Arthroscopically assisted anatomical coracoclavicular ligament reconstruction using tendon graft

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Abstract We describe a method of arthroscopically assisted, mini-open, anatomical reconstruction of the coracoclavicular ligament. This method restores both components of the native ligament with the aim of achieving maximum stability with minimal disruption of the normal anatomy. Using the same principles of ligament reconstruction that are employed in other joints, transosseous tunnels are created following the native footprints of the conoid and trapezoid ligaments and an autologous graft is fixed using a PEEK screw. Adequate healing of the ligament occurs within the bone, to prevent stress risers with an appropriate working length. This procedure is unique, as it replaces the torn ligament with a natural substitute, in the appropriate location, through a minimally invasive procedure. This technique would be suitable for treatment of patients with either grade III or V acute acromioclavicular dislocations. Clinical outcomes for the first 13 consecutive patients treated with this procedure are reported, revealing excellent satisfaction rates with a Constant score of 96.6 at final follow-up.

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Introduction

Acromioclavicular (AC) joint dislocations are common injuries in active individuals secondary to direct force on the lateral aspect of the adducted shoulder. Depending on the magnitude of the insulting force, complete disruption of the AC and coracoclavicular (CC) ligaments may occur. The majority of these injuries are successfully treated without surgery. However, in cases where surgical management is warranted, there are more than 100 surgical techniques described and no undisputed “gold standard” technique. The first surgical management of an AC joint dislocation described was an arthrodesis performed by Cooper in 1861 [1]. Since then, a variety of procedures have been developed to repair disrupted AC and CC ligaments, including open and arthroscopic procedures, such as the use of hardware fixation from the clavicle to acromion or clavicle to coracoid, reconstruction of torn ligaments with synthetic materials, autologous hamstring grafting, allografts and the use of conjoined tendons [2, 3, 5, 7–13].

However, the usual techniques reconstruct only one of the two components (the conoid or trapezoid) of the native CC ligament. Additionally, the synthetic materials that are typically used have characteristics very different from those of the natural ligaments [10]. Some clinicians have attempted anatomical reconstruction by drilling tunnels within the natural footprint of the CC ligament on the inferior surface of the clavicle or by creating bone tunnel sockets on the coracoid [6]. However, no attempts have been made to construct transosseous tunnels within the natural footprint of the coracoid base independently. We believe that development and implementation of methods for the repair of CC ligaments that more closely mirror natural anatomy will result in greater stability of the AC joint and higher patient satisfaction.

Here, we describe a new double-bundle, three-tunnel method for anatomical reconstruction of CC ligaments using a semitendinosus tendon. This technique is intended for use in acute cases (within two weeks of injury) for Rockwood type V AC separations and for type III separations in high-demand patients. The technique is designed to stabilise the AC joint by recreating the natural anatomy of the CC ligaments with an arthroscopically assisted, mini-incision approach through the subacromial space, without disturbing the rotator interval.

Surgical technique

The entire procedure is completed arthroscopically with the addition of a mini-incision over the posterior aspect of the distal clavicle. With the patient in a modified beach-chair position, a standard posterior portal is created approximately 2 cm inferomedial from the posterolateral corner of the acromion. After diagnostic arthroscopy of the glenohumeral joint, the scope is introduced into the subacromial space through the posterior portal. An anterolateral portal is made approximately 1.5 cm lateral to and in-line with the anterior border of the acromion. A 3.5-mm right angle radio-frequency ablation device is introduced through an anterolateral portal, and the subacromial bursa is removed for better visualisation and ease of tissue dissection at the base of the coracoid.

