

Distal Biceps Tendon Repair: Anchor Versus Transosseous Suture Fixation

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Abstract

Suture anchor fixation and transosseous suture fixation were compared in 12 fresh-frozen cadaveric radii using either No. 2 braided polyester suture or single Mainstay 3.5-mm threaded anchors (made at the time by Howmedica, Rutherford, NJ) with No. 2 suture. Suture fixation failed at a mean strength of 162 N (range, 129-179 N), anchor fixation at 136 N (range, 121-150 N). Neither technique is strong enough to safely allow immediate biceps activity. Nevertheless, suture anchor fixation to the radial tuberosity offers a lower but clinically comparable strength to transosseous suture fixation while limiting postoperative risks.

Although rupture of the distal biceps tendon is less common than that of the long head of the biceps,¹ reports of its repair through an anterior approach have noted cases of temporary and permanent radial nerve/poste-

rior interosseous nerve (PIN) palsy.¹⁻³ While some authors have proposed suturing the biceps tendon to the brachialis,^{1,4} Boyd and Anderson⁵ reported a 2-incision technique for anatomic repair with significantly less danger to the PIN than a 1-incision technique. Although this is perhaps the most common method being used for this repair, radial-ulnar synostosis has been recognized as a complication,⁶ and we have seen a late PIN palsy caused by dorsal scar tissue.⁷

Several case series⁸⁻¹⁰ have reported techniques to repair the distal biceps tendon to its tuberosity using suture anchors and a limited single anterior approach. Use of suture anchors for this type of tendon repair is unusual in that it places an inline force on the anchor rather than the tangential force common to other suture anchor applications. We sought to determine whether suture anchor fixation to the radial tuberosity provides as much tensile strength as transosseous suture fixation. In addition, we sought to determine the tensile strength of cadaveric native distal biceps tendons.

MATERIALS AND METHODS

Specimens

Twelve elderly fresh-frozen cadaveric forearms (6 matched pairs), free of gross disease, were harvested with isolation and removal of the proximal radius with attached biceps tendon. All soft tissue except the biceps tendon was detached from the specimens. After each specimen was thawed to room temperature, the proximal radius was mounted in full supination (for all tests) on a custom-built test stand. This line of

action for pull duplicated the rupture position that is reported by almost all patients.^{1,11}

Suture Anchor and Suture Specifications

The suture anchors used in this study were 3.5-mm (medium) Mainstays (made at the time by Howmedica, Rutherford, NJ), which are older anchors of a threaded design like the Fastak (Arthrex, Naples, Fla) rather than the deployable hook design like the Mitek (DePuy-Mitek, Raynham, Mass). These medium-sized anchors are 3.5 mm in diameter by 10 mm in length—the largest possible size for subchondral fixation in the tuberosities of all the cadaveric specimens. A No. 2 braided polyester (Tevdek, Deknatel, Teleflex Medical, Mansfield, Mass) suture was used for the anchors and for transosseous fixation to maintain a basis for comparison (suture size was dictated by the dimensions of the chosen anchors).

Procedure

An MTS machine (Bionix MTS, MTS Systems Corporation, Eden Prairie, Minn) was used for mechanical testing of the specimens and anchors. The first experiment was pullout of the native tendon, used as a reference for the strength of the repairs. The test stand was affixed to the base of the MTS, with the radius held in supination. Direct clamp fixation was used to secure the tendon to the MTS grip. Load was placed on the biceps tendon at 10 cm/s perpendicular to the radius to simulate the high-rate conditions of physiologic failure. Strength as recorded by MTS load cell is that at terminal failure, with measurements taken 100 times per second.

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The second experiment, investigating suture–tendon interface strength, was similar to the first, pullout experiment, while the first crosshead was attached with a 0.25-in eye bolt to a woven Krachow suture of No. 2 braided polyester placed through the tendon, while the other crosshead was attached to the native tendon itself using a clamp fixation.

