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Original article

Triple-bundle anatomical reconstruction using the coracoacromial ligament and the short head of biceps tendon to stabilize chronic acromioclavicular joint dislocations: A cadaver feasibility study

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ABSTRACT

Introduction: In cases of chronic acromioclavicular joint separation, the biomechanical properties of anatomical reconstructions are closer to the native configuration than the Weaver–Dunn procedure. Consequently, the radiological and clinical outcomes are better. However, an additional incision is needed to harvest the graft, which increases the procedure's morbidity.
Hypothesis: Triple-bundle reconstruction can be performed with the coracoacromial ligament (CAL) and the semi conjoined tendon (SCT).
Material and methods: Bilateral dissection was performed on the upper limb of six fresh-frozen cadavers. Measurements useful to the procedure were taken on one limb, specifically the minimum graft length needed and the available length. The surgical procedure was performed on the other limb. The proximally based SCT was passed through the base of the coracoid process, then divided into two strips tightened from the superior aspect of the coracoid process to the clavicular insertion points of the conoid and trapezoid ligaments. The CAL was detached from the coracoid process and then secured in the medullary canal of the clavicle, after its lateral one-quarter was resected (i.e., 10 mm).
Results: The mean length of the SCT was 101.7 ± 7.6 mm (95.1–114.5) and the mean length of the CAL was 35.3 ± 4.7 mm (28.7–42.5). The SCT length needed for this reconstruction was 58 ± 4.3 mm (51.5–62) medially and 60.3 ± 4.6 mm (54.3–66.3) laterally. The procedure was feasible in all six cadavers with an average excess length of 39.9 ± 5.7 mm (32.2–47) for the conoid bundle, 37.6 ± 5 mm (31–45.1) for the trapezoid ligament and 6 ± 2.7 mm (3–9.5) for the CAL.
Discussion: Triple-bundle anatomical reconstruction using the SCT and CAL is feasible. However, the strength of this construct must be evaluated biomechanically before it can be used clinically.
Level of evidence: Not applicable – cadaver study.

1. Introduction

Along with dynamic contributions of the deltoid muscle anteriorly and the trapezius muscle posteriorly, stability of the acromioclavicular (AC) joint depends on three main ligament structures: the AC ligaments (considered as one functional unit) and the two coracoclavicular (CC) ligaments, including the conoid ligament medially and the trapezoid ligament laterally [1]. Given the anatomical position of this joint, acute AC joint separations are relatively common, representing 3.2% of all shoulder girdle injuries. They usually occur following a direct impact on the shoulder during high-energy falls [2]. On the other hand, the development of chronic instability is rare due to the availability of effective surgical techniques that stabilize high-grade acute tears and the overall effectiveness of conservative treatment for low-grade tears [3]. Nevertheless, simple stabilization is not sufficient in cases of chronic instability given that the healing potential of ligaments

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decreases over time [4]. For this reason, the Francophone Society of Arthroscopy recommends adding a biological graft if the injury is more than 10 days old [5].

Historically, acromioclavicular ligament reconstruction involved local grafts that were pedicled to the coracoid process anteriorly and secured to the clavicle posteriorly. In 1942, Vargas proposed using either the lateral part of the conjoined tendon (i.e., semi conjoined tendon – SCT) or the short head of biceps tendon [6]. Thirty years later, Weaver and Dunn described a reconstruction procedure using the coracoacromial ligament (CAL) [7]. Despite the popularity of these reconstruction methods, they do not reproduce the anatomy of the native triple-bundle ligament complex. Their biomechanical properties were found to be less than those of the native joint, leading to unpredictable radiological and clinical outcomes [8–10].

More recently, anatomical reconstruction techniques have been proposed to restore the native ligament configuration and its various bundles more faithfully. Consequently, their biomechanical properties are close to that of the native joint, and the clinical and radiological outcomes appears to be better [11–13]. The drawback of these procedures is that the grafts are harvested from a separate surgical site, increasing the morbidity [14].

The aims of this cadaver study were:

- to assess the feasibility of triple-bundle reconstruction using local grafts (i.e., SCT and CAL);
- to describe the anatomical features needed to carry out the procedure.

2. Material and methods

2.1. Study population

Bilateral dissection was performed on the upper limb of six fresh-frozen cadavers (2 male, 4 female) thawed for 24 hours at room temperature. Medical records of the donors were reviewed to ensure they had no history of acromioclavicular joint injury or surgery. In addition, radiographs were taken of the AC joints bilaterally before the dissection was initiated. Measurements useful to the procedure were taken on one limb, specially the minimum graft length needed and the available length. The procedure was performed on the other limb. The side was chosen randomly.