After the tip of the coracoid and AC joints are identified by palpation, an anterior portal is created 1 cm lateral and 1 cm inferior to the AC joint. Soft tissue around the coracoid base is removed through the anterior portal to facilitate graft passage (Fig. 1a). Next, a 2.0-cm skin incision is made over the posterior margin of the distal clavicle at its most convex point. After the trapezius muscle is dissected off of the clavicle, a special delivery system (Imhoff Delivery Device, Arthrex, Inc., Naples, FL, USA)

is inserted through this incision and placed onto the posterosuperior surface at the base of the coracoid on the footprint of the conoid ligament (Fig. 1b). A 3.2-mm guide pin is then directed just lateral to and approximately 20° inferiorly from the base of the coracoid, advancing approximately 10 mm. An AC TightRope® drill guide (Arthrex, Inc., Naples, FL, USA) is then introduced through the anterior portal under direct vision and placed under the base of the coracoid arch, while its other end (the drill sleeve) is placed in the pre-drilled hole on the posterosuperior surface of the coracoid base. With the drill guide held in this position and under clear arthroscopic view, a 2.4-mm guide pin is drilled from the posterosuperior surface of the coracoid to its proximal undersurface. Next, a 5.5-mm coracoid tunnel is made based on the 2.4-mm pre-drilled tunnel, using a reamer guide pin. Using the guide pin and reamer, two clavicular tunnels are then created.

The tunnel for the conoid ligament on the clavicle is drilled at 1 cm anterior to the conoid tubercle which corresponds to the most convex portion of the distal clavicle, where it is at the same level as the coracoid tunnel orifice. The superior positioning of the tunnel on the clavicle for the conoid ligament permits automatic anatomical reduction of the joint while fixing the conoid ligament. A 5.5-mm reamer is placed over the guide pin carefully, so as not to jeopardise the posterior clavicular cortex. For the trapezoid ligament, the guide pin is placed 20 mm lateral from the centre of the conoid tunnel and slightly more anteriorly, then reamed with a 5.5-mm reamer (Fig. 2). After all three tunnels are reamed, a double-loop semitendinosus tendon graft 5.5 mm in diameter is whipstitched into place with sutures at each end. One limb of the graft is threaded through the conoid clavicular tunnel in the clavicle and followed through the base of the coracoid (Fig. 3). The free end of the graft, exiting the coracoid tunnel at its undersurface, is then threaded through the clavicular

Fig. 1 **a** Three portals used during arthroscopically assisted CC reconstruction: posterior (*P*), anterolateral (*AL*) and anterior (*A*), with an additional incision for coracoid and clavicular drilling (*) **b** Gross depiction of the posterior skin incision and placement of the Imhoff Delivery Device to create a provisional tunnel for the final coracoid tunnel

Fig. 2 **a** 3-D depiction of the clavicle and coracoid tunnels. **b** Intraoperative positions of the clavicular tunnels

trapezoid tunnel (Fig. 4a). Two PEEK (8×5.5 mm) screws (Arthrex, Inc., Naples, FL, USA) are used to fix each end of the graft to the clavicle; one PEEK screw is used to fix the graft in the coracoid tunnel (Fig. 4b).

With this procedure, our focus is to create ligament footprints, both on the coracoid process and on the undersurface of the clavicle, with bony tunnels rather than

Fig. 3 One limb of the graft is threaded through the conoid clavicular tunnel in the clavicle and followed through the base of the coracoids

a loop/sling around the coracoid. In this way, the reconstructed ligaments replace the torn ligaments in a natural, anatomical fashion.

Postoperatively, the arm was placed in a Kenny Howard brace for three to four weeks. Then, patients were allowed to perform pendulum exercises and to use their arm for waist level activities of daily living. Activity above shoulder level was prohibited for the first two postoperative months.

Stretching exercises for overhead activity was started after two months, and return to contact or overhead sports was allowed at six months.

Materials and methods

Between August 2007 and January 2009, 13 patients, suffering from shoulder pain following traumatic AC dislocations, underwent arthroscopic reconstruction using our new technique. All 13 patients were operated upon by the same surgeon. There were ten men and three women with a mean age of 28.4 years (range 22–39 years). Radiological imaging demonstrated Rockwood type V dislocations in ten patients and type III dislocations in three patients. All patients were assessed clinically and by radiological examination after an average of 17 months (range 12–26 months) after the procedure. The radiological evaluation included anteroposterior, 30° of cephalic tilt and axillary views of both shoulders.

