Biomechanical Comparison of Interference Screw and Cortical Button With Screw Hybrid Technique for Distal Biceps Brachii Tendon Repair

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abstract

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Various fixation techniques have been described for ruptured distal biceps tendons. The authors hypothesized that no significant differences would be found between the mean failure strength, maximum strength, and stiffness of the interference screw and hybrid technique. Fourteen fresh-frozen human cadaveric elbows were prepared. Specimens were randomized to either interference screw or hybrid cortical button with screw fixation. The tendon was pulled at a rate of 4 mm/s until failure. Failure strength, maximum strength, and stiffness were measured and compared. Failure strength, maximum strength, and stiffness were 294±81.9 N, 294±82.1 N, and 64.4±40.5 N/mm, respectively, for the interference screw technique and 333±129 N, 383±121 N, and 56.2±40.5 N/mm, respectively, for the hybrid technique. No statistically significant difference existed between the screw and hybrid technique in failure strength, maximum strength, or stiffness (P>.05). The interference screws primarily failed by pullout of the screw and tendon, whereas in the hybrid technique, failure occurred with screw pullout followed by tearing of the biceps tendon. The results suggest that this hybrid technique is nearly as strong and stiff as the interference screw alone. Although the hybrid technique facilitates tensioning of the reconstructed tendon, the addition of the cortical button did not significantly improve the failure strength of the interference screw alone.

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Figure: Illustration of the interference screw technique showing the screw insertion abutting the distal biceps tendon.
Historically, rupture of the distal biceps brachii tendon was rare. Recent literature has shown that this injury could represent up to 10% of injuries to the biceps brachii, which translates to 1.2 ruptures per 100,000 per year. Although this injury continues to be more common in the dominant extremity of active males in their fourth through sixth decade of life, it has also been reported among individuals of any age or sex. In athletes, younger age groups participating in contact sports and strength training, particularly weightlifters, represent the majority of reported cases, with rare cases involving overhead athletes. The literature has also suggested that the use of anabolic steroids may contribute to increased stiffness in the tendon, which may predispose individuals to an acute tear. Smokers have also been cited as having a 7.5-times increased risk for rupture.

Distal biceps ruptures are clinically diagnosed on the basis of history, mechanism of injury, and physical examination. Typically, an acute complete distal biceps rupture follows a traumatic event in which excessive eccentric tension occurs as the arm is forced from a flexed to an extended position. Alternatively, this injury has been reported with attempts to avoid a sudden fall. Initial complaints include an audible pop or a snapping sensation followed by pain and weakness in the upper extremity during elbow flexion and wrist supination. Immediate intense pain often subsides within a few hours and is followed by a dull aching pain that may last from weeks to months.

The hook test, with a reported 100% specificity and sensitivity, is performed with the examiner’s index finger literally “hooking” the cordlike tendon in the antecubital fossa 1 cm deep to the tendon. If no cordlike structure is palpated, then the biceps is not in continuity. Occasionally, radiographs may show an irregular or avulsed fragment of bone from the bicipital tuberosity. Magnetic resonance imaging and ultrasonography have been proven to be more useful in equivocal cases involving clinically missed or partial injuries.

Nonoperative management is generally reserved for the treatment of low-demand patients in poor health. The superiority of surgical treatment has shown improved strength for flexion and supination as well as increased upper-extremity endurance. With brachialis tenodesis resulting in weakened supination, early anatomic reattachment of the tendon in active young patients is the treatment of choice. Both extensile Henry single volar and Boyd and Anderson 2-incision techniques have been modified to minimize previously published risks of neurovascular injury and heterotopic ossification, respectively. Regardless of the approach used, reconstruction techniques aim to minimize soft tissue dissection and secure initial fixation to allow for early range of motion.

Reconstruction of the ruptured distal biceps brachii tendon remains an area of biomechanical interest. Previous biomechanical investigations have shown that the cortical button technique exhibits significantly higher maximum strength and stiffness when compared with alternatives. Sethi et al. and Sethi and Tibone showed that the hybrid technique of cortical button and interference screw provide optimal tendon/bone fixation to promote healing between the tissues, prohibit gap formation, and allow for more aggressive rehabilitation schedules. By combining 2 techniques, a hybrid cortical button and interference screw technique suggests superior failure strength compared with the standalone button system.

