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Biomechanics of a novel technique for suprapectoral intraosseous biceps tenodesis

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Background: The Caspari-Weber (C.W.) tenodesis is a standard miniopen intraosseous technique to fix the long head of the biceps tendon. The suprapectoral intraosseous biceps tenodesis (SPIBiT) is a novel arthroscopic, intraosseous, tendon-sparing alternative using a cortical button. No biomechanical data exist comparing the time-zero performance of the SPIBiT and C.W. constructs.
Methods: Nine pairs of human cadaver shoulders were tested. The SPIBiT used a finger-trap suture pattern holding the tendon inside a humeral tunnel above the pectoralis tendon, anchored with a cortical button on the anterior humerus distal to the bicipital groove. The subpectoral C.W. used a Krackow suture technique. Specimens underwent 500 cycles of uniaxial loading, followed by ultimate failure testing.
Results: The SPIBiT was placed in 5 left and 4 right humeri (5 female, 4 male; 59 $\pm$ 6 years). The C.W. was initially stiffer ($P = .003$), whereas the SPIBiT exhibited higher energy dissipation (hysteresis; $P = .006$). Metrics decreased for both constructs over 500 cycles ($P \leq .050$). Constructs failed through suture bunching and tendon tearing within the main suture bundle. The SPIBiT exhibited a novel failure in 2 specimens, with the cortical button pulling distally and suture cutting through cortical bone. Failure occurred at 272.0 $\pm$ 114.3 N and 282.3 $\pm$ 59.4 N for the SPIBiT and C.W., respectively ($P = .766$). The C.W. was stiffer ($P < .001$).
Conclusion: The SPIBiT is an arthroscopic suprapectoral intraosseous alternative to the C.W. biceps tenodesis, but in light of the novel failure mode, clinical use is not recommended. Future investigations should quantify the impact of construct compliance on healing, and future constructs should avoid suture point loading on thin cortical bone.
Level of evidence: Basic Science Study, Biomechanics.

Keywords: Biceps tendon; tenodesis; C.W. technique; intraosseous; biomechanics

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Biceps tenodesis is used to treat pathologic conditions involving the long head of the biceps tendon (LHB), including LHB tears, superior labral anterior-posterior lesions in older patients, and LHB instability.[7] Numerous techniques have been described and vary on the basis of the location of fixation of the LHB in relation to the tendon of the pectoralis major (suprapectoral vs. subpectoral)[1–4,9,11,18,30] and the method of visualization (open vs. arthroscopic).[9,10,30,31] The ideal technique should provide adequate visualization to perform the procedure safely, with sufficient fixation strength to resist displacement during the period of tendon to bone healing. Numerous fixation methods have been described for tenodesis of the LHB, including suture anchors, interference screws, cortical button fixation on the anterior and posterior humerus, and bone tunnels (e.g., keyhole technique).[2,9,31,34] Techniques also differ in terms of intraosseous vs. extraosseous fixation of the tendon. Although controversial, evidence suggests that intraosseous tendon length and tendon-bone diametrical mismatch both affect the healing capacity and biomechanics of the tendon-bone interface.[12] Because nonbiologic constructs may ultimately fail with cyclic loading in the absence of healing, augmentation of healing with intraosseous fixation may improve the construct's longevity.

Coined the "C.W." biceps tenodesis after Drs. Richard Caspari and Stephen Weber, an arthroscopically assisted, miniopen, subpectoral biceps tenodesis method is a "gold standard" for intraosseous biceps tenodesis.[31] Using bone tunnels without an implant, the C.W. procedure is a modification of the original keyhole technique described in 1975.[9] Although it is clinically successful, displacement of the construct on the order of 8 to 10 mm after cyclic loading[17] may affect healing potential and long-term construct longevity. Also, to obtain adequate visualization and to protect the adjacent neurovascular structures, an open incision in the axilla is required. This may affect cosmesis, increase the risk of infection or nerve or vascular damage, and add to the time and cost of the procedure. By placing LHB fixation above the pectoralis major tendon and below the bicipital groove, an arthroscopic biceps tenodesis in the distal suprapectoral region may reduce the risk of infection, neurovascular injury, and "groove pain."[16,19,27] However, this location carries its own unique challenges. The regional bone morphology is unique as it transitions from cortical to soft metaphyseal bone with a very thin cortex and minimal underlying cancellous bone. In this area, traditional screw or push-in anchors may find limited application as they rely on substantial bone quality for secure fixation.[35]

On the basis of these observations from the clinic and literature, a new arthroscopic suprapectoral intraosseous biceps tenodesis technique (SPIBiT) was developed. This procedure incorporates intraosseous fixation with a small bone tunnel matching the tendon diameter, a tendon-sparing finger-trap suturing technique,[26,33] and a cortical button for robust fixation distal to the bicipital groove. Despite these potential advantages, there are no studies evaluating the biomechanical properties of this construct. Therefore, the purpose of this study was to compare the mechanical behavior of the SPIBiT and the C.W. biceps tenodesis. We hypothesized that there would be no difference in cyclic loading properties or failure properties between the SPIBiT and C.W. constructs.

Methods

Specimen preparation

Nine pairs of fresh frozen human cadaver shoulders were thawed at room temperature before dissection. Each shoulder was dissected down to the glenohumeral joint, and any specimen with significant soft tissue disease, including biceps fraying or tears, previous rupture, fractures, or evidence of prior surgery, was excluded. The upper border of the pectoralis major tendon insertion was marked on the bone and tendon with a surgical pen as a reference point for implant placement. The LHB attachment to the superior labrum at the supraglenoid tubercle was cut, and the humerus was disarticulated. All soft tissue was removed from the humerus, leaving the proximal humerus, biceps tendon, and biceps muscle belly. The width and thickness of each tendon were measured with a digital caliper for calculation of tissue cross-sectional area.

The SPIBiT construct

A distal hole was placed at the mark on the humerus indicating the upper border of the pectoralis major tendon (Fig. 1, *A*). The 2-mm guide pin from a cannulated reamer set was drilled through the anterior humeral cortex and left in place. A reamer 0.5 mm larger than the biceps tendon width was then used to drill over the guide pin. Another hole in the anterior cortex was placed 25 mm proximal to the uppermost edge of the distal hole using the same guide pin.

On the tendon, a second mark was made 25 mm proximal to the upper border of the pectoralis major tendon plus the radius of the distal bone hole (Fig. 1, *A*). The tendon was cut 15 mm proximal to this second mark. Beginning 10 mm distal to the level of the tendon coinciding with the upper border of the pectoralis tendon, a finger-trap style suture construct was placed (Fig. 1, *B*).[26] Briefly, a simple half-hitch was placed with a strand of No. 3-4 polyethylene suture (Force Fiber; Tornier, Montbonnot Saint Martin, France), then clamped with the tip of a hemostat to maintain tension (Fig. 2). Next, both ends of the suture were passed completely around the tendon with each suture tail angled at 45° from the long axis of the tendon. This sequence was repeated until the fourth half-hitch was tied at the level of the proximal hole. Hemostats were sequentially removed as each additional half-hitch was placed so that only 2 hemostats were in place at a time.

The final half-hitch was then converted into a "rolling hitch." One suture end was passed twice around the tendon, and the other suture limb was laid down on the tendon. A third pass around the tendon was made with the wrapping limb, trapping the non-wrapping limb. The wrapping suture was then passed under the