Sports Medicine

Anatomic approach to reconstruction of the unstable acromioclavicular joint

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ABSTRACT

Acromioclavicular separation is a common athletic shoulder injury. While many can be treated nonoperatively, high-grade injuries can result in pain and loss of shoulder function. While numerous operative techniques have been proposed, a recent renewed focus on the anatomy of the coracoclavicular ligaments has led to anatomic reconstructive techniques that show promise in biomechanical comparisons. These techniques involve reconstruction of the conoid and trapezoid ligaments through anatomically-based tunnels in the clavicle. Preservation of the distal clavicle improves the biomechanical stability of this construct. Reconstruction of the acromioclavicular joint may be added in revisions in patients with distal clavicular deficiency. While clinical outcomes are still early, longer-term studies and prospective trials are needed to elucidate the optimal technique for management of this operative condition.

Keywords
acromioclavicular joint, coracoclavicular ligament, reconstruction

INTRODUCTION

Injury to the acromioclavicular (AC) joint accounts for nearly half of all sports-related shoulder injuries.[1] Low-grade injuries often can be conservatively managed, as the coracoclavicular ligaments remain intact and keep the clavicle in close proximity to the scapula. However, higher grade injuries result in the complete disruption of these ligaments and often result in both inferosuperior and anteroposterior instability. Operative stabilization often is indicated and can minimize the discomfort and disability associated with this instability. The unstable AC joint has been treated with a multitude of operative techniques over time, with many reporting good to excellent outcomes.[2]

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However, recent anatomic work has better defined the ligamentous and bony anatomy of this region.[3] This has led to the development of the anatomic-based coracoclavicular (CC) ligament reconstruction technique, which has been shown to be superior to the Weaver-Dunn technique with a biomechanical evaluation.[4] However, clinical results and randomized comparative trials are needed to determine the optimal treatment.

ANATOMY

The AC joint is a diarthrodial joint at the confluence of the scapular acromion and the distal clavicle. The joint is easily palpable from the surface of the skin and is a reliable landmark in various operative procedures. The joint is surrounded by a capsule with synovium and contains a meniscus-type structure that may contribute to load distribution and joint stability.[5] Osseous structures important to the AC joint include the clavicle, coracoid and acromion. The orientation of the AC joint in the sagittal plane has been shown to vary among individuals, ranging from an overriding clavicle to an orientation where the clavicle is underriding.[6] On the inferior surface of the clavicle, the trapezoid line and conoid tubercle can be identified, representing the respective attachments for the trapezoid and conoid ligaments. Rios *et al.*[3] demonstrated that the origin of the coracoclavicular (CC) ligaments on the clavicle could be reliably identified intraoperatively based on distance from the AC joint. Ligamentous structures that provide the AC joint with static stability include the joint capsule, the acromioclavicular ligaments and the coracoclavicular ligaments. The dynamic stabilizers include the trapezius and deltoid muscles. Innervation to the AC joint is provided by the suprascapular, axillary and lateral pectoral nerves. Its blood supply is from the acromial branch of the thoracoacromial artery, the suprascapular artery and the posterior humeral circumflex artery.

BIOMECHANICS

The AC joint primarily rotates in the axial plane of the clavicle and translates in the anteroposterior and superoinferior directions. Although the trapezius and deltoid muscles have been acknowledged as important dynamic stabilizers of the AC joint, their exact biomechanical roles have not been determined.

The ligamentous structures around the AC joint have been described as well as their individual contributions to joint stability.[3,6–8] Fukuda *et al.*[7] demonstrated that each of the ligamentous structures surrounding the AC joint play a pivotal role in its stability. In their study they determined that the AC ligaments act as the primary constraint for posterior translation especially at smaller degrees of displacement. CC ligaments, primarily the conoid ligament, are responsible for constraining motion in the anterior and superior directions especially at greater degrees of displacement. They also determined that the primary role of the trapezoid ligament is stability of the AC joint during axial compression toward the acromial process. From their study, Fukuda *et al.*[7] concluded that each of the ligamentous structures surrounding the AC joint provides stability depending on the force and direction of the load. Therefore, operative procedures that allow the greatest number of structures to remain intact will provide superior strength after healing. The authors also noted that some procedures, such as distal clavicular resection, may not allow this to occur.