2.2. Cadaver study

After a large anteroposterior skin incision was made over the shoulder, the trapezius and deltoid muscles were detached from the clavicle and scapula. Next, the pectoralis major and minor muscles were detached from the humerus and coracoid process, respectively, to expose the conjoined tendon. The proximal portion of the conjoined tendon was left intact. The distal portion was transected at the musculotendinous junction, then, separated from the muscle belly using a scalpel. It was then divided longitudinally over its entire length, to end up with a 12-mm wide lateral strip [15]. The musculocutaneous nerve was identified and its distance from the tip of the coracoid process was recorded. The subscapularis, supraspinatus and infraspinatus muscles were then detached distally and reflected proximally to allow the glenohumeral joint to be disarticulated. Lastly, the clavicle was transected laterally to the pectoralis major insertion, and the scapula horizontally under the glenoid, and in a parasagittal plane medial to the neck, in order to remove the acromion and lateral portion of the scapular spine. Once the scapuloclavicular unit was isolated, various bone, ligament and tendon structures were measured using a slide caliper with 0.1 mm accuracy (Mitutoyo, Kawasaki, Japan). The grafts were measured first, specifically the length of the SCT (labeled L) and the anterior width and lateral length of the CAL (labeled l). The CC ligaments were measured next:

- length at medial edge for conoid ligament and anterior edge for trapezoid ligament (labeled c and c′, respectively);
- distance between tip of coracoid process and anterior edge of their coracoid insertion (labeled, CORc and CORt, respectively);
- distance between acromioclavicular joint line and the middle of their clavicular insertion (labeled AACc and AACt, respectively).

The bone elements were measured next. The length of the coracoid process was measured from its tip to the precipice, defined by Salzmann et al. as the point where the horizontal direction of the underside of the coracoid process becomes vertical [16]. Its medial to lateral width and its superior to inferior thickness (labeled b) were measured at its base [17]. The clavicle dimensions were taken over the conoid and trapezoid ligament insertions, along with the anterior–posterior width and superior–inferior thickness (labeled d for the conoid and d′ for the trapezoid). Once these measurements had been taken, the distances D and D' were calculated, such that $D = a + b + c + d$ and $D' = a + b + c' + d'$. These values reflected the minimum graft length needed to carry out anatomical reconstruction of the conoid and trapezoid ligaments, respectively, with the SCT pedicled proximally onto the coracoid process (Fig. 1A and B).

2.3. Surgical technique

The specimen was placed supine with a block between the shoulders and the arm along the body. A deltopectoral approach was used to expose the coracoid process and the conjoined tendon. Once isolated, the conjoined tendon was divided longitudinally, and a 12-mm wide lateral strip was raised with a scalpel in an anterograde manner by progressively flexing the elbow to prevent excessive traction onto the musculocutaneous nerve [15]. The length of the harvested strip was measured. The musculocutaneous nerve was identified where it enters the coracobrachialis muscle and it was reflected backwards with the muscle body when the tendon was elevated. The SCT was then divided into two 6-mm wide strips. Each was reinforced with a Krackow suture using Ethibond® #2 (Ethicon, Somerville, NJ, USA) and then preserved in a humid compress (Fig. 2) [18,19]. A second incision was made on top of the distal clavicle and curved forwards and outwards, in order to access the CAL without placing tension on the skin. The deltoid and trapezius muscles were detached subperiosteally from clavicle. A Rockwood type III injury was then simulated by transecting the AC and CC ligaments (Fig. 3) [20]. Once the two SCT strips were retrieved through the second incision, the CAL was detached from the coracoid process and reinforced with a Krackow suture using Ethibond® #5 [15].

The clavicle was then prepared for the reconstruction. A 4-mm wide hole was drilled 35 mm from the AC joint and centered on the superior surface of the clavicle in the anteroposterior direction. This hole was extended to the base of the coracoid process, until it pierced it in the middle. A second hole was drilled 25 mm from the AC joint through the clavicle only [17]. Lastly, the distal 5–10 mm of the clavicle was resected [21], allowing two 1-mm tunnels to be drilled using K-wires. These were started 10 mm inside the resection margin on the superior clavicular surface and ended in the cut edge, 10 mm apart in the sagittal plane. The acromioclavicular defect created by resecting the AC joint and the distal tip of the clavicle was measured from the midline portion of the clavicular cut to the posterior portion of the CAL's acromial insertion. The reconstruction was then finalized. The two SCT strips were passed below the coracoid process. After crossing its base, the two strips were separated into their individual clavicular tunnels. After the joint