Although several studies have found maximum failure loads to be significantly higher for cortical button constructs, no study to date has evaluated clinically relevant biomechanical failure when comparing standard interference screw fixation with the cortical button combination technique. Information is lacking regarding the performance of the hybrid system relative to the standalone screw system. The goal of this study was to evaluate the load-to-failure performance of the interference screw and a hybrid screw-button system.

Materials and Methods

Fourteen fresh-frozen human cadaveric elbows were procured and thawed 24 hours before use. Twelve of the elbows were match paired. All muscle and adipose tissue except for the biceps tendon

Figure 1: Photograph of the test setup. The specimen was mounted to the table of the test frame with the radial tuberosity facing upward and the linear actuator pulling in a direction 90° from the long axis of the bone.
were removed from the radii. The proximal and distal ends of each radius were embedded in urethane resin (Smooth-Cast 300; Smooth-On, Easton, Pennsylvania) and secured to the table of a materials test frame (Instron 8521; Instron, Norwood, Massachusetts). The long axis of the bone was oriented parallel to the plane of the table (Figure 1) with the radial tuberosity facing upward.

After all 14 specimens were mounted on the resin, the paired right and left specimens were randomized to 1 of 2 tendon repair groups. The first group included an interference screw repair technique, and the second group included a hybrid cortical button with interference screw technique. In both techniques, a #2 polyester suture (FiberLoop; Arthrex, Naples, Florida) was used to secure the distal 2.5 cm of the incised biceps tendon in a locking-loop fashion. The tuberosity was debrided of soft tissues if necessary.

The interference screw technique (Figure 2A) was performed as described by Idler et al. A 2-mm guide pin was placed in the center of the tuberosity perpendicular to the long axis of the radius and penetrated only the anterior cortex. An 8-mm acorn reamer (Arthrex) was used to ream a hole through the cortex to a depth of 15 mm; the posterior wall was not penetrated. One limb of the FiberLoop was passed through an 8×12-mm bioabsorbable (polyglycolic acid) tenodesis screw and screwdriver (Arthrex), thus bringing the distal end of the tendon to the tip of the screwdriver, and secured around the back of the screwdriver. The screw and tendon were inserted into the hole and screwed down flush to the tuberosity. The remaining ends of the suture were then secured by tying them over the screw with 5 square knots. This procedure reinforces the tendon with both interference of the bone/tendon and a suture anchor effect.

The hybrid technique (Figure 2B) was then performed as described by Sethi et al.25 and Sethi and Tibone.26 A 3.2-mm guide pin was used to drill through the central aspect of the radial tuberosity from anterior to posterior, aiming 15° in the ulnar direction. The anterior cortex and intramedullary canal were then reamed with an 8.0-mm cannulated reamer to allow for flush seating of the end of the distal biceps tendon. The suture was then threaded through the biceps button. The first strand was fed through the right hole and then back through the left hole. Then, the opposite was performed with the other tail of the same suture. Tension was then held on all 4 suture limbs as the cortical button was inserted through both cortices of the radial tuberosity. The free suture limbs were then pulled to seat the button against the radius. A 7×10-mm polyetheretherketone tenodesis screw (Arthrex) was then loaded onto the tenodesis driver (Arthrex), and 1 suture limb was passed through the driver. The screw was then inserted on the radial side of the bone tunnel until it seated flush with the anterior cortex, pushing the tendon more ulnar. Once the tendon was fully seated, a free needle was used to pass the remaining suture limb through the tendon to tie a knot over the screw.