Follow-up evaluation included the Constant score, the pain level based on the visual analog scale (VAS: 0=no pain, 10=maximum pain) and the degree of AC joint displacement (Fig. 5). The distance between the inferior border of the acromion and the distal clavicle on the anteroposterior view was measured in both affected and unaffected AC joints. Also, the distance between the anterior border of the acromion and the distal clavicle on the 30° of cephalic tilt view was measured in both affected and unaffected AC joints. The degree of both superior and anterior AC joint displacement was determined by comparing those distances in both joints.

At final follow-up, less than 2 mm of difference was graded as minimal, 2–4 mm as mild, 4–6 mm as moderate and more than 6 mm as marked displacement. The patients' subjective satisfaction was also assessed. Additionally, the patients were asked whether they would return to original activity with the affected shoulder.

Results

Pain, as assessed by the VAS, was significantly improved following surgery, from an average of 7.9 preoperatively to 1.2 at last follow-up. The average Constant score was 73.4 preoperatively and 96.6 at last follow-up.

Fig. 4 Arthroscopic (a) and 3-D modelling (b) views of the anatomical double-bundle CC ligament reconstruction with a coracoid tunnel

Immediate postoperative radiographs confirmed anatomical reduction of the AC joints in 11 patients. Two patients demonstrated an incomplete reduction of the AC joint with a slight upward and anterior displacement of the distal clavicle, but these remained within the definition of minimal displacement. At final follow-up, ten patients,

including the two patients with initial incomplete reduction, had remained with the definition of minimal displacement in both anteroposterior and 30° cephalic tilt views. Three patients, with initial anatomical reductions, demonstrated mild displacement. Nevertheless, the functional and subjective results were excellent in all cases at the last follow-

Fig. 5 a Preoperative radiograph of a type V AC dislocation (left shoulder). b Postoperative anteroposterior view demonstrates anatomical reduction of the distal clavicle against the underside of the acromion. c A 30° cephalic tilt view demonstrates the anatomical position of the distal clavicle. † tunnel for conoid ligament on clavicle, ‡ tunnel for trapezoid ligament on clavicle, * tunnel of the coracoid process

up. All patients stated that they were satisfied with the procedure and had returned to their original activity. Patient data and results, including radiological imaging and functional scores, are summarised in Table 1

Discussion

The CC ligament is the prime suspensory ligament of the AC joint, although each component of the joint provides AC joint stability in different directions. Debski et al. identified the conoid ligament as the major safeguard against anterosuperior loading with the trapezoid guarding against posterior loading of the clavicle [4]. Therefore, recreating these two components of the AC joint as close to the natural anatomy as possible during surgical repair may improve joint stability and joint kinematics.

In this study, we describe a new CC reconstruction technique using a coracoid tunnel. This reconstruction successfully resisted not only superior translation of the clavicle, but also anteroposterior translation, more closely replicating the AC-deficient state [13]. Meanwhile, the majority of conventional repair techniques do not reconstruct the CC ligament in the natural anatomical position and, therefore, do not address the functional differences of these two components. Procedures that reconstruct the CC ligament as a single structure, using either synthetic material or grafts, may successfully reduce the superior displacement of the distal portion of the clavicle [4, 6, 8, 10]. However, inconsistent results have been reported for these methods in long-term follow-up as non-biological materials do not provide adequate durability when assessed in the long-term. These procedures are also prone to being horizontally unstable. The Weaver-Dunn and Bosworth

