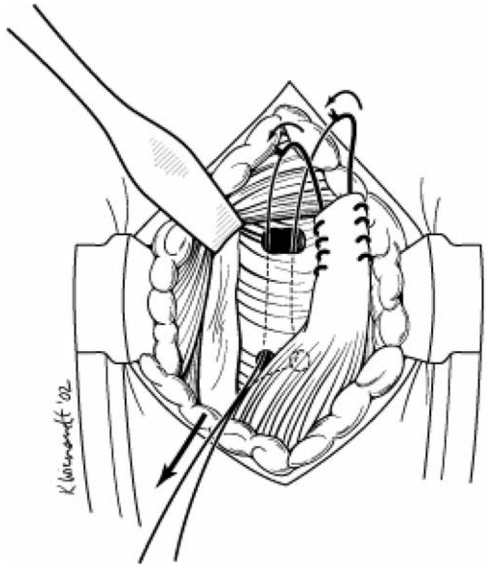

**FIGURE 2.** The biceps tendon is pulled into the bone tunnel in a retrograde fashion using the inferior holes as a suture shuttle.

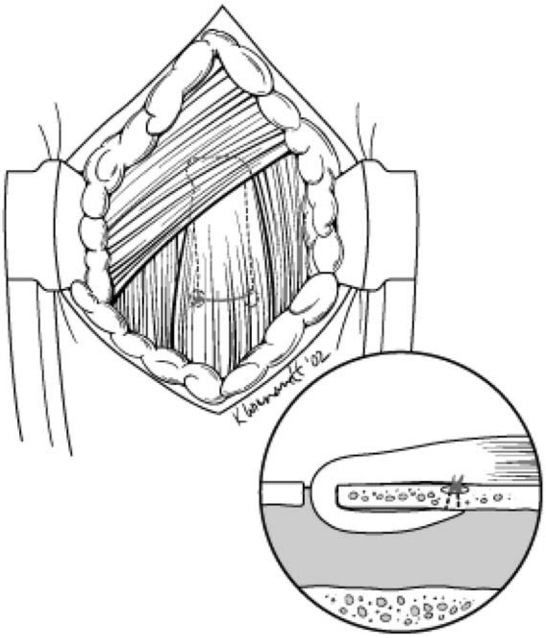

**FIGURE 3.** This drawing illustrates the fact that the musculotendinous junction lies underneath the inferior edge of the pectoralis tendon. The inset shows how the tendon is secured into the bone tunnel.

**FIGURE 4.** The biotenodesis screw driver with tendon-measuring device on thumb pad. The bioabsorbable screw is loaded.

were then tied in a square knot underneath the biceps tendon (Fig 3).

## Group 2: AIS Technique

This technique uses the Arthrex Biotenodesis screw driver (Fig 4) for interference screw fixation of the biceps tendon according to techniques published by Mazzocca and Romeo[23] and Richards et al.[24] The Biotenodesis screw driver has a 20-mm excursion when using a 23-mm length screw. Therefore, in order to reapproximate the amount of intra-articular biceps tendon and to ensure that our experimental technique was similar to the in vivo tenodesis technique, 20 mm of the proximal biceps tendon was removed, and a whipstitch using 36-inch long No. 2 Fiberwire was placed in 15 mm of tendon. This allowed the tenodesis screw driver to bury the tendon with the whipstitch suture and confirm correct placement in the bone tunnel (Fig 5).

An 8-mm reamer was used to make a 25-mm deep bone tunnel at the proximal portion of the bicipital groove that anatomically lies superior to the pectoralis major tendon. The Arthrex Biotenodesis screw driver and biotenodesis screw (8 × 23 mm) were used to perform the biceps tenodesis. When the screw was flush with the bone tunnel, the screw driver was removed, and the limb of suture juxtaposed to the tendon and screw was tied to the limb of the suture through the screw. This provided both an interference fit, due to the screw fixation, as well as suture anchor stability (tendon-screw construct) (Fig 6).