In the third, main experiment, each pair of radii (left, right) was divided randomly into transosseous suture fixation and suture anchor fixation specimens. Method comparison involved use of simplified fixation techniques. Suture fixation was undertaken by drilling two 2-mm holes 7 mm apart in the periphery of the biceps tuberosity. A No. 2 braided polyester (Tevdek) suture formed a single loop through the 2 holes, tied on the dorsal surface of the tuberosity with 1 surgeon's throw and 5 single square throws. The anterior part of the loop was placed over a 0.25-in eye bolt secured to the MTS crosshead. The radius with attached suture was clamped in supination on the test stand. After the suture was pretensioned to approximately 5 N, load was applied by the crosshead at 0.1 mm/s, as failure immediately after repair would clinically not be at high velocity. Strength was recorded as the highest tension before terminal failure. Mode of failure was recorded for each specimen.

Suture anchor fixation of the other component of each matched pair was undertaken with a 2-mm bit to predrill the outer cortex of the periphery of the biceps tuberosity. A No. 2 braided polyester (Tevdek) suture was threaded into a 3.5-mm (medium) Mainstay anchor. A single anchor was then inserted into the predrilled hole, set with the head deep to the outer cortex. The suture was tied into a loop with 1 surgeon's throw and 5 single square throws, with the knot placed adjacent to the suture anchor. The remainder of the experimental configuration and testing procedure was identical to that of the sutured fixation.

RESULTS

For native tendon strength testing, different methods (looped tendon, No. 5 suture, wire suture, frozen musculoten-

dinous junction, standard clamp grip) were used to grasp the native tendon, as the best way to hold the tendon was not known at the beginning of the experiment. The MTS standard clamp grip ($n = 3$) yielded the highest tensile strengths, with the midsubstance tears more than 580 N (maximum, 633 N). No specimens for the native tendon pull experiment (first experiment) using any of the tendon grasping methods failed at the bone–tendon junction. In the second experiment (tendon–suture interface), Krachow stitches of No. 2 braided polyester (Tevdek) attached to the tendons failed at the tendon–suture interface at approximately 280 N. These 2 experiments established the strength for the native biceps tendon and the strength for the suture–tendon interface. The third experiment then compared transosseous fixation and suture anchor fixation for the suture–bone interface.

During transosseous suture fixation, mean strength at failure was

162 N (SD, 18.0 N; range, 129–172 N) (Table). One specimen (129.2 N) failed by cutout of the knot through both cortices of the tuberosity (Figure 1); the others failed by rupture of the suture on the edge of one of the 2 drill holes (Figure 2).

During suture anchor fixation, mean strength at failure was 136 N (SD, 11.0 N; range, 121–150 N) (Table). Two specimens (120.7 N, 145.5 N) failed by anchor cutout; the others failed at the knot in the suture. Anchor fixation was significantly weaker than sutured fixation ($P = .03$, paired t test).

DISCUSSION

The first part of the experiments involved testing the rupture strengths of intact biceps tendons. Although these strengths cannot correlate with the strength of failure in clinical cases, in which tendons always show evidence of underlying degenerative



Figure 1. Cutout of intact knot through tuberosity. Straight arrows indicate original drilled holes; curved arrow shows where knot pulled through.

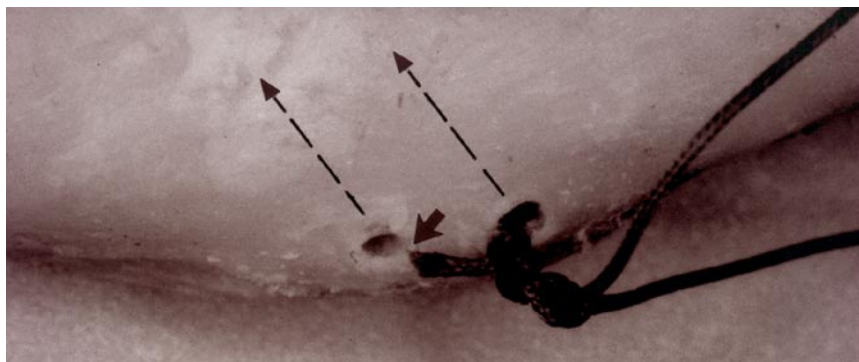


Figure 2. Dorsal side of tuberosity shows where sutures ruptured on edge of hole (arrow). Note suture being pulled from other side of radius (dashed arrows) and knot with long tails.

