Various techniques throughout the years have been published on surgical repair of the distal biceps tendon for acute ruptures or for recalcitrant biceps tendinosis. The first report of a single incision technique to repair this tendon was in 1897 by S. Johnson in the New York Medical Journal. Since that time many different approaches and techniques have been developed. Interference screw fixation has been a reliable and well-tested method of tendon/ligament to bone attachment. There is a large body of literature concerning the various aspects of interference fit in the anterior cruciate ligament and proximal biceps tendon literature. Anatomic measurements, osteological analysis, and radiographic examination have provided information for the design of an interference screw that can be safely used in the proximal radius. We describe a technique using an interference screw through a single incision. We present two techniques for open tenodesis of the long head of the biceps.

KEY WORDS: distal biceps, interference screw, elbow, tendon rupture.

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Ruptures of the distal biceps tendon have received increased attention recently. A MEDLINE search identified 53 articles with "distal biceps tendon" in the title published since 1995 and only 58 in the previous 25 years. One theory to explain this interest is an apparent increase in the incidence of injury. This trend is probably the result of increased demands placed on the upper extremities as well as increased activity in the middle-aged population. Treatment options have also expanded simultaneously with this renewed interest.

Historically, a single extensile anterior exposure was used to reinsert the avulsed tendon. Boyd and Anderson subsequently described a two-incision technique designed to minimize anterior exposure and limit the risk to neurovascular structures in proximity to the tuberosity.¹ Their two-incision technique introduced heterotopic ossification and proximal radioulnar synostosis as new complications. In 1985, Morrey and coworkers modified Boyd's original approach by splitting the supinator and avoiding subperiosteal dissection.² These modifications led to a decrease in the rate of heterotopic bone formation and synostosis.

Modifications in the method of fixation have also been proposed. Single incision techniques have been revived with the advent of suture anchors. These procedures use a Henry exposure and secure the tendon to the cortical surface of the tuberosity and not into a tunnel or trough. Benefits of the single incision technique include decreased morbidity as well as technical ease in use of the suture anchors. Biomechanical studies have shown that the suture anchor techniques are not as stiff or strong compared to fixation over a bone bridge.³ However, in cyclic loading, the suture anchors have performed adequately to allow early passive range of motion.⁴

To combine both a single incision and the use of a tunnel into which to place the tendon, Bain has described a technique using the Endobutton (Acuflex; Smith & Nephew Endoscopy, Mansfield, MA).⁵ Studies evaluating its stiffness and strength are ongoing but the Endobutton has performed well in other applications. However, potential complications in passing a Beath pin through the radius, approximating the length of the suture loop, and "flipping" of the device on the posterior cortex can make it a challenging technical procedure. Furthermore, cyclic loading early on might lead to pistoning of the tendon in the tunnel and impaired healing.

Bioabsorbable interference screw fixation has become popular, especially around the knee. Multiple studies testing the biomechanical properties of bioabsorbable interference screws have been performed. They have routinely shown that the constructs fail by graft slippage past the screws but at a level equal to or greater than other fixation methods.⁶⁻¹⁶ In cyclical loading models, the screws have performed favorably as well. On a histological level, direct tendon healing to bone has been observed with interference screw fixation.⁶,⁷ A mature fibrocartilage intratunnel, direct ligamentous insertion can be found at 9 to 12 weeks.⁹ When indirect methods of tendon fixation are
Fig 1. The anterior approach of Henry is used in this technique. A longitudinal incision on the radial aspect of the proximal forearm of 3 to 4 cm is used. If needed, this incision can be extended proximally.

used, healing progresses via a zone of vascular, highly cellular fibrous tissue that matures through orientation of collagen fibers over a period of 12 to 26 weeks.10,11

With the development of new equipment, a bioabsorbable screw can be delivered into a prepared socket without the need for passage of a needle or suture through the socket. The combination of intratunnel fixation, a bioabsorbable device, and a single anterior approach provide an attractive alternative to other techniques. These technical advances provide the surgeon with yet another useful option for fixation of the avulsed distal biceps tendon.

OPERATIVE TECHNIQUE

APPROACH

We will describe and illustrate a single incision approach to fixation of the distal biceps tendon with an interference screw. However, one of the senior authors (N.S.E) uses the same fixation technique through the modified Boyd-Anderson two-incision approach. Tuberosity preparation and fixation with the interference screw can proceed as described below through the posterior incision. The Boyd-Anderson surgical approach has been described multiple times1,2 and is illustrated elsewhere in this issue.

The patient is positioned supine on the operating room table with all anatomical protuberances padded. The arm is placed on a padded arm board with a tourniquet placed as close to the axilla as possible to allow room for an extensile approach if needed. If this is impossible secondary to patient habitus, then a sterile tourniquet is used.

The approach is a modification of an anterior longitudinal Henry approach with extension along the antecubital fossa if needed (Fig 1). The subcuticular tissue is dissected with Metzenbaum scissors to avoid injury to the lateral antebrachial cutaneous. The plane of the dissection should be in the direction of the incision that also parallels the superficial sensory nerve.

The muscular interval between the pronator teres and brachioradialis (Fig 2) is bluntly developed to the level of the lacertus fibrosis and surrounding hematoma or scar. Directly in the plane of the dissection lies a series of veins (Leash of Henry) and the recurrent branch of the radial artery that must be addressed by suture ligature, coagulation, or retraction. The frayed edge of the tendon should be found at this level or proximally.