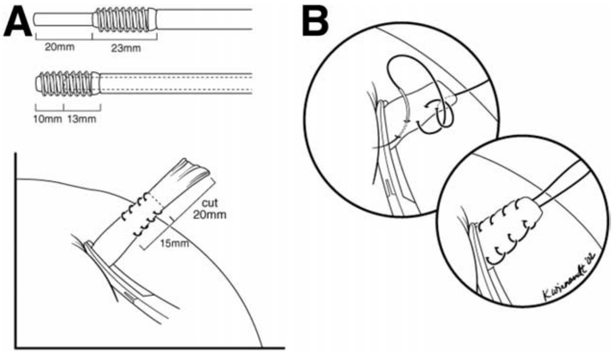

**FIGURE 5.** (A) Amount of biceps tendon to be removed (20 mm) ensuring adequate tension of the tendon. (B) A braided suture is placed on the end of the tendon using a tendon stitch technique as described by Krakow. Our preferred suture is a No. 2 Fiberwire 36 inches in overall length.

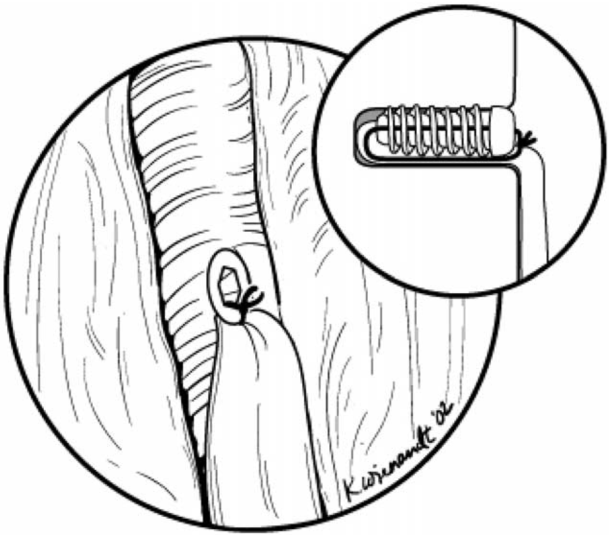

**FIGURE 6.** The biotenodesis screw with the biceps tendon adjacent, illustrating interference fit. Inset: A knot comprised of multiple half hitches tied over the top of the interference screw. This ensures that the tendon is now secured by 2 methods. The primary method is the interference fit and the secondary method is the "suture anchor" (accomplished when the tendon is sutured around the interference screw itself).

## Group 3: SIS Technique

This technique uses the same Arthrex Biotenodesis screw driver for interference screw fixation as described in group 2, but the location of the tenodesis and hence the size of the interference screw was changed. In this case, the tenodesis was performed 1 cm proximal to where the inferior border of the pectoralis major tendon would theoretically be (Figs 7, 8, and 9). In contrast to the location of the tenodesis in group 2, the subpectoral location of this tenodesis could not accommodate a 23-mm long biotenodesis screw. Therefore, a new biotenodesis screw was used measuring 12 mm in length. This is important because the length of the screw dictates the length of suture

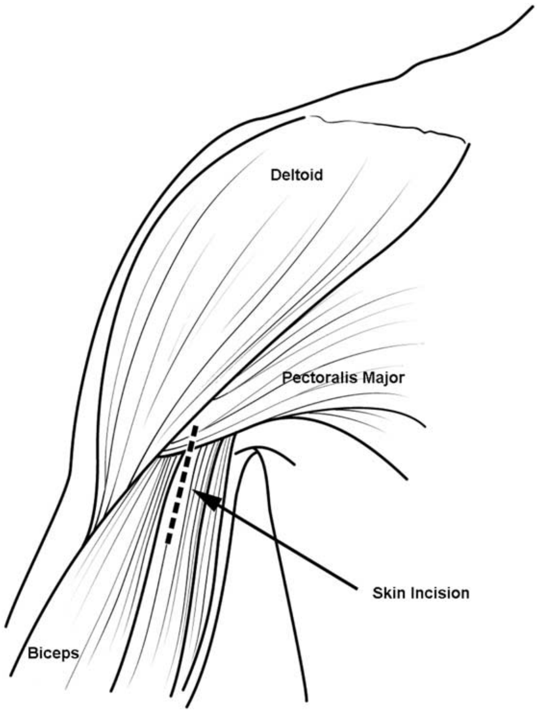

**FIGURE 7.** The skin incision for the subpectoral interference screw tenodesis is made in the medial one third of the arm. It extends 1 cm superior to the inferior border of the pectoralis tendon to 3 cm below this border. This tendon can be palpated by resisted internal rotation with the arm abducted and internally rotated 10° to 15°.