Table. Mean Strength at Failure for Transosseous Suture and Anchor Fixation

Fixation Type	Strength at Failure (N*)		
	Mean	SD	Range
Transosseous suture	162	18.0	129-172
Anchor	136	11.0	121-150

*N indicates newtons.

disease, we are unaware of any published data regarding strengths of normal distal biceps tendons.

Although only 3 tendons were pulled to failure by the direct clamp fixation method (which yielded the highest failure strength of the methods tested), the strength of the biceps tendons was found to be 580 N, or 130 lb. This strength is unexpectedly low, as it translates into an applied force at the palm of 21 lb as supported at 90° flexion by the biceps alone, for a total force of 58 lb at the palm when the proportional contributions of the biceps, brachialis, and brachioradialis are considered (assigning a biceps contribution of 36% to the load-carrying distribution when the elbow is at 90°) (Figure 3).¹² In addition to representing few specimens, the low value likely reflects the artifactual attributes of cadaveric soft-tissue testing, including the condition of the dead tissue, as well as the stress risers caused by the nonphysiologic force-loading imposed by materials testing techniques.

Reattachment Techniques

Prior reattachment techniques for fastening the ruptured tendon stump back into the tuberosity include suture attachment to an area excavated by a burr,¹¹ into a cut trough,¹³ into a trapdoor,⁵ into a 0.25-in unicortical drill hole¹⁴ (2 cases of using an anterior approach with pullout sutures placed to exit over a button on the dorsal forearm^{15,16}), and to the tuberosity with an AO (Arbeitsgemeinschaft für Osteosynthesefragen) screw and washer.¹⁷

A more recent technique is suture anchor repair to the tuberosity⁸⁻¹⁰ by anterior approach. Slightly different techniques, using 1 or 2 suture anchors for fixation, have been reported. All the authors provided for a period of immobilization with the forearm in supination followed by a gradual return to motion and strengthening.

We sought to determine, using a cadaveric model, whether single suture anchor fixation is as strong as single transosseous suture fixation and whether each technique allows enough strength to permit immediate activity.

Despite the common clinical practice of using No. 5 braided polyester suture (or multiple suture anchors) for transosseous repairs, we chose for simple comparative purposes to use a single stitch of No. 2 suture. Suture size was dictated by the suture requirement of the largest possible bicapital tuberosities.

Our results of 162 N for sutured fixation and 136 N for anchor fixation show that suture anchor fixation is

significantly weaker ($P = .03$, paired *t* test). This difference in strength, though statistically significant, has no clinical relevance with respect to the ability to comfortably modify postoperative rehabilitation protocols. Nicol and colleagues¹⁸ determined that the typical force experienced by the biceps during eating or dressing is 135 N. Fixation strengths obtained for both techniques in this study are too close to this value to comfortably allow early activity.

Similar strengths for suture and suture anchor repairs for other anatomic locations have been found. Goble and colleagues¹⁹ reported that suture anchors withstood a tangentially applied force of 217 to 684 N when anchors were placed into cortical bone—comparable to the strength of a transosseous suture repair (134-867 N). Mode of failure is either pullout of the anchor or failure of the attached suture^{19,20}—similar to our findings. Lower strengths were reported by Carpenter and colleagues,²¹ who found the pullout strength of a Statak anchor in proximal tibia to be 74.7 to 103.2 N, varying with distance from the plateau and with line of pull being parallel with (inline) or perpendicular to (tangential) the axis of the anchor.

