Journal of Orthopaedics 13 (2016) 177–180

Contents lists available at ScienceDirect

Journal of Orthopaedics

journal homepage: www.elsevier.com/locate/jor

Original Article

Biomechanical properties of tenotomy versus biceps knot in a cadaver model

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ARTICLE INFO

Article history:
Received 12 January 2016
Accepted 3 April 2016
Available online 6 May 2016

Keywords:
Biceps knot
Biceps tenodesis
Purse string knot
Tenotomy

ABSTRACT

Background: Biceps tenotomy and biceps tenodesis are the primary methods of treating biceps pathology. This study describes a new technique of tenotomy with the goal of autotenodesis to give the biceps a higher load to failure and decreased chance of a Popeye deformity.
Purpose: The purpose of this study was to evaluate the strength of the "biceps knot", which is an outlet tenodesis of the biceps tendon and compare the biomechanical properties of this technique to tenotomy.
Methods: Ten matched cadaver shoulder pairs were used. In the tenotomy group, an arthroscopic tenotomy was performed at the labral biceps junction using a narrow angled biter. For the biceps knot group, a self-retrieving suture passing device was used to pass a suture as far lateral as possible. The suture was passed from just distal to the biceps insertion on the superior labrum and tied with a standard non-sliding arthroscopic knot. The humerus and biceps tendon were rigidly fixed to a materials testing machine and cyclically loaded at 10–20 N for 100 cycles at 1 Hz. After cyclic testing, a 2 N preload was placed on the tendon and the tendon was pulled in line with the bicipital groove until failure.
Results: The peak load to failure for the biceps knot was 58.9 N (SEM 8.2 N) and 37.3 N (SEM 4.6 N) for the tenotomy group ($p = 0.046$). The average stiffness for the biceps knot group was 4.2 N/mm (SEM 0.4 N/mm) and 3.2 N/mm (SEM 0.2 N/mm) for the tenotomy group ($p = 0.031$).
Conclusion: Performing the biceps knot is a quick, easy and cost effective alternative to the current tenodesis options available.

1. Introduction

Biceps tendon pathology is a frequent cause of pain and disability.[1–5,15] The long head of the biceps tendon (LHBT) is an independent pain generator that is a frequent complaint in patients with shoulder pain.[3] There is a "net-like pattern" of sensory and sympathetic neural fibers concentrated at the tendon origin on the glenoid that is a major contributor to pain in the shoulder.[2] LHBT pathologies have recently become more commonly recognized in association with other pathologies of the shoulder. Ignoring LHBT pathology has been shown to lead to an inferior outcome.[4]

While there is little disagreement that the LHBT generates pain, the function, and consequently biomechanical relevance, of the tendon in normal shoulder activity remains controversial.[1,4–6] Biomechanical cadaver studies indicate that the LHBT plays a significant role in stabilizing the glenohumeral joint in all directions of movement.[1,6] However, the load placed on the biceps in these studies varied significantly, and even exceeded physiologic levels in several studies.[1,6] Clinical studies using electromyography demonstrate a minimal role for the LHBT in active shoulder stabilization, supporting those who claim it to be a vestigial structure.[3,6,7] There is no clear answer in the literature as to what the function of the LHBT is and if it is needed at all in a fully functional shoulder.[2,7,8]

The two most common techniques used to treat LHBT pathology are biceps tenotomy and biceps tenodesis.[1] Tenotomy has been shown to be effective at resolving complaints of pain but can cause a cosmetic deformity commonly referred to as a Popeye deformity from 3 to 70% of the time.[4,9] A deep muscle ache related to early fatigue in 38% of young active individuals has also been reported.[10] A tenodesis may help to conserve normal anatomy.[11] By maintaining the length tendon relationship of the biceps, it less

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http://dx.doi.org/10.1016/j.jor.2016.04.001

frequently causes cosmetic complaints and muscle ache, but can cause bicipital groove pain[1,6,12] and a tenodesis more technically demanding procedure requiring additional operative time and implants.[10,13–16]

No consensus has been reached regarding the benefit of tenodesis over tenotomy in the published literature due to variable patient characteristics, methodology, and results.[8] Given that there has been no proven difference in functional scores or patient satisfaction between the two interventions, an option that is less challenging and avoids complications is desirable.[6] There is a known phenomenon of autotenodesis that occurs when the long head of the biceps tendon adheres to the bicipital groove after tenotomy.[6,7] Promoting this process would enable a best of both worlds approach to the treatment of biceps tendon pathology.

The purpose of this study was to evaluate the biomechanical properties of the biceps knot at time zero in a cadaver model and directly compare it to the biceps tenotomy. Our secondary objectives were to describe the arthroscopic biceps knot technique and compare the time required for the two techniques studied.

2. Materials and methods

Twenty matched fresh frozen cadaver shoulders were used. The shoulder was placed in the beach chair position. The standard posterior viewing portal was established, a diagnostic tour of the shoulder was performed, and the acceptability of the specimen was confirmed. An anterior portal was established at the inferior aspect of the rotator interval by standard practices. An appropriate sized passport flexible cannula (Arthrex, Naples, FL) was placed in the anterior portal. An arthroscopic shaver was used as needed to debride degenerative tissues about the joint to enable visualization. Finally, either the biceps tenotomy or knot procedure was initiated and we began timing the surgical treatment.