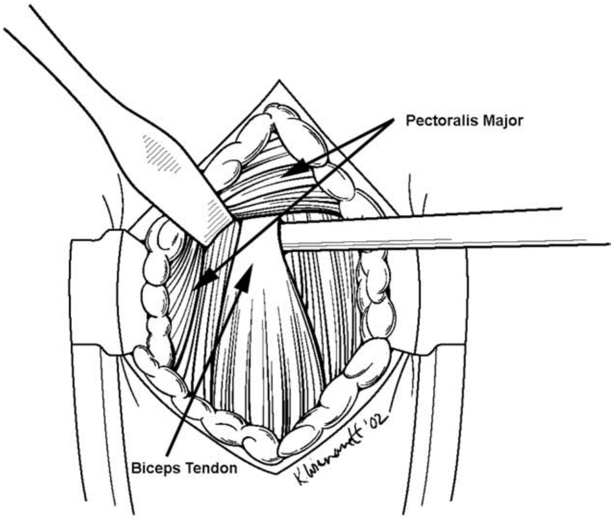

**FIGURE 8.** Once the superficial dissection is completed, the fascia at the inferior portion of the pectoralis major tendon is incised. This reveals the biceps tendon, which can be retrieved using a right angle clamp.

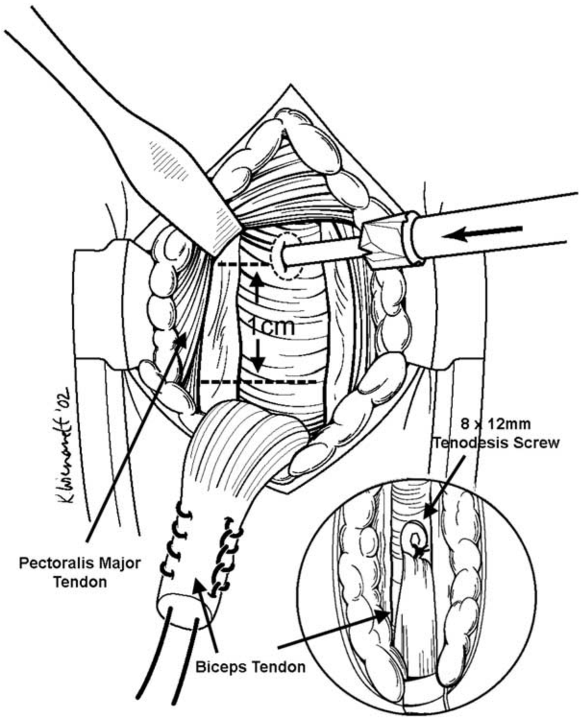

**FIGURE 9.** The tenodesis hole is drilled 1 cm proximal to where the inferior border of the pectoralis major tendon lies. The inset shows the final tenodesis using the 8 × 12 mm biotenodesis screw (instead of the 8 × 23 mm screw used in the AIS technique).

placed in the proximal biceps tendon and may have an influence on the pullout strength of the biotenodesis construct.

A 36-inch long No. 2 Fiberwire was placed into the proximal 15 mm of biceps tendon in a whipstitch fashion. Once the whipstitch was completed, a square knot was placed at the end of the suture-tendon interface. An 8-mm reamer was used to make a 15-mm deep bone tunnel 1 cm proximal to where the inferior border of the pectoralis major tendon would theoretically be (Fig 9). The same technique for tenodesis using the Biotenodesis screw driver was then followed as described in group 2.

