Type III Acromioclavicular Separation: Rationale for Anatomical Reconstruction

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Abstract

Treatment of acute type III acromioclavicular separation is controversial. In some patients, nonoperative treatment is associated with pain, weakness, and stiffness. Many acromioclavicular joint reconstructions are associated with complications and results not substantially better than those of nonoperative treatment. Use of autogenous free tendon graft to anatomically reconstruct the acromioclavicular and coracoclavicular ligaments offers several advantages over other surgical techniques. These advantages include improved biomechanical properties, no foreign body implantation, biological fixation, anatomical reconstruction, and early rehabilitation.

Injuries to the acromioclavicular (AC) joint are common, and there is general agreement regarding treatment for all injury types[1-3] except acute type III AC dislocation. In this article, we review the pertinent anatomy of the AC joint and its stabilizing structures; the epidemiology, mechanism of injury, physical examination findings, and radiographic workup of AC separations; the nonoperative and surgical treatment options, emphasizing their limitations and complications; and the rationale and technique for using autogenous free tendon graft to treat acute type III AC dislocations.

Acromioclavicular Joint Stability

Contact between the clavicle and the acromion provides the bony contribution to AC joint stability.[2,4-8] The AC joint is surrounded by a thin capsule that is reinforced by the superior, inferior, anterior, and posterior AC ligaments. The aponeurosis of the trapezius and the deltoid merge with the parallel fibers of the superior AC ligament, making it the strongest and most biomechanically important of the AC ligaments.[5,9] Urist[10] showed that AC ligaments are the primary restraint to anterior and posterior displacement, providing horizontal AC joint stability. Fukuda and colleagues[11] confirmed the importance of AC ligaments in providing horizontal stability with small (physiological, eg, daily activities) and large (pathologic, eg, injuries) loads, suggesting that AC ligaments provide a substantial amount of vertical AC joint stability at small loads.

The coracoclavicular (CC) ligament, a strong ligament that runs from the outer inferior surface of the clavicle to the base of the coracoid process of the scapula, has 2 components: the conoid and trapezoid ligaments. The conoid ligament attaches to the posteromedial side of the base of the coracoid process[5] and to the posterior undersurface of the clavicle at the junction of the middle and lateral thirds of the clavicle.[5] The trapezoid ligament arises from the base of the coracoid process, anterior and lateral to the attachment of the conoid ligament, and extends superiorly to the undersurface of the clavicle, where it inserts anteriorly and laterally to the conoid ligament along the trapezoid ridge on the clavicle.[5] Strength of the intact CC ligament ranges from 500±134 N to 725±231 N, and stiffness ranges from 103±30 N/mm to 116±36 N/mm.[12,13]

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Although the AC ligaments provide more constraint at small physiologic loads, at larger loads the CC ligament provides more vertical stability than the AC ligaments do.[11] Fukuda and colleagues[11] showed that the conoid ligament is primarily responsible for this vertical stability, that it also provides substantial anterior stability, and that the trapezoid ligament provides stability during axial compression. Debski and colleagues[9] showed biomechanically that the trapezoid and conoid ligaments act separately but synergistically in restraining superior-, anterior-, and posterior-directed loads to the AC joint.

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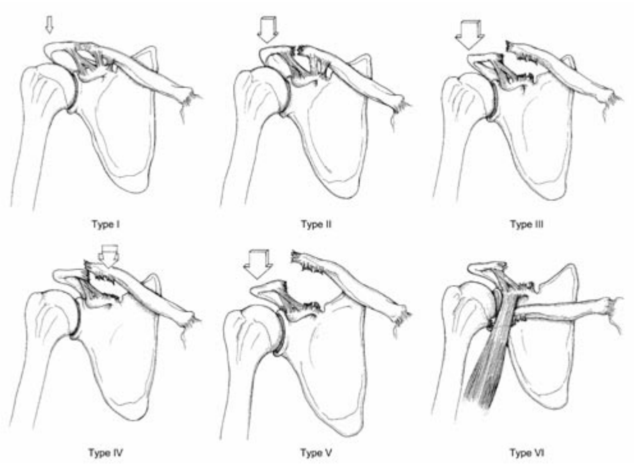

Figure 1. Classification of acromioclavicular joint injuries. Copyright 1997 American Academy of Orthopaedic Surgeons. Reprinted from the *Journal of the American Academy of Orthopaedic Surgeons,* Volume 5(1), pp 11-18 with permission.