In both techniques, the biceps tendon was then attached to the actuator of the test frame with a custom fabricated tendon clamp and oriented 90° from the long axis of the bone. The actuator was load controlled to pull the tendon to a load of 5 N to ensure appropriate tensioning of the tendon and to establish the data for strain and stiffness measurements. The tendon was then pulled in tension at a rate of 4 mm/s until visual failure (Figure 3).21,27,28

Load, displacement, and time were recorded to determine construct stiffness and failure strength. Stiffness was defined as the linear region of the load displacement curve following the initial toe region. Strength was the maximum load recorded within the first 12 mm of displacement, which was defined as clinical failure. The difference between the failure strength and maximum strength was established.
primarily for the hybrid specimens that continued to resist rupture of the tendon-suture interface beyond 12 mm of excursion. The failure mode of the repaired tendons was noted. The outcome measures for testing were stiffness (N/mm), failure strength at 12-mm excursion (N), and maximum strength at construct failure (N). All statistical calculations were performed with JMP version 5.0 software (SAS Institute Inc, Cary, North Carolina) and Excel (Microsoft, Redmond, Washington). Each outcome measure was compared between the 2 treatment groups by a 1-way analysis of variance t test for significant differences with alpha set to 0.05. Statistical power was calculated for all mean comparisons at alpha equal to 0.05.

RESULTS

Mean age of the specimens was 67 years (range, 59-79 years). Six were from men, and 2 were from women. Each specimen failed distally at the interface between the implant and tendon, except for 4 specimens. Three specimens repaired with the hybrid technique failed proximally at the musculotendinous junction near the clamp and were not included in the results. One specimen repaired with the interference screw technique was not included in the results because of a tuberosity fracture as noted by the surgeon immediately after implantation and before testing. The hybrid group failed by 1 of 3 mechanisms: (1) the distal tendon tore out of the tubercle, causing suture failure with intact screw and cortical button in 2 specimens; (2) screw pullout failure with intact cortical button in 1 specimen; and (3) suture failure in 1 specimen. The interference screw group failed by 1 of 2 mechanisms: (1) screw pullout failure in 5 specimens; and (2) failure in the distal biceps tendon in 1 specimen.

Results showed that the screw and hybrid techniques had similar stiffness and strengths. Mean failure strength, maximum strength, and stiffness were 294±81.9 N, 294±82.1 N, and 64.4±40.5 N/mm, respectively, with the interference screw technique and 333±129 N, 383±121 N, and 56.2±40.5 N/mm, respectively, with the hybrid technique (Figures 4-6). The hybrid technique often reached peak strength after the first 12 mm, whereas the screw-only system always yielded before the first 12 mm. Although a trend existed for higher strengths with the cortical button, statistically insignificant differences were observed between the 2 constructs and all outcome measures (P=.05), including failure strength (P=.57), maximum strength (P=.76), and stiffness (P=.51). The power of these observations was 94% for stiffness, 92% for failure strength, and 77% for maximum strength.

DISCUSSION

The results of this study showed no significant difference between mean failure strength, maximum strength, or stiffness of the interference screw and hybrid technique tested. Pulling the repaired tendon at a rate of 4 mm/s allows differentiation between failure and maximum strength. The cadaveric model showed that failures always occurred within the first 12 mm of displacement for both techniques. In the hybrid group, the cortical button remained intact until catastrophic failure involved tearing of the tendon and suture. Clinical failure occurs within 12 mm of translation either stretching the repaired tendon or displacing it completely from bone-tendon contact. Nonetheless, the difference in maximum strength between the 2 groups was also insignificant. Given the reported tension (52 N) on the tendon with active flexion of the forearm against gravity, one could begin early active range of motion after interference screw fixation alone, even without the addition of the cortical button.

Several other biomechanical studies have addressed the failure strengths of different distal biceps tendon repair techniques. However, the results of cortical button technique and interference screw have conflicted because of the techniques used and the biomechanical testing methodology (Table 1). The current study aimed to address this discrepancy in methodology and technique. Unlike previous authors who tested the cortical button with the #5 polyester suture with a 0.88-mm diameter (Ethibond; Ethicon, Somerville, New Jersey),
this study used the #2 polyester suture (FiberLoop) with a 0.69-mm-diameter suture in concordance with the hybrid surgical technique. Although literature is sparse on the significance of the difference between suture materials, this variable has provided conflicting results in studies looking at cortical button-only repairs.\(^{34,35}\) For instance, when the smaller-diameter suture was used, a dramatically lower mean failure load (259 N and 274 N) resulted compared with studies that used the larger-diameter suture (584 N and 439 N).\(^{22,23,31,33}\) In addition, the current study adopted the tension rate of 4 mm/s as opposed to 120 mm/s. This allows for the detection of both clinical failure and ultimate tensile load.\(^{21,31}\) Sethi et al\(^{25}\) pulled the tendon at the faster rate, which can account for the difference in the pullout strength for the hybrid technique used in the current study (ie, 432 N vs 383 N, respectively). When comparing interference screw repair techniques, size and diameter also act as additional variables. Kettler et al\(^{22}\) compared a smaller-sized 5.5-mm diameter screw; the present study used an 8-mm diameter screw, resulting in differences of 131 N and 294 N, respectively. Although 1 study recently attempted to address this variable, the screws compared (7- vs 8-mm diameter) showed no significant difference.\(^{30}\)