## Group 4: Arthroscopic SA Technique

In this technique, 2 suture anchors (Mitek GII Suture Anchor; Mitek, Norwood, MA) were placed at the proximal bicipital groove, above the theoretical location of the pectoralis major tendon (similar to the location used in group 2). The suture anchors were loaded with No. 2 Fiberwire. To reapproximate the amount of intra-articular biceps tendon and to ensure that our experimental technique was similar to the in

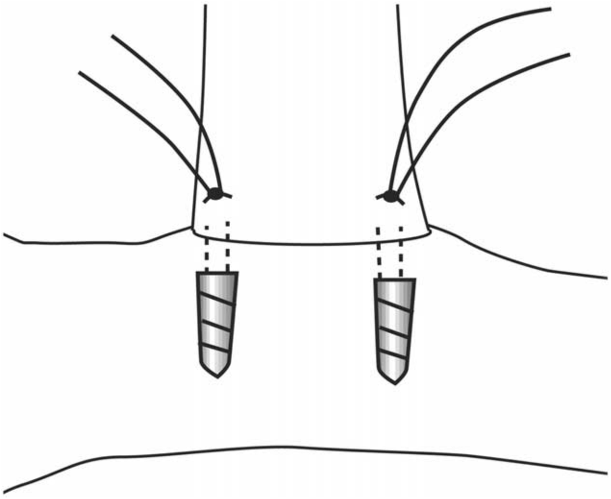

**Figure 10.** Anchors were inserted into the proximal biceps groove. Each of the suture tails from the suture anchors were then passed through the proximal biceps tendon in a modified Mason-Allen stitch fashion and tied to oppose the tendon to bone.

vivo tenodesis technique, 20 mm of the proximal biceps tendon was removed. Each of the suture tails from the suture anchors were then passed through the proximal biceps tendon in a modified Mason-Allen stitch fashion and tied to oppose the tendon to bone (Fig 10).

### Testing of Specimens

The specimens were each mounted for Instron testing (Model 1321; Instron, Canton, MA) in an axial direction (Fig 11). A custom-made clamp was used to couple the biceps tendon to the servohydraulic actuator. The humerus and biceps tendon were aligned such that the cyclic loading forces and ultimate pullout strength forces were parallel to the longitudinal axis of the humerus, thus reapproximating the in vivo direction of force along the biceps muscle and tendon.

The testing was performed at room temperature. A spray bottle was used with a 0.9% normal saline solution to keep the biceps tendon graft moist and avoid desiccation. The tendons were preloaded to 11 N, and then 50% of the average failure load for the biceps tenodesis (100 N, taken from pilot study work) was used to evaluate the fixation displacement during 5,000 load cycles at 1 Hz. After the cyclic loading, an axial load to failure test was conducted on the same specimens at a rate of 1 mm/second to a maximum displacement of 100 mm. The maximum displacement was theoretically set well above any physiologic tendon displacement without complete failure of the construct.

Data recorded for the cyclic displacement included maximum and minimum displacement for each cycle, as well as for the entire 5,000 cycles. Data recorded for the axial load to failure test included the ultimate load to failure and the location of tendon failure.

Statistical analysis was performed using SPSS software (SPSS Inc, Chicago, IL). Univariate analysis of variance was used to compare the bone mineral density (DEXA scan data), cyclic displacement data, and ultimate load to failure for each of the 4 experimental groups. Any statistically significant differences were followed by use of Tukey's post hoc analysis for multiple comparisons between each of the groups; $P < .05$ was considered significant.

## RESULTS

Initial randomization of the specimens to the 4 experimental groups did not show any statistically significant differences between the groups in terms of age or sex. DEXA scan data did not show statistical differences in bone mineral density at the greater tuberosity among the groups tested ($P = .79$).

**Figure 11.** The fixture used for mounting the specimens for Instron testing. A custom-made clamp was used to couple the biceps tendon to the servohydraulic actuator. The humerus and biceps tendon were aligned such that the cyclic loading forces and ultimate pullout strength forces were parallel to the long axis of the humerus.