The biceps tenotomy group had a standard biceps tenotomy performed arthroscopically just distal to the superior labrum using a narrow angled biter. In the biceps knot group, a self-retrieving Scorpion suture passing device (Arthrex, Naples, FL) was used to pass a Stryker #5 force fiber suture (Stryker, Kalamazoo, MI) from inferior to superior as far lateral as possible. The same suture limb was passed from superior to inferior just distal to the biceps insertion on the superior labrum. Care was taken to leave room to perform the tenotomy without violating either the labrum or the suture. Once it was confirmed that the sutures were passed cleanly, they were tied with a standard non-sliding arthroscopic knot (Fig. 1). The limbs were cut with an arthroscopic knot cutter. The tenotomy was performed just distal to the superior labrum using a narrow biter. The timer was stopped after the completion of the tenotomy in both groups.

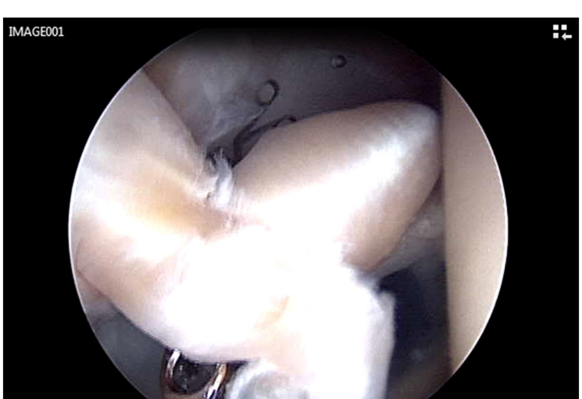

Fig. 1. Arthroscopic image of the biceps knot.

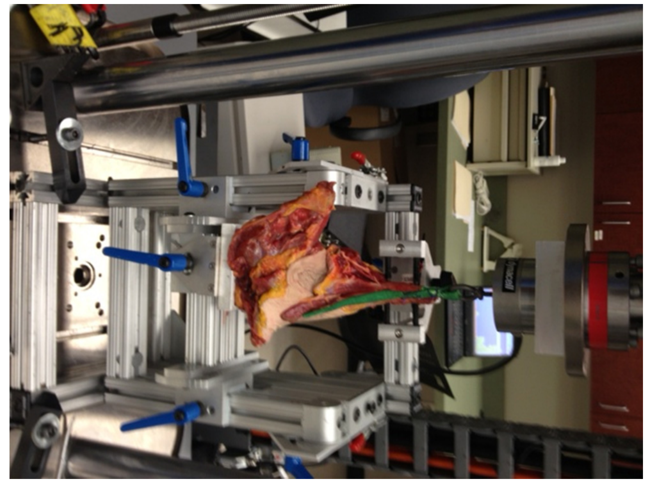

Fig. 2. Biomechanical set-up of the cadaveric shoulder.

The soft tissues were dissected away from the humerus distal to the inferior border of the pectoralis major insertion. The most distal aspect of the long head of the biceps tendon was identified and tagged with a suture, taking care not to tension it. Additional soft tissue was removed from the posterior and superior aspect of the shoulder, avoiding all soft tissues overlying the bicipital groove.

The humeri were secured in custom aluminum fixtures and rigidly fixed to the base of an electromechanical materials testing machine (ElectroPuls™ E10000, Instron, Norwood, MA) using a 1 kN load cell. The distal portion of the tendon was identified and secured to the actuator of the materials testing machine by sewing the proximal aspect of the distal biceps tendon to a Dacron rope in a modified Krackow fashion and clamping the tendon-webbing complex (Fig. 2). The Dacron rope has been used previously and has a stiffness of 255 N/mm in order to minimize any effect of the material on the values reported.

First, the specimens were subjected to cyclic loading. The distal end of the tendon was pulled in line with the bicipital groove from proximal to distal from 20 to 60 N for 100 cycles at 1 Hz. If the specimen did not fail during cyclic testing, a 2 N preload was applied and a load to failure test was performed at a rate of 10 mm/s until failure. Force and displacement were recorded by the Instron. Peak-to-peak displacement was considered to be the average difference between the highest and the lowest displacement of the last 3 cycles. The peak load was defined as the load to failure for all specimens. Maximum elongation was considered the displacement measured by the Instron at the peak load. The stiffness was calculated for each specimen after testing by calculating the slope of the line in the linear portion of the force/displacement curve. Average values for each group were determined along with the standard error. Data were compared by a paired, one-tailed Student's t-test for significance ($p < 0.05$).

3. Results

The average peak load to failure for the biceps knot group was 58.9 N (SEM 8.2 N) and 37.3 N (SEM 4.6 N) for the tenotomy group. The biceps knot group failed at a significantly higher load ($p = 0.046$) than the tenotomy group (Fig. 3). The average stiffness for the biceps knot group was 4.2 N/mm (SEM 0.4 N/mm) and 3.2 N/mm (SEM 0.2 N/mm) for the tenotomy group (Fig. 4) ($p = 0.031$).

The maximum elongation for the biceps knot was 17.9 mm (SEM 2.5 mm) and 13.2 mm (SEM 1.1 mm) for the tenotomy group ($p = 0.10$). The average peak-to-peak displacement for the biceps