techniques, with their various modifications, are currently the most popular procedures in use, alongside various fixation methods [2, 9]. These procedures are reported to produce good results, but are associated with complications, such as malpositioning of the distal clavicle, foreign body reactions to the absorbable polydioxanone suture augmentation and fixation loss from screw loosening. The conoid sling technique has also been widely used, with either free tendons or synthetic materials, although this technique is not based on anatomical reconstruction. Favourable results are reported using the conoid sling technique, but it is also known to induce significant anterior displacement of the clavicle in relation to the scapula. Additionally, grafts looped under the coracoid base stretch over time, resulting in healing difficulties and associated malfunctions of the reconstructed ligament. In contrast, the anatomical coracoid tunnel technique described in this study is thought to be effective in achieving accurate reduction, better healing of the coracoid tunnel and enhanced stability in both anterior and superior directions, as the graft is anchored in the tunnel and runs in an oblique orientation that more closely replicates the native CC ligaments [14]. Along with these advantages, the degree of reduction and the functional outcomes of this procedure are quite encouraging, even though two patients did initially experience a suboptimal reduction with less than 2 mm of displacement in both anterior and superior directions. The two cases with initial suboptimal reduction can be explained by an inaccurate coracoid tunnel, which was drilled anterior to the conoid footprint. The cause of reduction loss at final follow-up is less certain but may be due to stretching of the graft over time or slippage from the clavicular tunnel, caused by a weak fixation.

Table 1 Patient data and results

Case	Gender	Age	Side	Rockwood grade	Follow-up (months)	Mechanism of injury	Degree of reduction	Follow-up displacement	Constant score
1	M	21	R	V	12	Skiing	Complete	Minimal	100
2	M	25	R	V	13	Fall	Complete	Minimal	90
3	F	31	L	V	22	Fall	Incomplete	Minimal	98
4	M	33	R	III	24	Snowboarding	Complete	Minimal	94
5	M	26	L	V	17	Skiing	Complete	Mild	98
6	F	32	L	V	21	Biking	Complete	Minimal	98
7	M	41	L	V	15	Fall	Complete	Mild	94
8	M	29	R	V	26	Skiing	Complete	Minimal	92
9	F	32	R	III	13	Fall	Complete	Minimal	98
10	M	18	L	III	17	Skiing	Complete	Mild	98
11	M	20	L	V	12	Soccer	Incomplete	Minimal	100
12	M	26	R	V	16	Traffic accident	Incomplete	Minimal	96
13	M	28	R	V	13	Snowboarding	Complete	Minimal	100

This study does have several limitations. The new procedure carries the risk of coracoid fracture, due to the wide coracoid tunnel and the degree of surgical complexity required. However, the coracoid tunnel is located quite posterior, when compared to most non-anatomical reconstruction methods. Therefore, the socket exit point is situated in a relatively thicker portion of the coracoid process. This procedure also poses a risk to suprascapular nerve and artery in coracoid tunnelling because these structures are very close to the posterosuperior part of the coracoid. For this reason, we used a special delivery system (Imhoff Delivery Device) to create a pre-drilled hole on the coracoid and applied the right-angled retractor to take both structures including trapezius muscle away from the reamer. Indeed, we did pay extra attention to the tunnelling process during reconstruction in order to prevent any injuries which could occur.

This procedure may not be effective in chronic cases of fixed scapular malpositioning, as 5.5-mm double-loop semitendinosus tendon grafts may not be strong enough to maintain an anatomical position of a scapula-clavicle complex that has significantly deteriorated. Although our technique is not the first arthroscopic approach for AC joint reconstruction, it is, to our knowledge, the first to involve the arthroscopic passage of graft material through the coracoid by a subacromial approach without violating the rotator interval. We believe that natural anatomical reconstruction of the CC ligaments, using a semitendinosus graft threaded through bony tunnels in the clavicle and coracoids, has excellent potential to replicate the function of normal ligaments, achieving both maximum therapeutic efficacy and patient satisfaction.

Conflict of interest The authors declare that they have no conflict of interest.

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