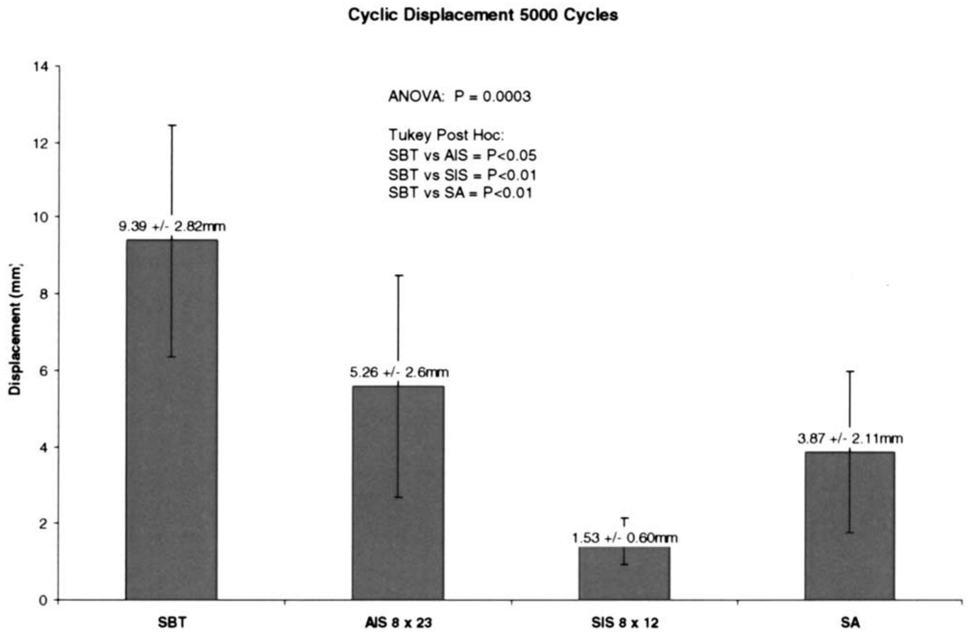

**Figure 12.** Data on the cyclic displacement after 5,000 cycles (1 Hz). Statistically significant differences were found between the SBT and AIS, SBT and SIS, and SBT and SA groups.

### Cyclic Displacement Data (Fig 12)

The mean cyclic displacement recorded for each experimental group was as follows: SBT group, 9.39 ± 2.82 mm; AIS group, 5.26 ± 2.60 mm; SIS group, 1.53 ± 0.60 mm; and SA group, 3.87 ± 2.11 mm. There was a statistically significant difference between the means of the various groups at the 0.05 significance level using analysis of variance ($P = .0003$). Further evaluation using Tukey's post hoc analysis to discriminate among the means revealed statistically significant differences between the SBT group and AIS group ($P < .05$), the SBT group and SIS group ($P < .01$), and between the SBT group and SA group ($P < .01$). There were no statistically significant differences noted between the AIS and SIS groups, the AIS and SA groups, or the SIS and SA groups.

### Ultimate Load to Failure Data (Fig 13)

Each of the specimens failed at the tendon-bone (i.e., fixation-device/tendon) interface. There were no failures of the bone itself (i.e., fractures) or intratendinous failures (i.e., slippage or cut-through of the biceps tendon). The mean ultimate failure loads after 5,000 cycles were as follows: SBT group, 242.4 ± 51.33 N; AIS group, 237.6 ± 27.58 N; SIS group, 252.4 ± 68.63 N; and SA group, 164.8 ± 37.47 N. Analysis of variance revealed a small statistically significant difference among the means of the various groups ($P = .04$), but further evaluation with Tukey's post hoc analysis failed to find statistically significant differences between any pair of means at the 95.0% confidence level. Therefore, there was no statistically significant difference in failure loads among the biotenodesis groups after 5,000 cycles.

## DISCUSSION

Proximal biceps tenodesis is recommended during open or arthroscopic shoulder procedures when the biceps tendon is found to be diseased or is the source of pain about the shoulder joint. In our opinion, tenodesis is recommended over tenotomy because it allows the maintenance of the length-tension relationship of the biceps muscle, it allows maximum elbow function with maintenance of elbow flexion and supination, and it results in a better cosmetic appearance.[11]

Many proximal biceps tenodesis techniques have been described in the literature, ranging from open[5,6,8,11-15] to arthroscopic methods.[12,14,16-21] Unfortunately, there is a paucity of biomechanical data reported in the literature supporting the techniques available to the surgeon for proximal biceps tenodesis.