Inline, Versus Tangential, Force. One mechanical difficulty imposed by the location of this injury is that supination to relax the biceps tendon also subjects the repair to an inline force rather than a tangential force (Figure 4). Almost all other tendon and ligament repairs are immobilized

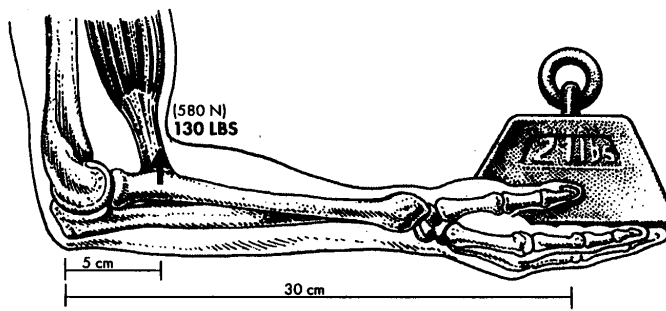


Figure 3. Force-balance diagram shows tendon failure at 580 N equivalent to biceps-only supported weight at wrist of 21 lb. Considering that biceps supports 36% of flexion force with elbow at 90°, this is equivalent to 58 lb of weight at wrist.¹²

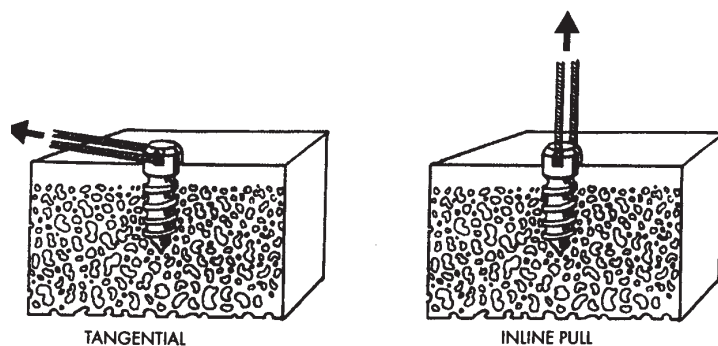


Figure 4. Fixation of rotator cuffs and collateral ligaments places tangential force on suture anchor. Because of radius rotation, suture anchor used for biceps repairs undergoes both tangential and inline forces.

in the more protected position (for the anchors) of tangential loading.

Except for Carpenter and colleagues,²¹ authors have not addressed inline force on the anchors, as they are more commonly used for repairs in which they are inserted into cortical bone, and the pull of the tendon is tangential to the axis of the suture anchor. Burkhart²² discussed the importance of tangential pull in the mechanics of suture anchor placement by an analogy to the placement of a “dead man” stake to support a corner post for a wire fence.

Unfortunately, because of the rotational motion of the radius, the suture anchor for the distal biceps tendon repair will experience both inline and tangential forces, unless the forearm is immobilized. If this motion is allowed, it adds the element of cyclic loading to the construct. Such loading will cause micromotion of the anchor, contributing to either gross loosening or osteolysis at the point of implantation. The end result of motion may be anchor pullout, anchor–suture failure, or other failures. We did not address the effect of fatigue on our constructs.

Limits on Suture Size. For fixation both with sutures and with suture anchors, we believe that increasing suture size will improve repair potential. Sutures that are too large, however, will cause problems during in vivo use by creating knots that block rotational motion and by physically obstructing healing of the tendon end to the radius. In addition, use of

suture anchor repair precludes use of large suture such as No. 5, because such suture is not available on suture anchors of the size necessary for use in the biceps tuberosity.

Study Limitations. A limitation of this study is the small number of cadaveric specimens available for testing. Although a statistically significant difference was found between the 2 fixation methods, suture fixation had several failure modes, making this difference less clear.

CONCLUSIONS

The goal for distal biceps tendon repair is to limit postoperative complications while achieving a secure construct. Failure strength was statistically higher for transosseous suture fixation than for suture anchor fixation. These techniques, however, had clinically comparable strengths. Neither technique offered a margin of safety above low-level biceps force, as described in the literature.

Given the theoretical benefits of using suture anchors as applied to distal biceps tendon ruptures, we believe that anterior suture anchor fixation is a reasonable alternative to the more traditional transosseous suture repair.

AUTHORS' DISCLOSURE STATEMENT AND ACKNOWLEDGMENTS

The authors report no actual or potential conflicts of interest in relation to this article.

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