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Distal biceps tendon rupture: An in vitro study ☆

Dave R. Shukla, Bernard F. Morrey, Andrew R. Thoreson, Kai-Nan An, Shawn W. O'Driscoll *

Biomechanics Laboratory, Department of Orthopedic Surgery, Mayo Clinic Rochester, MN 55905, USA

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ABSTRACT

Background: Options for repair of distal biceps tendon ruptures are well-described. However, scant data exist in the literature regarding failure strength of the native tendon. We hypothesize that a) the distal biceps tendon failure strength is sensitive to loading angle, and b) the failure strength is greater than what has been previously reported in the literature.
Methods: 15 radii were potted in a simulated supine position, and the native tendon was pulled from the tuberosity at angles of 90, 60, and 30° of flexion (5 per group) relative to the long axis of the radius. The failure load and stiffness were recorded and compared.
Findings: The native tendon's mean failure load tended to increase as flexion angle decreased. Due to the large variability in strength, mean failure loads of the 90° (mean 358 (SE 117 N)), 60° (mean 617 (SE 141 N)), and 30° (mean 762 (SE 130 N)) groups were not statistically different from each other ($P=0.12$). The mean stiffness results for each group (mean 501 (SE 176 N/mm), mean 763 (SE 226 N/mm), and mean 756 N (SE 179 N/mm), respectively) were not significantly different from each other ($P>0.6$).
Interpretation: The load to failure of the distal biceps tendon may be higher than what has previously been reported, and may be dependent on the elbow flexion angle. Though this difference may be attributed to the difference in methodology it should be taken into account during consideration of repair and rehabilitation.

1. Introduction

Biceps tendon ruptures represent 3% of injuries involving the biceps, usually in the dominant extremity, with a reported incidence of 1.2 per 100,000 (D'Alessandro et al., 1993; Safran and Graham, 2002). Although there is no consensus regarding the pathophysiology, some authors have described tendon degeneration due to bony abnormalities (Morrey, 2000), mechanical impingement, and partial tendon hypovascularity (Seiler et al., 1995). The mechanism of tendon injury is typically a traumatic event involving an abruptly applied extension force to a partially flexed elbow, resulting in eccentric contraction of the biceps (Ramsey, 1999). Although disruption at the musculotendinous junction has been reported (Schamblin and Safran, 2007), the majority of injuries are due to tendon avulsion from the bicipital tuberosity (Morrey, 2000; Ramsey, 1999).

The advantages of operative management over conservative treatment in restoration of normal function have been reported (Baker and Bierwagen, 1985; Morrey, 1993). While much has been published regarding the technique and biomechanics of tendon repair (Berlet et al., 1998; Idler et al., 2006; Krushinski et al., 2007; Mazzocca et al., 2007a; Lemos et al., 2004; Pereira et al., 2002; Spang et al., 2006), we know of only one study that has investigated the strength properties of an intact biceps tendon. Idler et al. (2006) reported a mean stiffness of 30 (SE 12 N/mm), a mean failure strength of 204 (SE 77 N), and a mean maximum strength of 222 (SE 66 N) using force–displacement data for 9 cadaveric specimens. In that study, the native muscle was secured in a testing device and pulled at a constant rate of 4 mm/s to failure, with the tendon fibers oriented perpendicular to the radius. Those reported failure loads of the biceps tendon seem to be relatively low compared to the potential force generated in the tendon during activities of daily living. This may be due to the manner in which tendon avulsion was performed. The actual orientation of the tendon insertion may not be the same as the angle of the joint.

The objectives of this study were to a) investigate the ability of the distal biceps tendon to withstand rupture and b) investigate the degree to which tendon failure strength is sensitive to loading angle.

2. Methods

Fifteen fresh frozen cadaveric elbows were obtained from our institutional cadaver bank, with 5 elbows assigned to each group (90°, 60°, and 30° of elbow flexion). Specimens were obtained from donors with an average age at death of 78 (range, 49–92) years in the 90° group, 83 (range, 69–92) years in the 60° group, and 68 years (range, 49–90) in the 30° group. In each group, the ratio of male to female donors was 4:1. Specimens were randomly chosen and provided

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* Corresponding author at: Department of Orthopedic Surgery, Mayo Clinic, Rochester, MN 55905, USA.
E-mail address: odriscoll.shawn@mayo.edu (S.W. O'Driscoll).

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to us one at a time by our cadaver donor program. We completed each testing group prior to proceeding to the next group, starting with the 90° group and continuing with the 60° then 30° groups.

A power analysis based on the standard deviation of previously reported results demonstrated that a minimum of 17 samples per study group (total of 51 specimens) would be required to achieve $\beta=0.2$. However, given the significant cost associated with testing 51 samples, we limited our study to a total of 15 specimens.

2.1. Specimen preparation

The specimens were thawed at room temperature prior to testing. The muscle, tendon, tendon insertion, and bicipital tuberosity were grossly examined for any signs of pathology. The biceps muscle and tendon were isolated and mobilized. The remaining forearm soft tissues were removed from the radius. After dissecting out the proximal quarter of the radius, the radial head was excised, facilitating fixation of the bone/tendon in our custom-shaped PMMA mold.