In our opinion, interference screw fixation provides a safe and reliable method of proximal biceps tenode-

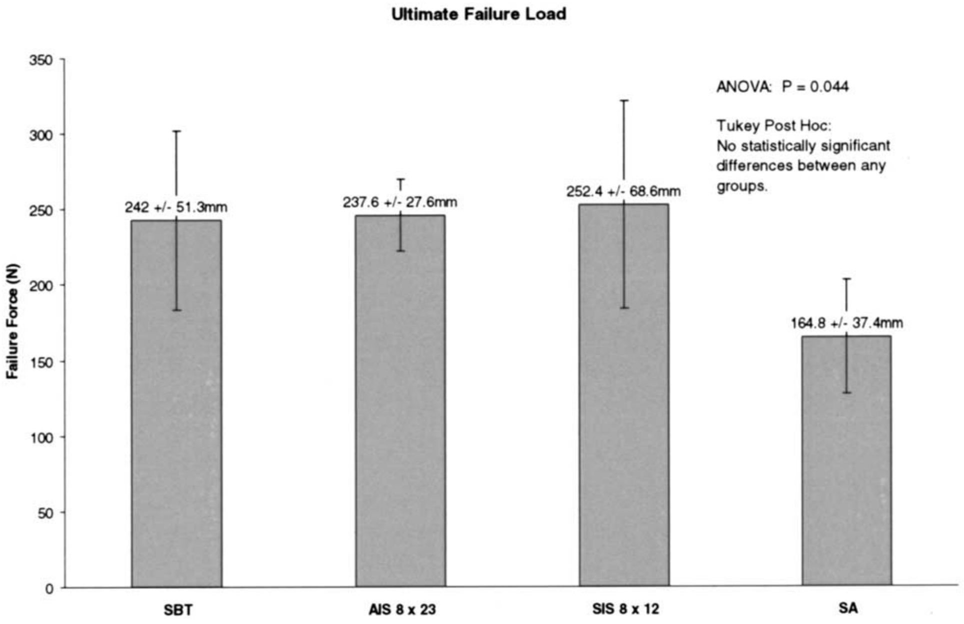

**FIGURE 13.** Data on the ultimate failure strength of the tenodesis techniques. There were no statistically significant differences found among any of the biceps tenodesis groups.

sis. Previous techniques used by one of the senior authors (A.A.R.) included the open subpectoral bone tunnel biceps tenodesis technique. Although a safe technique, the dissection needed to visualize both the tenodesis tunnel and the more distal suture passing bone tunnels is significant. In addition, careful attention must be paid to the distance of the suture-passing bone tunnels in relation to the tenodesis tunnel. If they do not match the radius of curvature of the needle being used, the procedure becomes a struggle.

With the advent of arthroscopy and more reliable suture anchor fixation, the idea of using suture anchors was applied to the proximal biceps tenodesis. This technique, though, requires arthroscopic knot tying skills that may deter some surgeons from performing the procedure.

Interference screw fixation began to be used for proximal biceps tenodesis as our familiarity with the technique grew with its use about the knee. An early technique was described by Boileau et al.[12] whereby a guide pin was used with an eyelet that passed through the bicipital groove anteriorly and out the posterior aspect of the humerus. The angle of the guide pin was placed 1 cm below the rotator cuff insertion in the bicipital groove and perpendicular to the axis of the humerus with the axillary nerve. The technique is said to avoid potential neurologic injury. However, passing a guide pin through the posterior aspect of the humerus is a concern, and may be responsible for complications in less experienced hands.

Further advances in interference screw fixation have led to the new instrument, the Biotenodesis screw driver, which was designed to allow the surgeon the ability to place the biceps tendon within a bone tunnel and then hold that tendon in place at the base of the bone tunnel while placing an interference screw over the top of the tendon. The key feature is a reverse screw mechanism on the distal segment that allows insertion of the interference screw while holding the tendon in the base of the bone socket, thus preventing the tendon from displacing relative to the socket.

The expansion of this instrument to allow for large tendon fixation has led to the development of an arthroscopic technique for biceps tenodesis using interference screw fixation.[23] In addition to the interference fixation provided by the screw-tendon interface, the Biotenodesis screw driver also allows the pulling sutures placed in the tendon to be tied around the interference screw. Thus the tendon is now secured using 2 methods, interference fit and secondary fixation accomplished by tying the suture to the screw anchor (i.e., suture anchor fixation). For the construct to fail, not only does the tendon have to slip from the side of the screw (i.e., loss of interference screw fixation), but the entire screw tendon complex must