Acromioclavicular Joint Separation

There are 6 types of AC joint separations (Figure 1).[1,3] Type III separations represent a complete dislocation of the AC joint, with disruption of the AC and CC ligaments and attenuation of the deltotrapezial attachment.[3]

The most common cause of injury is a direct force, produced by a fall onto the point of the shoulder with the arm adducted,[3,14-20] that drives the acromion downward and medially. The force magnitude determines the severity of the injury and the structures involved.

Patients with type III AC separations typically present with shoulder pain, local tenderness, and visual and palpable displacement of the AC joint.[14,21] The AC joint is best visualized with dedicated anteroposterior radiographs of the affected and contralateral AC joints and an axillary radiograph of the shoulder, which is useful for evaluating the position of the distal clavicle with respect to the acromion in the anteroposterior plane. A 15° cephalic-tilt radiograph (Zanca view) precludes the superimposed acromion obscuring the AC joint.[22] Stress or weighted radiographs are not recommended because of patient discomfort, ineffectiveness, added cost, and additional radiation exposure.[23] In type III injuries, the lateral end of the clavicle is displaced 100% above the superior border of the acromion, and the CC interspace is markedly larger than that on the contralateral side.

Treatment of Acute Type III Acromioclavicular Injuries

Most clinicians recommend nonoperative treatment for type I and type II injuries and operative treatment for types IV, V, and VI.[2,10,17,20,24,25] However, treatment for acute type III injuries is controversial. Recommendations have shifted from nonoperative treatment[10] (pre-1960s) to surgical treatment[18] (1970s) and back to nonoperative intervention.[26,27]

Nonoperative Intervention

Many authors have reported good results with nonoperative treatment.[15,24,28,29] As there seems to be little difference in functional results among nonoperative regimens, most authors currently recommend short-term use of a simple sling followed by early motion.[15,17,21,24,27,29,30]

Studies have found that nonoperative outcomes equaled or exceeded surgical outcomes and without the risk for surgical complications.[19,21,26,30-32] Some authors have reported that patients treated nonoperatively returned to sports and work sooner and regained motion faster.[26,30] Complete reduction is unnecessary for good results.[15,19,21] However, there is a 10% to 20% rate of unsatisfactory results with nonoperative treatment, primarily because of persistent pain, limited motion, and instability.[10,16,28] Devices used to maintain reduction (eg, harnesses, casts, braces) are associated with the risk for skin irritation and ulceration and the need for frequent reduction assessments and device adjustments.[19,28,33,34]

Surgical Intervention

Surgical treatment is absolutely indicated for open injuries and severe brachial plexus injuries. It is relatively indicated for heavy laborers, high-level overhead athletes, and patients with severe displacement (>2 cm).[14,17,19,25,26,30,35-38]

More than 100 surgical procedures for treating AC joint instability have been described in the literature—an indication that none is ideal.[2] The main surgical treatments are primary AC joint fixation, dynamic muscle transfer, CC stabilization, distal clavicle excision, and CC ligament reconstruction; free graft anatomical reconstruction is another choice.

Primary Acromioclavicular Joint Fixation. This procedure, involving Kirschner wires, Steinmann pins, screws, suture wires, or plates,[19,32,39] attempts to hold the acromion–clavicle–coracoid triad in a reduced position long enough to allow healing of the ruptured CC and AC ligaments. This technique often is used to supplement a CC and/or AC ligament repair or reconstruction.[6,8,32,38,40]

Primary AC joint fixation is complicated by loss of reduction (5%), persistent instability,[6,30,40] and superficial infections.[6,25,30,32,41] In addition, transarticular fixation devices can damage the AC joint's meniscus and articular cartilage, which may lead to early degenerative changes.[6,19,40,41] Pin fixation is complicated by risk for pin breakage and migration.[6,19,30,32,38,40-45] Pins have migrated into the spinal canal, eye, lung, neck, heart, great vessels, and abdomen, occasionally resulting in death.[2,30,42-46] To avoid such risks, most surgeons remove pins 4 to 16 weeks after surgery.[6,19,30,32,38,40-42,44]