A mold was shaped which allowed the section of bone around the tuberosity to be secured in PMMA. Also included in this assembly was a small acrylic fixture with two threaded holes to be used as an interface between the material testing machine and the potted specimen (Fig. 1). We reinforced the PMMA with loops of steel wire, which increased the tensile strength of the block. PMMA was poured into the mold containing the wire. The bone/tendon was held in an optimal position until the cement set, taking care to avoid getting PMMA on any of the soft tissues.

2.2. Specimen mounting

Two screws were inserted into the block, and the specimen was gripped onto a custom fixture mounted on the MiniBionix 858 servohydraulic testing machine (MTS Systems, Eden Prairie, MN, USA) (Fig. 2). The segment of proximal radius was mounted in a manner that simulated forearm supination. In this position, the radial tuberosity faced medially, with the tendon fibers attaching at the most extreme ulnar aspect of the bicipital tuberosity, as has been described (Fig. 3). The width and thickness measurements were taken along the narrowest portion of the tendon. The width, thickness, and length of each tendon were measured using digital calipers (Fowler, Newton, MA, USA) and the approximate cross-sectional area was calculated, by multiplying thickness and width of the specimens. Approximately 5 cm of muscle/tendon was clamped within a customized cryogrip to provide secure attachment, leaving approximately 4.5 cm of tendon free. Cooling with carbon dioxide gas resulted in the muscle/tendon

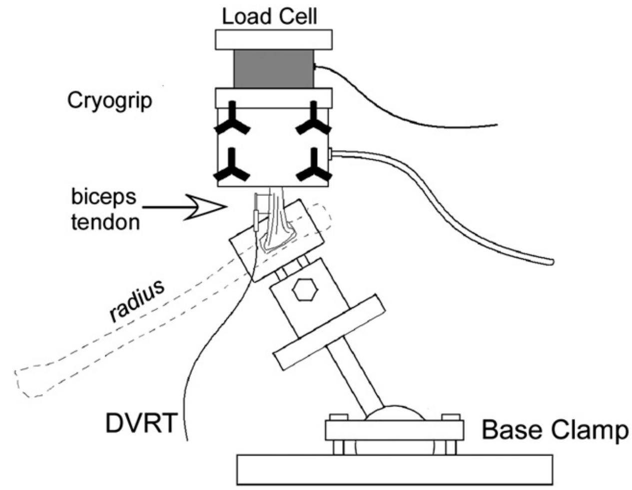

Fig. 2. Schematic diagram demonstrating the manner in which the biceps tendon was fixed into the testing device. The radius, portrayed by the dashed line, was not included in the model, but is shown here to demonstrate the bone–tendon angle.

freezing to the grips, providing a more secure clamping of the soft tissue. The cryogrip was attached to the load cell.

2.3. Test conditions

When the forearm is supinated, the bicipital tuberosity is oriented medially. Numerous recent anatomic studies have shown that the tendon footprint is located on the posterior/ulnar side of the tuberosity (Athwal et al., 2007; Hutchinson et al., 2008; Mazzocca et al., 2007b). In each testing condition, the bicipital tuberosity was oriented horizontally. The distraction force in each group was applied in a vertical direction, or upwards, relative to the tuberosity. With the tendon being pulled vertically, the bone–tendon angle was then altered, but only in a plane corresponding to the sagittal clinically. There were three testing conditions (5 specimens in each group) according to the bone/tendon angle: a) 90°, b) 60° and c) 30° of flexion. Each condition was tested at the same displacement rate, 4 mm/s, as previously described (Idler et al., 2006).

2.4. Load testing

Once the sample was clamped, the tendon was pre-loaded with 1 N and pre-conditioned by cyclicly loading it for 10 cycles with a displacement amplitude of 1 mm at a frequency of 0.1 Hz. The initial

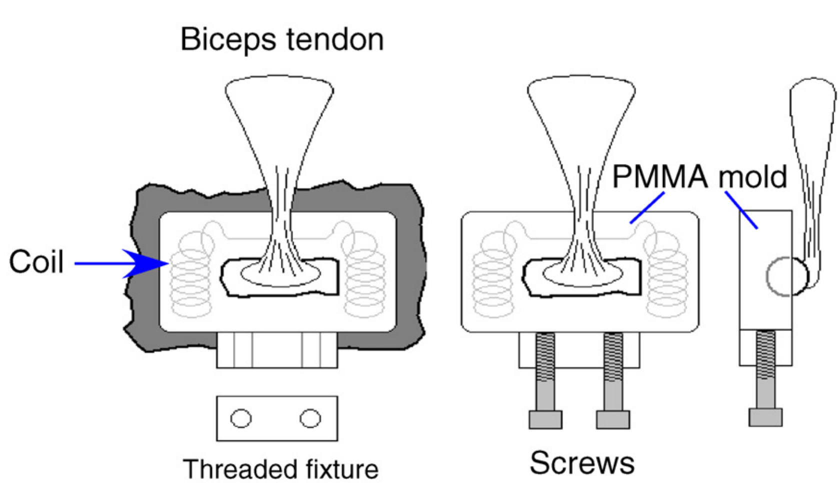

Fig. 1. Method for potting the proximal radius bone segment into wire-reinforced PMMA.