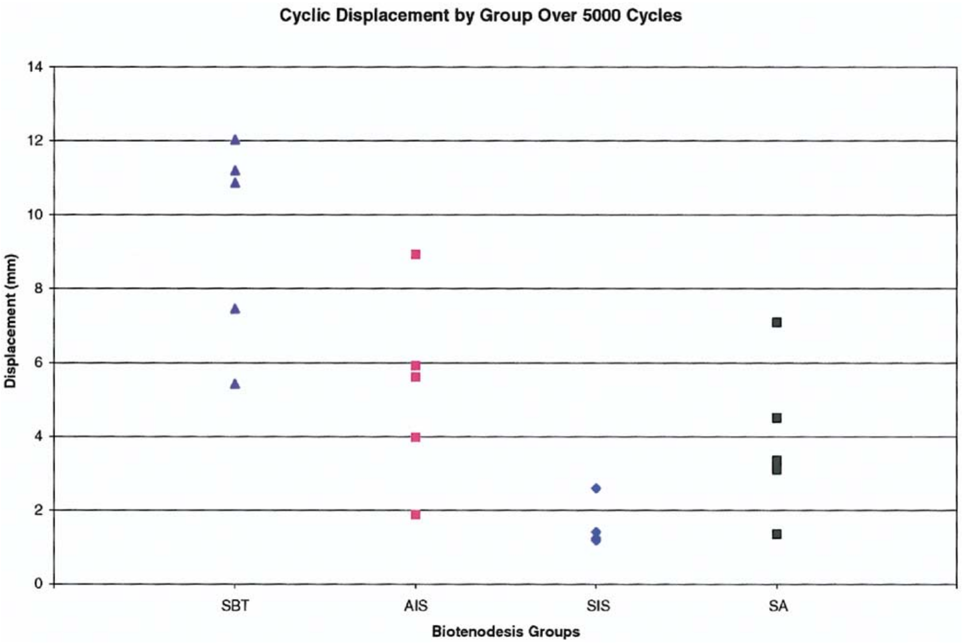

**FIGURE 14.** Scatter plot data on the cyclic displacement groups show that the SIS technique using the 8 × 12 mm interference screw has the tightest fit of results around the mean for the group.

displace from the bone (i.e., loss of suture anchor fixation).

Early pilot work from our laboratory looked at the optimal bone-tunnel:screw-diameter ratio using the novel Biotenodesis screw driver. Data looking at initial pullout strength showed that an 8 × 23 mm screw placed in an 8-mm bone tunnel provided the best initial fixation strength. Further work looking at cyclic data and postcyclic pullout strength not only verified that the 8 × 23 mm screw provided stable fixation after cyclic loading, but that there was no difference in pullout strength between precyclic and postcyclic tendon tenodesis with interference screw fixation.

Clinical follow-up with the arthroscopic proximal biceps tenodesis technique, which placed the tenodesis proximal to the pectoralis major tendon in the intertubercular groove, showed significant screw reaction, tenosynovitis, and pain about the anterior shoulder. With this in mind, a subpectoral biceps tenodesis technique was described,[11] in which the biceps tendon is tenodesed with a bioabsorbable interference screw distal to the intra-articular bicipital groove and deep to the pectoralis major tendon. To accommodate the new location of the tenodesis (i.e., subpectoral versus intertubercular suprapectoral—shorter bone tunnel needed for a subpectoral tenodesis) a new type of tenodesis screw was made. The 8-mm diameter, 23-mm long biotenodesis screw used in the arthroscopic biceps tenodesis technique was changed to an 8-mm diameter, 12-mm long screw.

The subpectoral interference screw technique offers several advantages over the other methods described above. The technique is an efficient and reproducible method with no violation of muscle-tendon units, and it also allows the preservation of soft tissues with minimal dissection. The relevant anatomy is clearly identified, and the length-tension relationship of the proximal biceps tendon can be easily reproduced. The technique removes the tendon from the confines of the intertubercular groove, a region lined with synovium and a possible source of continued tenosynovitis and shoulder pain. Finally, the subpectoral interference screw technique offers the biomechanical advantages of interference screw and suture anchor fixation with 1 tenodesis screw.