The current study reproduced biomechanical testing of bone-tendon interfaces using previously established standards.\(^{21,27,28,31}\) Therefore, the results of this study are directly comparable with a greater number of studies in this field. By using these standards, this study differentiates clinical failure strength from maximum failure strength. However, this differentiation ultimately proved inconsequential because no significant difference was found between any of the parameters tested. Nonetheless, this study further supports prior studies that used this technique.

One limitation of this study is that the bone mineral density of the cadavers was unavailable. However, by using matched specimens in a randomized fashion, an attempt was made to eliminate this variable. With poor bone mineral density, early failure by fracture of the radial tuberosity was evident in 1 specimen of the interference screw technique. A smaller interference screw used in coordination with the cortical button in the hybrid technique appeared to eliminate this problem, suggesting that this construct may be better suited in a population with poor bone mineral density. A second limitation is that this study had 3 proximal failures in the interference screw technique. A smaller interference screw used in coordination with the cortical button in the hybrid technique supports prior studies that used this technique.

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of specimens for cortical button alone. However, given the direct comparison of the methodology of this study with prior studies using this technique, sufficient literature shows the mean failure load for this group.\textsuperscript{22,31} In addition, the superiority of the interference screw with minimized gap formation in cyclic loading has already been established.\textsuperscript{25} Therefore, it was not necessary to include this additional arm in the study.

Although prior studies suggest biomechanical superiority of the hybrid cortical button-screw technique when compared with the interference screw alone, the results of this study suggest that they are similar. Although one study found no significant difference in the maximum strength of the hybrid cortical button-screw technique vs the cortical button alone, this study did not use previously established biomechanical testing techniques.\textsuperscript{25} It also could not account for failure strength with the novel methodology. Only case reports exist of cortical button techniques in the literature, with the exception of one study that evaluated tendon-to-tendon repair.\textsuperscript{36} Desai et al\textsuperscript{37} reported a 44-year-old right-hand-dominant man who had failure at the suture and cortical button interface 7 days postoperatively while attempting to prevent a fall on ice. Naidu\textsuperscript{38} reported on failure of technique with a cortical button and interference screw backing out within 6 days postoperatively in a 40-year-old man. Given that only case reports of failed repair techniques exist, the lack of significant differences between failure strengths of these techniques suggest that the surgeon should take into consideration factors beyond biomechanical failure when choosing the most appropriate repair technique. These factors and areas of future clinical research may include surgeon experience, ease of surgical technique with tensioning of the biceps tendon, patient bone mineral density, cost of implants, and/or complications associated with surgical approach.

**CONCLUSION**

The current cadaveric study showed that biceps tendon repair via an interference screw provided mean failure strength, maximum strength, and stiffness that were not significantly different with the addition of a cortical button. This study used established biomechanical testing protocols, which allow the results to be directly comparable. Although the tension slide technique facilitates seating of the distal biceps tendon, the addition of the cortical button may not significantly increase failure strength in techniques with interference screw alone. However, when using a cortical button-only technique, prior studies have shown that the addition of an interference screw would decrease gap formation and improve tissue integration.\textsuperscript{25,30}

A thoughtful postoperative rehabilitation protocol, which includes early active range of motion, can be initiated immediately with the interference screw-only technique.

**REFERENCES**


25. Sethi P, Obopilwe E, Rincon L, Miller S, Mazzocca A. Biomechanical evaluation of