These conclusions have been further supported in the recent work of Dawson *et al.*,[9] who performed a biomechanical study investigating the relative contribution of AC joint capsule and CC ligaments to AC stability. In their study they quantified anteroposterior and superoinferior AC joint translations in a cadaveric model at varying levels of AC joint compressive forces and translational loads. Their results demonstrated significant increases in both the anteroposterior and superoinferior planes after transection of the AC joint capsule and CC ligaments, respectively. With the AC joint capsule cut and CC ligaments intact, increased anteroposterior translation was observed. Additionally, superoinferior translation was greater with transected CC ligaments. These data support prior research demonstrating the importance of both the AC and CC ligaments but also provide a "comparison of the biomechanical characteristics of the AC joint capsule and CC ligaments." Dawson *et al.*[9] concluded that for optimal operative repair the strategy should include reconstruction of both the AC joint capsule and the CC ligaments.

Mazzocca *et al.*[10] performed a biomechanical study to determine how the conoid and trapezoid ligaments contribute to the stability of the AC joint after complete AC joint injury. In their study, they sectioned the AC ligaments in 40 cadaver shoulders. Ten shoulders were loaded to failure to evaluate the normal failure pattern and the remainder had either the conoid or trapezoid ligaments sectioned after creation of an AC joint injury. Radiographs were taken before and after injury, and stability testing was performed. Their results demonstrated that the conoid ligament always failed first. Sectioning of the conoid resulted in increased posterior and superior translation when evaluated with radiographic and materials testing. Sectioning of the trapezoid ligament resulted in increased posterior translation with materials testing and increased superior translation on radiographic evaluation. From this information, they concluded that failure of either the conoid or trapezoid in conjunction with AC ligament disruption is sufficient injury to significantly decrease AC joint stability. They also postulated that their findings may help explain some variability in clinical outcomes in Type II injuries.

OPERATIVE INDICATIONS

The typical mechanism of injury is a direct force over the superior portion of the shoulder of an adducted arm, forcing the acromion inferiorly and medially. Indirect injuries are a result of a fall on an outstretched arm forcing the humerus superiorly into the acromion disrupting the AC articulation. In both mechanisms, disruption of the AC ligaments is followed by disruption of the CC ligaments and the deltotrapezial fascia.[10] AC joint dislocations were initially categorized into 3 types but later expanded by Rockwood[11] into the familiar six category classification of AC injures widely used today. Nonoperative management of type I and II injuries is recommended. Operative intervention is recommended for high-grade AC joint dislocations, types IV, V and VI. The management of type III AC injuries remains controversial; however, it is certainly indicated in active patients in whom nonoperative treatment has failed.

OPERATIVE OPTIONS

Numerous procedures have been described to treat the unstable AC joint.[9,12–20] Technical options have included primary fixation at the AC joint (K-wires, hook plate), fixation between the coracoids and clavicle (CC screw, suture anchor, suture loop), dynamic muscle transfer, and ligamentous reconstruction.[2] The traditional ligament reconstructive technique has been the Weaver-Dunn AC ligament transfer.

While no clear consensus exists, recent anatomic and biomechanical research suggests that an anatomical reconstruction of the CC ligaments may provide a superior clinical outcome.[4,10,21] In 2006, Mazzocca *et al.*[4] published the results of a biomechanical evaluation of an anatomical CC ligament reconstruction. In their study, they randomly placed 42 fresh-frozen cadaveric shoulders into three operative groups: arthroscopic reconstruction, anatomical CC ligament reconstruction and a modified Weaver-Dunn procedure. In their study, they found that the mean anterior, posterior and superior translation of an intact specimen after a 70-N load was applied was 9.82 ± 4.51, 7.39 ± 4.16 and 5.63 ± 2.14 mm, respectively. After reconstruction using the described techniques, they determined that the Weaver-Dunn method demonstrated a significant increase in posterior translation: 11.17 ± 4.60 mm ($P = 0.0315$). The arthroscopic technique resulted in no change in translation in any plane when compared with the intact specimen. Anatomic CC ligamentous reconstruction demonstrated decreased posterior and superior translation when compared with the intact specimen. The authors concluded that "the anatomical CC reconstruction has less anterior and posterior translation and more closely approximates the intact state, restoring function of the AC and CC ligaments".[4]

Tauber *et al.*[21] recently published the results of their prospective comparison between anatomical CC ligament construction using an autogenous semitendinosus graft and reconstruction using the modified Weaver-Dunn technique. In their study, they assigned 12 patients to the Weaver-Dunn group and 12 patients to the semitendinosus group. Patients were followed for a mean of 37 months and were evaluated using the American Shoulder and Elbow Surgeons (ASES) shoulder score and the Constant score. At follow-up, patients in the semitendinosus group demonstrated significant improvements in both their ASES shoulder scores and Constant scores. The authors concluded that CC ligamentous reconstruction using semitendinosus autograft resulted in significantly better outcomes when compared to the modified Weaver-Dunn technique.[21]

