Anterior Cable Reconstruction Using the Proximal Biceps Tendon for Large Rotator Cuff Defects Limits Superior Migration and Subacromial Contact Without Inhibiting Range of Motion: A Biomechanical Analysis

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Purpose: To assess an anterior cable reconstruction (ACR) using autologous proximal biceps tendon for large to massive rotator cuff tears. **Methods:** Nine cadaveric shoulders (mean age, 58 years) were tested with a custom testing system. Range of motion, superior translation of the humeral head, and subacromial contact pressure were measured at 0°, 30°, 60°, and 90° of external rotation (ER) with 0°, 20°, and 40° of glenohumeral abduction. Five conditions were tested: intact, stage II tear (supraspinatus), stage II tear + ACR, stage III tear (supraspinatus + anterior half of infraspinatus), and stage III tear + ACR. ACR involved a biceps tendon tenotomy at the transverse humeral ligament, preserving its labral attachment. ACR included nonpenetrating suture-loop fixation using 2 side-to-side sutures and an anchor at the articular margin to restore anatomy and secure the tendon along the anterior edge of the cuff defect. ACR was performed in 20° glenohumeral abduction and 60° ER. **Results:** ACR for both stage II and stage III showed significantly higher total range of motion compared with intact at all angles ($P \leq .001$). ACR significantly decreased superior translation for stage II tears at 0°, 30°, and 60° ER for both 0° and 20° abduction ($P \leq .01$) and for stage III tears at 0° and 30° ER for both 0° and 20° abduction ($P \leq .004$). ACR for stage III tear significantly reduced peak subacromial contact pressure at 30° and 60° ER with 0° and 40° abduction and at 30° ER with 20° abduction ($P \leq .041$). **Conclusions:** ACR using autologous biceps tendon biomechanically normalized superior migration and subacromial contact pressure, without limiting range of motion. **Clinical Relevance:** ACR may improve rotator cuff tendon repair longevity by providing basic static ligamentous support to the dynamic tendon while helping to limit superior migration without restricting glenohumeral kinematics.

The rotator cuff tendon adheres to the superior capsule of the glenohumeral joint.[1,2] For rotator cuff tears with mobile tendons that do not have tissue loss, footprint restoration can be achieved using transosseous-equivalent repair techniques.[3-6] For massive irreparable tears, superior capsular reconstruction (SCR) has been described.[7,8] However, for tears that do not allow anatomic restoration, such as medialized repairs or partial repairs, any repair or remaining defect requires the tendon to act as both a tendon and ligament[9,10]; the residual dynamic tendon may be prone to insufficient healing or recurrent injury given the relative lack of static ligamentous support. Partial repairs have had less predictable results,[11] and some tears are simply irreparable, leaving large defects. In these cases, the dynamic tendon would preferably be supported by a static structure that would provide ligamentous support. Ideally, any such supporting structure would help maintain glenohumeral congruency, acting to prevent humeral head superior migration, but would not overconstrain the joint.

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The long head proximal biceps tendon could act as a ligamentous structure in this setting for several reasons: its proximal attachment on the glenoid is close to the native capsular attachment site and would not require glenoid fixation, obviating the risks for graft healing insufficiency and potential implant failures. The biceps are often tenotomized; using this redundant tissue would mean an efficient use of graft tissue. Further, the biceps would provide an autologous source of tissue. The tendon could be maintained at the labrum transition, resected distally at the level of the bicipital groove transverse ligament; the distal end could then be fixated on top of the footprint at the native superior capsule attachment site, thus leaving biceps tendon spanning over the humeral head. The graft, placed anterior to any residual cuff defect, in the case of irreparable tears or after partial repairs, would effectively create an anterior cable reconstruction (ACR).

This is in contrast to a routine biceps tenodesis where the tendon is released at the labrum and fixated at the proximal end of the tenotomy. This is also in contrast to a procedure described whereby the long head tendon is released at the labrum junction and then used to "augment" rotator cuff repairs.[12-14] For both routine tenodeses and augments, the distinctive feature is that there is no biceps tissue spanning the humeral head with these latter techniques, unlike the proposed ACR. In addition, 2 technical notes have recently described the biceps tendon as functioning as a superior capsule reconstruction.[15,16] In contrast, ACR as described in the current study is not a superior capsule reconstruction, and several technical features distinguish our procedure from those cited, which include fixation technique and method.

The current study was designed to biomechanically assess and characterize the kinematic and contact characteristics of an ACR for residual stage II (entire supraspinatus tendon) tears and stage III (supraspinatus + anterior half of infraspinatus) tears of the rotator cuff using a similar methodology as that used for SCR. Therefore, the purpose was to assess an ACR using autologous proximal biceps tendon for large to massive rotator cuff tears. We hypothesized that the current technique would substantially normalize superior humeral head migration, subacromial contact pressures, and anterior-posterior translations, without restricting overall range of motion.

Methods

Specimen Preparation

Nine fresh-frozen cadaveric shoulders (3 right and 6 left) were dissected and prepared for testing. The mean donor age was 58 years old (range, 33-77 years) and consisted of 5 males and 4 females. All specimens were dissected, removing all skin and subcutaneous tissue but preserving the joint capsule and coracoacromial ligament. All specimens were assessed by a fellowship-trained shoulder surgeon (Y.I.) prior to testing. None of the donors showed any evidence of rotator cuff tendon, superior labrum, or proximal biceps tendon tears. The long head of the biceps tendon was transected just proximal to its muscle belly. To accommodate muscle loading during testing, a Krackow stitch was sutured into the tendinous insertions of shoulder muscles and the long head of the biceps tendon using a no. 2 FiberWire suture (Arthrex, Naples, FL). The humerus was transected at 2 cm below the deltoid insertion.

Setup

The scapula was mounted to a custom shoulder testing system using a metal plate attached to the infraspinatus fossa (Fig 1). The scapula was placed in 20° tilt in the sagittal plane. The transected humerus was rigidly fixed to the intramedullary rod, which was attached to a custom arc system that enabled axial rotation of the humerus and controlled glenohumeral abduction. A 360° digital goniometer was placed at the distal end of the humeral cylinder to measure range of motion. Ninety degrees of external rotation (ER) was defined as the position at which the anterior edge of the acromion aligned with the long head of the biceps tendon in the bicipital groove at 60° of glenohumeral abduction; 0° of glenohumeral abduction was defined as the position at which the humeral rod lined up perpendicular to the ground.

Physiological muscle force vectors were replicated with an adjustable cable-pulley system. Muscle loading was applied with braided low-stretch fishing lines (Dacron Fishing Line, Izorline, Paramount, CA), which were attached to no. 2 FiberWire (Arthrex) Krackow stitches at the tendinous insertions.[17] Two different muscle loading conditions were tested: balanced and unbalanced conditions. In the balanced condition, anterior-posterior and superior-inferior balanced force couples were applied to obtain a centered humeral head in the glenoid socket. Muscles were loaded with 10 N on the supraspinatus (2 lines—accommodating the width of the muscle divided into 2 sections); 5 N on the infraspinatus (2 lines—accommodating the width of the muscle divided into 2 sections); 5 N on the teres minor (1 line—following center of the musculotendinous junction); 5 N on the long head of the biceps (1 line—following center of the musculotendinous junction); 10 N on the subscapularis (2 lines—accommodating the width of the muscle divided into 2 sections); 20 N on the latissimus dorsi (2 lines—accommodating the width of the muscle divided into 2 sections); 20 N on the pectoralis major (2 lines—accommodating the width of the muscle divided into 2 sections), and 40 N on the deltoid (3 lines—attaching to the anterior, middle, and