PREPARATION OF THE DISTAL BICEPS TENDON

Anatomical evaluation has revealed that the distal biceps tendon attaches on the ulnar side of the tuberosity in a 2 × 14 mm ribbon-like configuration after rotating 90° from the musculotendinous junction. Depending on the chronicity of the tear, the biceps tendon is usually retracted from the tuberosity with a bulbous end. The tendon is then measured and trimmed to an 8-mm thickness. If the tendon end is frayed with degenerated collagen, up to 1 cm can be resected from the end with no adverse effects. A no. 2 Fiberwire (Arthrex, Inc., Naples, FL) is then placed in a Krackow or whipstitch fashion (Fig 3) for a distance of 12 to 13 mm proximally. The Fiberwire has a Kevlar core allowing it to have the strength of a no. 5 nonabsorbable braided suture but the size of a no. 2. Strength and durability are critical when using the Arthrex Tenodesis driver as the metal end can damage and prematurely cut standard braided suture.

BICIPITAL TUBEROSITY PREPARATION

The arm is placed in maximal supination and extension to adequately visualize the tuberosity. Care should be taken with deep tissues not to retract too vigorously on the radial side of the proximal radius as the posterior interosseous nerve can be damaged. The tuberosity is generally covered with a fibrous layer of immature scar, which should be removed for visualization. An Arthrex guide pin is placed into the center of the tuberosity and an 8 mm acorn reamer (Arthrex, Inc., Naples, FL) is then used to ream an 8-mm hole through the proximal cortex only (12 to 15 mm; Fig 4).
TENODESIS

The Tenodesis driver consists of a cannulated handle and post. Sutures from the end of the prepared tendon can be passed through the driver after the chosen screw has been placed onto the driver. The post is used to insert the tendon to the bottom of the socket and hold the tendon in place while the interference screw is advanced over it via a threaded mechanism. To perform the tenodesis, one limb...
of the Fiberwire suture is then placed through the tenodesis driver with the 8 x 12 mm screw attached (Fig 5). The driver is then inserted into the 8-mm hole, ensuring that the tendon is on the ulnar side of the tuberosity (Fig 6A). While the tendon is stabilized with an Addson forceps, the screw is advanced via the tenodesis driver as described above (Fig 6B). After the screw is inserted and the tenodesis driver is removed, the suture passing through the cannulated screw is then tied to the outside of the interference screw. This allows both an interference fit of the tendon to bone as well as a suture anchor effect (Fig 7).

POSTOPERATIVE REHABILITATION

In the immediate postoperative period, the arm is held in a sling or posterior mold splint for wound healing and pain control. After the wound has been determined to be stable, active assisted range of motion in a neutral position is allowed. Active range of motion with the weight of a coffee cup or less is allowed in the first 6 weeks. Range of motion and strengthening exercises are then advanced as tolerated. Any pain producing activity is discouraged. The patient is generally discharged to work and full activities between 3 to 6 months.

BIOMECHANICAL AND ANATOMIC RESULTS

In an anatomical dissection and measurement of 26 cadaver specimens (mean age 78.5 ± 15) the mean length of the tendon attachment to the tuberosity was 14.3 mm with a mean width of 1.8 mm. The osteologic dimensions of the bicipital tuberosity measured 22 x 17 mm. In reviewing 178 specimens from the Hemann-Todd Osteological Collection, a consistent ridge on the ulnar side was identified as well as five different tuberosity types (Fig 8). The most common type was small (42%), followed by medium (35%), large (11%), no ridge or tuberosity (6%), and a bifid ridge (6%). Finally, computed tomography (CT) scans of a
A subgroup of 48 samples evaluated the actual depth of the tuberosity. A measurement from the periosteum of the outer cortex to the endosteum of the inner cortex had a mean length of 12.5 ± 1.4 mm. The screw was then designed from this data.

BIOMECHANICAL ANALYSIS

Eighteen fresh frozen cadaver elbows (mean age 77.6 ± 10.4) were then stripped of soft tissue, potted, and randomly assigned to three groups (Bone Tunnel, 7 × 12 mm screw with a 7-mm tunnel, and 8 × 12 mm screw with an 8-mm tunnel). The specimens were tested on an Instron material testing device (Instron Inc., Canton, MA) with the axial load orientated at 45° to better approximate the angle of pull of the biceps tendon. There was no statistical difference ($P < 0.05$) between the bone tunnel group (111.6 ± 63.2), 7 × 7 mm interference screw (168.3 ± 34.3) and the 8 × 8 mm interference screw (200.8 ± 87.5). Furthermore, the insertion of the distal biceps is long and thin and located on the ulnar aspect of the tuberosity. This method allows the tendon to be placed on the ulnar aspect of the tuberosity which mimics the anatomy closer than the other techniques.

DISCUSSION

The interference screw technique is new and its clinical effectiveness in the repair of distal biceps tendon ruptures...
has not been demonstrated to date. A substantial amount of anatomic and biomechanical research has been conducted in analyzing load to failure and tendon anatomy. This is the only technique that ensures the anatomic placement of the distal biceps tendon with the advantage of combined interference and suture anchor fixation. It has been shown to be as strong as the standard bone tunnel technique, which does not ensure anatomic placement of the tendon. Biomechanical cycling and clinical follow-up studies are ongoing at this time.

The interference screw technology has been a successful method of integrating a tendon or ligament into a bone. Our technique offers the surgeon many new options in treatment of these injuries. It can be performed either through a single anterior incision or a two-incision approach and emphasizes biologic, anatomic, and biomechanical principles of tendon healing. It is felt that the success demonstrated in the knee and the shoulder will be continued in the proximal radius.

REFERENCES