AUTHORS' PREFERRED TECHNIQUE

We currently prefer an anatomical reconstruction of the CC ligaments using a semitendinosus allograft. This technique is based on the work of Mazzocca *et al.*[4] and is an open version of the arthroscopic technique described by VanSice and Savioe.[22] The patient is positioned in the modified beach chair position under general anesthesia augmented with an interscalene block if not contraindicated. The surface anatomy is clearly marked to plan the incision (Figure 1). An approximately 8-cm transverse incision is made along the length of the distal clavicle. This allows for ease of exposure of the AC joint and acromion, although a vertical (saber-type) incision also is adequate and can facilitate exposure of the coracoid. Using a combination of sharp and blunt dissection, skin flaps are created allowing a view of the deltotrapezial fascia. The fascia is incised along the length of the distal clavicle and subperiosteally dissected anteriorly and posteriorly. At this point, the distal clavicle can generally be reduced into the AC joint. If necessary, soft-tissue debridement to include excision of the fibrocartilaginous disc within the joint capsule may be performed to aid in reduction. The dissection also is carried inferiorly to the coracoid base to allow passage of the graft inferior to the coracoid. At approximately 45 mm from the AC articulation, a guide pin is placed for the conoid tunnel and a 5.5-mm cannulated reamer is used to drill the tunnel. Then, approximately 15 mm lateral to that on the anterior border of the clavicle, the trapezoid tunnel is drilled again using a 5.5 mm reamer. The graft is passed inferior to the coracoid process and crossed over itself before being passed into the bone tunnels previously created in the clavicle. This cruciate graft position (Figure 2) approximates the origin of the ligaments on the coracoid process without the fracture risk associated with potting the grafts into the small coracoid process. The conoid ligament is then fixed to the clavicle using a 5.5×8 mm PEEK tenodesis screw (Arthrex, Naples, FL). Reduction of the AC joint is confirmed, and the graft is tensioned prior to fixation of the trapezoid ligament with another tenodesis screw (Figure 3). We do not resect the distal clavicle but routinely excise fibrous tissue that can block reduction of the clavicle into the AC joint.

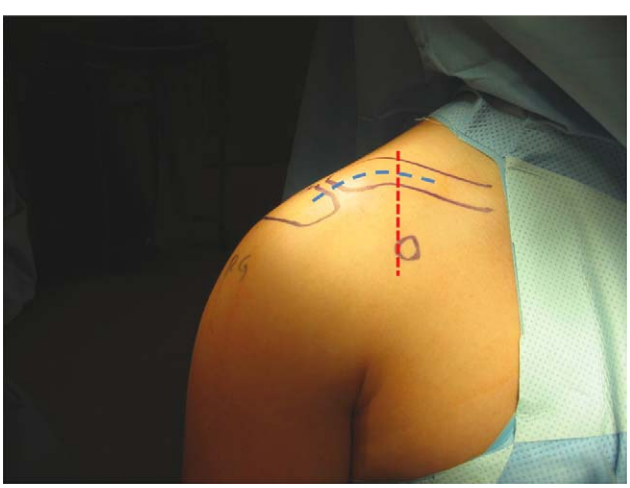

FIGURE 1. Intraoperative photograph of patient in the beach-chair position with surface anatomy marked to plan incision. The vertical incision (red dashes) provides excellent access to the coracoid process. A horizontal incision (blue dashes) can be used as well to facilitate access to the acromioclavicular joint.

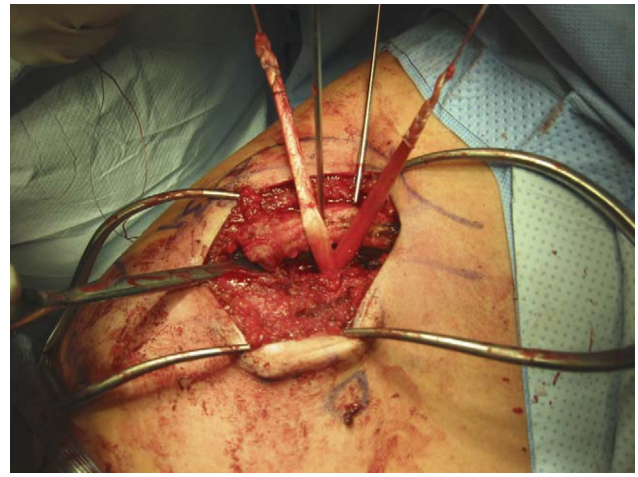

FIGURE 2. Intraoperative photograph of coracoclavicular ligament reconstruction. The hamstring allograft has been passed under the coracoid process and graft limbs crossed. Conoid and trapezoid tunnels will be passing a 5.5 mm reamer of the guide pins in the clavicle.