Sim and colleagues[39] used a hook plate to try to immobilize the AC joint while avoiding injury to the articular surfaces and possibly avoiding early degenerative arthrosis. Although 94% of their patients had good to excellent results, the technical difficulty and complications of this technique limited its use. The complications included infection (38%), hardware failure (12%), extensive surgery for plate removal (100%), and subluxation/dislocation after plate removal (12%).

Dynamic Muscle Transfer. Dynamic muscle transfers involve transfer and screw/wire fixation of the coracoid process, with the origin of the short head of the biceps and with or without the coracobrachialis, to the clavicle.[14,35,47-49] This procedure is limited by its complexity and complications, including persistent pain, infection, intraoperative fracture of the coracoid tip, musculocutaneous nerve injury, nonunion, irritation from the screw head (necessitating screw removal), weakness, stiffness, persistent subluxation, and loss of fixation.[14,47,48,50] It fails to provide static joint stability and may allow motion and pain.

Coracoclavicular Stabilization. CC stabilization procedures (with screws or cerclage loops connecting the coracoid process to the distal clavicle) attempt to hold the clavicle–coracoid dyad in a reduced position long enough to allow healing of the ruptured CC and AC ligaments. In addition to being a primary treatment option for type III AC separations, CC stabilization procedures may be used as supplemental fixation for other reconstructive or repair techniques.[2,36,37,51-58]

In 1941, Bosworth[51] was the first to describe percutaneously placing a screw between the clavicle and the coracoid. Since then, this procedure has been modified many times.[2,16,57,58] Associated complications include risk for screw cutout and subsequent loss of reduction (up to 9%), degenerative AC joint arthrosis, irritation from screw head, screw breakage and subsequent migration, infection, erosion of distal clavicle, weakness, and shoulder stiffness.[10,19,21,26,31,32,41,51,57,58] Bosworth[51] suggested that the screw could remain in place indefinitely, but others have recommended removing the screw 2 to 4 months after surgery to prevent hardware fatigue, failure, and migration.[19,21,26,32,41,57,58]

Some authors have recommended using cerclage loops between the coracoid and the clavicle to obviate the need for screw removal.[36,37,52-57] Cerclage loops may be fascial, synthetic, or metallic loops passed around all or part of the clavicle.[36,37,52-56] These procedures are associated with numerous complications, including infection (particularly with nonabsorbable tape or sutures),[53,54,59] aseptic foreign body reactions (with Dacron cerclage loops),[60] and internal rotation and displacement of the clavicle anteriorly away from the acromion (with cerclage devices looped around, not through, the clavicle and coracoid).[56,61] This displacement can be avoided if the loop is placed near the base of the coracoid and inserted through a hole in the clavicle at the junction of the anterior and middle thirds of the clavicle, rather than over the top of the clavicle.[56,61] Furthermore, if the loop is passed over the top of, rather than through, the clavicle, over time it may erode through the clavicle.[36,52-54,56] Erosion and fracture through the coracoid process also may occur.[55] Some authors have recommended using absorbable suture to prevent clavicular fracture, but such use is associated with substantial risk for infection and recurrent early subluxation.[36] Others have suggested suture anchors instead of a cerclage loop to avoid risk for clavicular displacement or rotation; this procedure has not been studied in vivo.[61-63]

Other problems with CC cerclage devices involve their biomechanical properties. CC slings and suture anchors provide strength similar to that of an intact native CC ligament but with significantly more deformity,[12,13] and, though a CC sling provides adequate AC joint stability in response to a superior translational force, it may be inadequate for similar anterior and posterior forces.[64] These biomechanical shortcomings may be partially responsible for late degenerative changes and distal clavicle erosions.[8]