## Biomechanics of Tenodesis Fixation

In our study, various tenodesis techniques were evaluated in a model that would replicate muscle tension in vivo. The techniques evaluated were the SBT tenodesis, the AIS tenodesis, the SIS tenodesis, and the SA technique for biceps tenodesis. Two important clinical entities were examined: how strong the construct was (axial load to failure) and can the construct hold up to daily use for accelerated rehabilitation (cyclic displacement). Our results show that among the tenodesis groups studied, there was no statistically significant difference in cyclic displacement (at 5,000 cycles) among the AIS, SIS, and SA techniques. There was a statistically significant difference ($P < .05$) between the SBT technique and the other 3 techniques (AIS, SIS, and SA), in terms of cyclic displacement (at 5,000 cycles) (Fig 12).

Therefore, our data suggest that the AIS, SIS, and SA techniques for proximal biceps tenodesis provide the least amount of cyclic displacement when compared with the SBT technique. This information has implications in clinical use in terms of the type of rehabilitation program prescribed for the patient. Patients who have undergone AIS, SIS, or SA proximal biceps tenodesis might benefit from an early accelerated rehabilitation program, knowing with confidence that the tenodesis technique will withstand the rehabilitation without significant tendon displacement. The accelerated rehabilitation program might allow the patients to recover faster and avoid the significant deconditioning seen with longer, more conservative rehabilitation programs.

Scatter plot data on the cyclic displacement groups shows that the SIS technique using the 8 × 12 mm interference screw has the tightest fit of data around the mean for the group (Fig 14). In addition, the SIS technique also had the least overall cyclic displacement values, although the values were not statistically significant when compared with the AIS or SA groups. Increased numbers of specimens within each tenodesis group might help to discover any significance between the SIS group and the AIS and SA groups.

The results for the postcyclic ultimate failure strength show that there were no statistically significant differences seen among any of the biceps tenodesis techniques studied (Fig 13). Therefore, all tenodesis techniques studies had favorable load to failure characteristics.

In a recent study by Jayamoorthy et al.[22] that analyzed the failure strength of the keyhole tenodesis technique versus 2 different interference screws, the conclusion was that the interference screw fixation was inferior to the keyhole method of biceps tendon fixation. However, there are several differences between our study and Jayamoorthy's. First, our study looked at human cadaver proximal biceps tenodesis, whereas their study was performed in a sheep model. Second, the data for the ultimate failure strength of the tenodesis methods presented by Jayamoorthy's group did not include cyclic loading before failure testing. As seen in other areas of the shoulder (rotator cuff tears) and knee (anterior cruciate ligament), cyclic loading more closely approximates the in vivo stresses seen at a reconstruction site. Our pilot data, presented above, looked at the precyclic ultimate failure strength of the biceps tenodesis methods studied, and the data presented in Jayamoorthy's report looked at the postcyclic ultimate failure strength. We believe that the postcyclic data better represent the ultimate in vivo strength of the tenodesis techniques. Finally, the interference screw technique they used only relied on interference screw fixation. Our interference technique using the Arthrex Biotenodesis screw driver not only relies on interference fit, but also suture anchor fixation (i.e., the entire tendon-screw unit must displace from the bone).

## CONCLUSIONS

We believe the results of this study are worthwhile in that all of the tenodesis techniques studied (SBT, AIS, SIS, and SA) had favorable load to failure characteristics and all but 1 tenodesis method (SBT) showed favorable cyclic displacement data. We hope that this will serve as a guide to the surgeon performing a proximal biceps tenodesis in choosing a fixation method.

Our data on interference screw fixation using the Biotenodesis screw driver after cyclic loading compares favorably with precycling data on the keyhole method of proximal biceps tenodesis. The value of any surgical procedure can be evaluated in terms of a risk/benefit ratio. Benefits of the subpectoral interference screw tenodesis include pain relief, the maintenance of functional biceps muscle strength, and cosmesis. The subpectoral interference screw technique is technically less demanding than the arthroscopic interference screw technique, the subpectoral bone tunnel technique, the arthroscopic suture anchor technique, or the keyhole technique. Moreover, current biomechanical data suggest that there is no difference between the arthroscopic and subpectoral interference screw tenodesis techniques in terms of ultimate failure or displacement. The operative risk to the patient of the biceps tenodesis is minimal, with disruption or recalcitrant tenosynovitis as the most common complications. The subpectoral approach with interference screw fixation appears to be a promising, reproducible technique for tenodesing the biceps tendon.

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