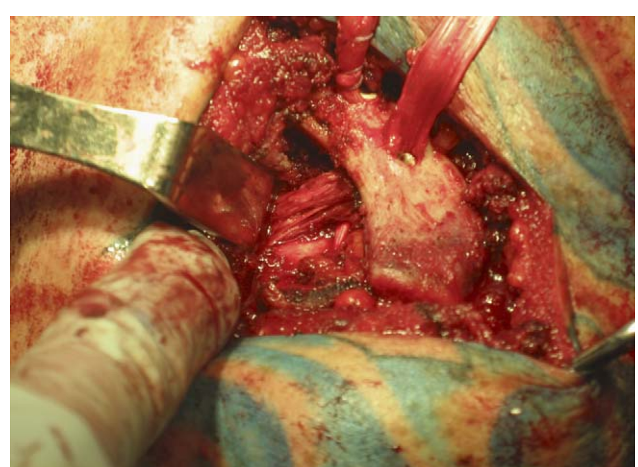

FIGURE 3. Intraoperative photograph showing conoid and trapezoid ligament grafts secured with PEEK interference screws. Reduction of the acromioclavicular joint is confirmed by direct view.

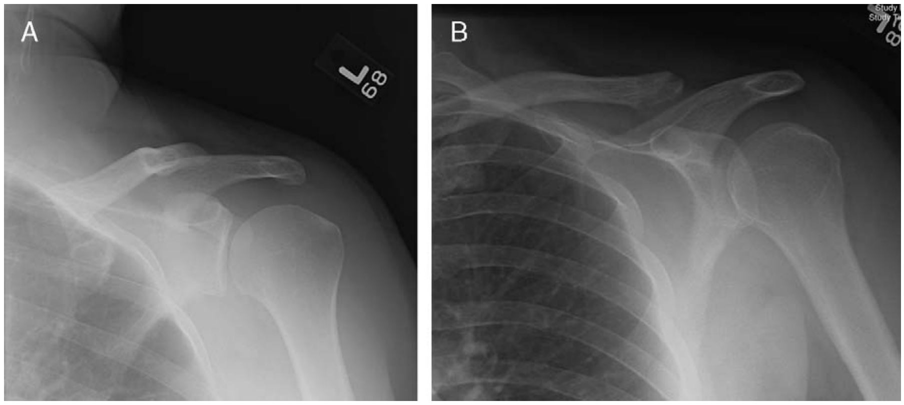

FIGURE 4. (A) Preoperative radiograph of 38-year-old patient who presented with acromioclavicular pain during activity. He sustained an AC separation and was treated at another facility with a primary and revision distal clavicular resection, neither of which improved his symptoms. His radiograph shows just under 100% displacement of his clavicle with 3 cm of distal clavicle resected. His physical examination revealed gross anteroposterior instability of his acromioclavicular joint. (B) Postoperative radiograph showing reduction of the acromioclavicular relationship, with osseous tunnels in the clavicle for the conoid and trapezoid ligament grafts, as well as a tunnel in the acromion to provide improved resistance to anteroposterior displacement.

We have used an isolated CC ligament reconstruction with success in primary surgeries and when the distal clavicle is intact. In revision cases or cases in which the distal clavicle has been excised (Figure 4), the ligament graft is fixed in the trapezoid tunnel, then swung over to the acromion where is it passed through an acromial tunnel and secured with either an interference screw (Figure 5) or by suturing the graft to itself (Figure 6). This adjunct of an AC reconstruction is critical to restore the anteroposterior stability, which may lead to failure of an isolated CC reconstruction.

Once the reconstructed ligaments are fixed, the adequacy of the reduction is confirmed by either direct view or fluoroscopy if necessary. The AC joint capsule is repaired if present, and the deltotrapezial fascia is closed with absorbable suture. The patient is placed in a shoulder immobilizer before waking from general anesthesia. We currently use a standard shoulder immobilizer; however, the use of a gunslinger-type brace that supports the weight of the arm should be considered for revisions.