Distal Clavicle Excision. Excision of the distal 1.5 to 2 cm of the clavicle is not recommended as the sole treatment for acute type III AC separations because it exacerbates pain and weakness and fails to address underlying instability.[2,4,10,16,20,65,66] However, many have recommended this procedure as an adjunct to CC stabilization/reconstruction in an effort to avoid degenerative AC arthrosis.[2,7,20,27,32,37,56]

Coracoclavicular Ligament Reconstruction. AC fixation and CC stabilization procedures attempt to hold the clavicle–coracoid dyad in a reduced position long enough to allow healing of the ruptured CC ligament. These procedures are likely to fail eventually if the ligament does not heal or does not heal with its preinjury length and strength.[67] In contrast, CC ligament reconstruction techniques attempt to reconstruct biologically the injured CC ligament. Primary CC ligament reconstruction can be done with coracoacromial (CA) ligament transfers, biceps tendon transfers, or free autografts.[20,38,68-70] Reconstruction procedures often require supplemental fixation for the healing period. Therefore, CC ligament reconstructions often are combined with CC stabilization or AC fixation and are susceptible to the complications associated with those procedures. CC ligament reconstruction techniques also are combined with distal clavicle excision because of the higher rates of AC joint arthrosis with distal clavicle preservation.[7,20,27]

Weaver and Dunn[20] excision of the distal clavicle with a coracoid-based transfer of the CA ligament is a popular technique, but it has its drawbacks: a tendency to displace the clavicle anteriorly[61] and (often) recurrent deformity.[20,37] The CA ligament may be biomechanically insufficient in terms of strength and stiffness as a replacement for an injured CC ligament.[12,64,71] Deshmukh and colleagues[72] showed that anteroposterior laxity of the AC joint was significantly ($P<.01$) greater after a Weaver–Dunn reconstruction than in the native state, which may account for the high rate of loss of reduction after a CC reconstruction via a CA ligament transfer.[20,37] Therefore, many have recommended augmentation procedures to protect the transferred CA ligament.[2,17,37,72,73]

Additional Choice: Free Graft Anatomical Reconstruction

Three studies[38,67,74] paved the way for use of autogenous free tendon graft in an anatomical reconstruction of the injured AC and CC ligaments in the treatment of acute type

Figure 2. The topical anatomy is identified, and the planned incision is marked.

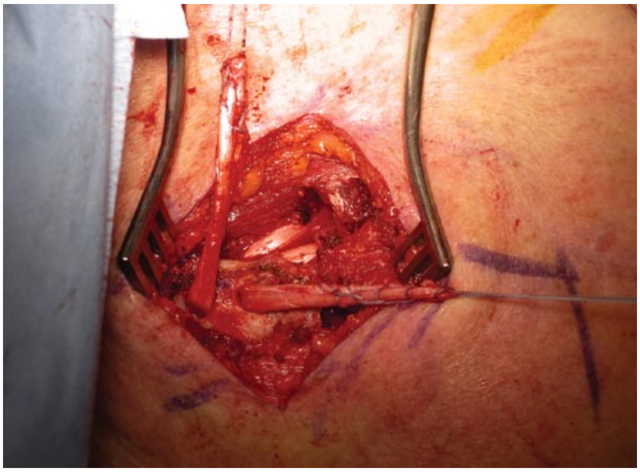

Figure 3. The graft has been advanced around the base of the coracoid and has been passed through both distal clavicle drill holes, recreating the coracoclavicular ligaments.

III AC dislocations. In 1976, Zaricznyj[38] reported using the extensor tendon of the fifth toe as a free tendon autograft. He reconstructed the AC and CC ligaments but did not reproduce the anatomical configuration of both limbs of the CC ligament; he augmented this repair with Kirschner wires across the AC joint. In 2001, Jones and colleagues[74] first described use of autogenous semitendinosus tendon as a free graft for reconstructing the CC ligament. They did not reconstruct the AC ligaments or attempt to restore the anatomical configuration of the trapezoid and conoid ligaments. They augmented their reconstruction with suture CC stabilization techniques. In 2003, Lee and colleagues[67] biomechanically compared the strength and stiffness of the native CC ligament with that of reconstructions with CA ligament or free tendon grafts (semitendinosus, gracilis, or long-toe extensor tendons). They reported that all tendon grafts had strengths equivalent to the native CC ligament strength, and all were significantly stronger ($P<.05$) than the CA ligament reconstruction.[67]