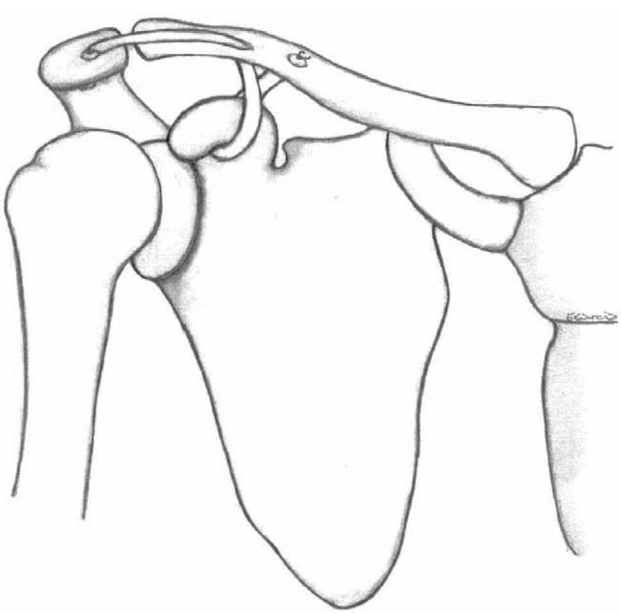

FIGURE 5. Artist's rendition of the anatomic coracoclavicular and acromioclavicular ligament reconstructions using a tendon graft passed under the coracoid process, crossed above the coracoids, fixed within drill holes in the clavicle with interference screws, and a single limb being secured to the acromion with an interference screw.

REHABILITATION

Postoperative rehabilitation consists of a program designed to initially protect the reconstruction, which then progresses to preserve shoulder range of motion (ROM) and eventually to regain strength and flexibility, allowing patients to return to physical activity. Strict compliance with the chosen rehabilitation protocol is critical to the

FIGURE 6. Intraoperative photograph of a revision reconstruction. The conoid and trapezoid grafts have been secured with interference screws, and the excess graft is brought through a tunnel on the acromion to be secured with an interference screw and tied to the excess graft exiting the conoid tunnel.

success of acromioclavicular reconstruction. Patients frequently feel significant symptomatic relief from being operatively stabilized and are often inclined to aggressively pursue an active lifestyle, which can compromise graft incorporation and may lead to failure of the reconstruction.

At our institution, patients are maintained in a shoulder immobilizer for a total of 6 weeks. Week 1 focuses on pain control and preservation of wrist and elbow active range of motion (AROM). Patients may take off their sling during physical therapy to perform supported pendulum exercises. Weeks 2–6 are focused on active assisted range of motion (AAROM). Physical therapy during this period consists of AAROM exercises with flexion up to 90 degrees, abduction to 60 degrees and external rotation as tolerated. The focus of weeks 6 through 12 are progressively increased ROM. At 3 months, patients are allowed to begin gentle strengthening. At 4–6 months, strength training is increased as well as sport-specific rehabilitation. Return to duty or sports is allowed at 6 months.

COMPLICATIONS

Pain and continued instability are the most common complications after nonoperative treatment. Complications can occur regardless of the treatment method chosen to treat AC joint dislocations. These complications include persistent pain, and instability, hardware failure and migration. The operative exposure and work around the coracoid process places the musculocutaneous nerve at risk in addition to the brachial plexus and subclavian vessels if the surgeon strays medially. Specific complications are associated with the operative technique chosen. Recent biomechanical studies have demonstrated that persistent anteroposterior translation after reconstruction using a modified Weaver-Dunn technique may be responsible for continued pain and instability.[23] More rigid materials have been used to prevent this continued instability but have also been associated with complications such as coracoid fracture.[24,25] The placement of drill holes in the clavicle for anatomic-based reconstructions can result in clavicular fracture. Potting a tendon graft into the coracoids base can result in coracoid fracture, as can the placement of a single drill hole through the coracoid for suture button fixation. In our practice, the greatest complication is failure of the reconstruction with recurrent deformity because of poor patient compliance with activity restrictions in the early postoperative period.

CONCLUSION

Several techniques have been described regarding operative treatment of AC joint dislocations, including primary repair of the AC and CC ligaments, clavicle fixation to the coracoid, plating across the AC joint, and distal clavicular resection with suture or graft augmentation. Over the years, some of these techniques have been abandoned secondary to poor outcomes while others continue to be used with good outcomes.[2] Although no current consensus exists, recent biomechanical studies comparing operative techniques demonstrate that anatomical reconstruction of the CC ligaments provides a more stable construct.[4,23] We currently prefer a technique of anatomic reconstruction of the CC ligaments and the AC joint if necessary. Prospective randomized trials with long-term follow-up comparing anatomical reconstruction of the CC ligaments to other operative techniques are required before a consensus can be reached.

REFERENCES AND RECOMMENDED READING

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- •• of outstanding interest

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This is a biomechanical cadaveric study demonstrating the role of the AC joint capsule in preventing anterior-posterior displacement and the CC ligaments in preventing superior-inferior displacement. This data supports anatomic reconstruction of the CC and AC ligaments. Additionally, the authors note that distal clavicle resection may have a detrimental effect on AC joint stability.

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