Some clinicians have attempted to recreate the anatomy, often stabilizing structures of the AC joint.[75] Debski and colleagues[9] showed that the trapezoid and conoid ligaments act separately to stabilize the AC joint and recommended that the conoid and trapezoid ligaments not be treated as a single structure during reconstruction.[9] Other studies have suggested that all AC joint soft tissues function synergistically to provide AC joint stability and should participate in the healing process for maximum stability.[9,11,76] These ideas form the rationale for anatomical reconstruction of the AC and CC ligaments.

Biomechanical studies have shown that, compared with other constructs, the semitendinosus tendon has clinically insignificant (<3 mm) permanent elongation after cyclic loading, and a stiffness that more closely approximates the stiffness of the intact CC ligament.[37,67,77] On the basis of the clinical and biomechanical success of this tendon in anatomical reconstructions,[67,74,77] Mazzocca and colleagues[75] used a semitendinosus autograft to reconstruct the anatomical configurations of the trapezoid and conoid ligaments, as well as the AC ligaments, without use of supplemental CC or AC stabilization.

Compared with the previously described techniques, autogenous free graft reconstruction has numerous advantages. First, the gracilis and semitendinosus tendons are easy to harvest[78] and biomechanically strong (favorable comparison with reported strength of intact CC ligament).[12,13,67,79] Second, the strength of these grafts obviates the need for augmentation with nonbiological devices. Such devices are the source of many complications (eg, foreign body tissue reaction, need for hardware removal) and lack the remodeling capacity of autologous grafts. Third, the strength of these grafts also lessens risk for premature failure, theoretically promoting earlier postoperative range of motion and rehabilitation, resulting in less shoulder stiffness, and facilitating earlier return to sports.[67] Fourth, the biological nature of these grafts allows healing and thereby increases the likelihood of long-term stability. Fifth, there are no reports of long-term functional morbidity from such graft harvest.[74] Sixth, these grafts are long enough to allow anatomical reconstruction that duplicates the origins and insertions of the trapezoid and conoid ligaments and that reinforces the ruptured AC ligaments.[76,79]

Historically, orthopedic surgeons have used nonanatomical reconstruction procedures in the treatment of other injuries. The Magnuson-Stack and Putti-Platt procedures for recurrent glenohumeral instability,[80-84] extra-articular iliotibial band tenodesis for anterior cruciate ligament deficiency, and Chrisman-Snook lateral ankle reconstruction for ankle instability are examples. Although these procedures provided good results initially, over time they "stretched out," with recurrence of instability symptoms, or "captured" the joint and led to posttraumatic arthritis.

As for the joints listed earlier, successful reconstruction of the AC joint would seem to require an anatomical approach.[75]

Technique. After anesthesia is administered, the patient is placed in a modified beach-chair position with the affected

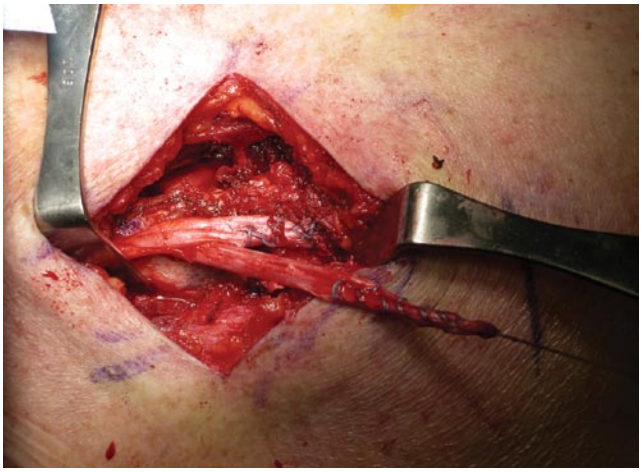

Figure 4. Once the graft has been passed through the clavicular drill holes, it is crossed and advanced laterally to the acromion for tensioning and attachment, recreating the acromioclavicular ligaments.

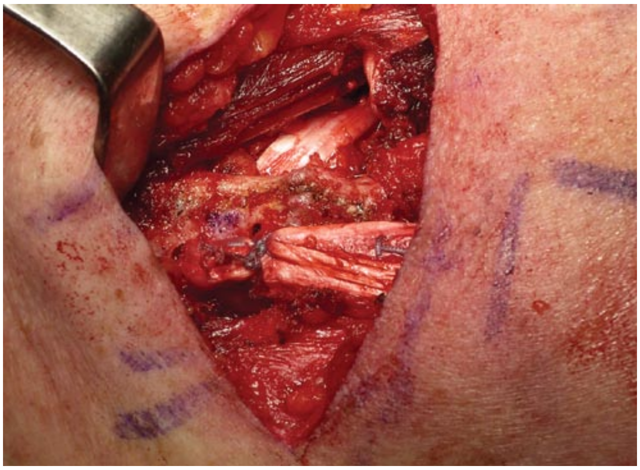

Figure 5. The anatomical reconstruction is complete.

and ipsilateral shoulders prepared and draped. The gracilis tendon is a simple, adequate graft with ample length and girth and minimal donor-site morbidity. After the gracilis tendon is harvested, a whip stitch is placed in each free end, and the donor site is closed.

The distal clavicle is exposed via a saber incision directly over the AC joint, from the posterior aspect of the AC joint to the coracoid (Figure 2). Once the deltotrapezial fascia is reached, medial and lateral flaps are developed. The deltotrapezial fascia is then divided, exposing the distal clavicle, for 2 cm, and care is taken to preserve a thick periosteal flap of the deltoid anteriorly and trapezius posteriorly. Then a 4- to 5-mm hole is drilled in the posterior half of the distal clavicle, 45 mm from the distal end of the clavicle, to accommodate the conoid limb of the graft. Another 4- to 5-mm hole is drilled centerline on the clavicle 15 mm lateral to the first hole to accommodate the trapezial limb of the graft. Then the distal 8 mm of the clavicle are excised with an oscillating saw.

The superior aspect of the coracoid neck is exposed, and the soft tissue is elevated. A curved suture passer is placed medial to lateral under the coracoid to retrieve the suture in the gracilis tendon graft and pull it around the coracoid. The free ends of the graft then are advanced through the clavicle drill holes (reconstructing the CC ligaments; Figure 3), crossed, and directed laterally to the medial aspect of the acromion (Figure 4).

Then the distal clavicle is held reduced, and the graft is tensioned and attached to the acromion, reconstructing the AC ligaments. The free graft ends can be attached laterally to the medial end of the acromion through the drill holes or with suture anchors. Any excess graft can be doubled back to the distal clavicle (Figure 5). Finally, the deltotrapezial fascia is repaired securely with interrupted nonabsorbable sutures. The soft tissue and skin are closed in a routine cosmetic fashion.

After surgery, patients begin to use a sling and a cryotherapy device and to perform Codman exercises. Sling use continues for approximately 6 weeks. Range-of-motion exercises begin at 4 weeks, and strengthening exercises begin at 6 weeks; rehabilitation progresses gradually thereafter. Full contact/collision sports are prohibited for 4 to 6 months. For throwing athletes, an interval throwing program may be started at 4 months. This relatively slow-paced rehabilitation protocol may be expedited after we gain more experience and comfort with this procedure and its rehabilitation.

Summary

Nonoperative treatment, still the best method for initial treatment, has good long-term results. Heavy laborers and elite overhead athletes represent a small group of patients who might do well with acute operative treatment. Anatomical reconstruction can permit nonoperative treatment. If the patient remains symptomatic, reconstruction can be recommended. Anatomical reconstruction can be used acutely or for chronic conditions because it does not depend on native CC ligament healing for ultimate stability. Reconstruction gives patient and surgeon more flexibility, because the decision to operate is based on symptoms, not injury acuteness or patient demands. It also does not require supplementation, with its attendant complications.

Authors' Disclosure Statement

The authors report no actual or potential conflict of interest in relation to this article.

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This paper will be judged for the Resident Writer's Award.