THE ANATOMIC CORACOCLAVICULAR LIGAMENT RECONSTRUCTION

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The surgical management of chronic or acute acromioclavicular joint dislocations can be divided into three broad groups. These are repair of the acromioclavicular and coracoclavicular ligaments, reconstruction of the acromioclavicular or coracoclavicular ligaments, and tendon transfer. Biomechanical analysis of the coracoclavicular and acromioclavicular ligaments has determined that the coracoclavicular ligaments play a major role with/without the acromioclavicular ligaments intact. Based on this biomechanical analysis, we have devised a novel technique to reconstruct anatomically the coracoclavicular ligaments. The anatomic position of the coracoclavicular ligaments is discussed as determined by osteological measurements as well as the technique.
KEY WORDS: shoulder, acromioclavicular joint, coracoclavicular ligament, clavicle, reconstruction

There are tremendous numbers of reconstructions and repair techniques involved in addressing dislocated or chronically unstable acromioclavicular joints. It is not the purpose or within the scope of this article to review these or comment on their efficacy. The purpose of this article is to describe some of the historical problems and present a novel technique.

The modified Weaver-Dunn procedure involves transfer of the coracoacromial ligament into the distal end of the clavicle after approximately a 10- to 12-mm resection has been accomplished. This is augmented with a suture, tape, or screw that keeps the acromioclavicular joint reduced while the ligament transfer heals. There have been numerous complications reported with this involving hardware migration and fracture, as well as infection and failure of fixation. Another criticism of this technique is that it is felt to place the clavicle in a nonanatomic position. It can also lead to dysfunction over time.

Finally, the acromioclavicular ligament at times may be insufficient and small, leaving an "unsatisfactory" feeling when reconstructing this joint, especially in an arm dominant professional. The increasing rate of failures in the nonanatomic position led us to examine the literature in an attempt to recreate the anatomy more effectively.

Fukuda and coworkers[1] stated, "If maximum strength of healing after an injury to the acromioclavicular joint is the goal, all ligaments should be allowed to participate in the healing process." This statement is the basis for our technique. Urist[2] determined that the acromioclavicular ligament was the primary restraint to anterior and posterior displacement, and the coracoclavicular ligament, specifically the conoid, resulted in an overall *superior displacement* or an inferior displacement of the entire scapulohumeral complex. Fukuda determined that the acromioclavicular ligament contributed about 50% of the total restraining torque for small amounts of posterior axial rotation by superior displacement (65%). The force contribution of the conoid ligament to resist superior displacement increased significantly to 60% of the total with further displacement.

Lee and coworkers[3] reported that the trapezoid and conoid ligaments play a major role in limiting excessive acromioclavicular joint displacements in both the superior and posterior directions, while the inferior acromioclavicular capsule ligament is the major restraint to anterior translation. They agreed with Fukuda's recommendation that the coracoclavicular as well as the acromioclavicular joint capsule ligaments should be considered for reconstruction.

Klimkiewicz and coworkers[4] confirmed and reported that the superior and posterior acromioclavicular capsule ligaments are the most important in preventing posterior translation of the clavicle to the scapula.

Finally Debski and coworkers,[5] advancing on past research, recommended that the conoid and trapezoid ligaments should not be considered as one structure when surgical treatment is considered and that capsular damage resulted in a shift of load to the coracoclavicular ligaments. They also reported that the intact coracoclavicular ligaments cannot compensate for the loss of capsular function during anterior–posterior loading, as occurs in type-II acromioclavicular joint injuries.

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Based on these five studies and anatomical and clinical observations, we set about to produce an operative procedure that would recreate both the conoid and trapezoid coracoclavicular ligaments and augment any remaining superior and posterior acromioclavicular ligaments.

The use of grafts for reconstruction of the acromioclavicular joint was first reported by Jones and coworkers.[6] In their study, an autogenous semitendinosus tendon graft was used to reconstruct the acromioclavicular joint. Lee et al[7] found that the semitendinosus graft stiffness was much closer than that of the acromioclavicular ligament transfer. They also found no statistical difference in load-to-failure among three tendon grafts tested (gracilis, toe extensors, and semitendinosus). They also found that stiffness after the suture and tape repairs was not significantly different from that after the tendon graft reconstruction. The clinical and biomechanical success of using semitendinosus auto- or allografts allowed us to modify these existing techniques and place them in an "anatomic" position. In the remaining sections of this paper, we describe the anatomic coracoclavicular ligament reconstruction.

SURGICAL PROCEDURE

APPROACH

In osteological analyses of 118 clavicles, the mean length from the end of the clavicle, or the acromioclavicular joint, to the coracoclavicular ligaments was 46.3 $\pm$ 5 mm; the distance between the trapezoid laterally and conoid medially was 21.4 $\pm$ 4.2 mm. Thus, we center our incision roughly 3.5 cm from the distal clavicle or acromioclavicular joint and make it curvilinear in the lines of Langer toward the coracoid process. Control of the superficial skin bleeders down to the fascia of the deltoid is accomplished with a needle-tip bovie. Once the entire clavicle is palpated, full-thickness flaps are made from the midline of the clavicle both posteriorly and anteriorly, skeletonizing the clavicle. This is done in the area of the coracoclavicular ligament, making those measurements important (Fig 1).

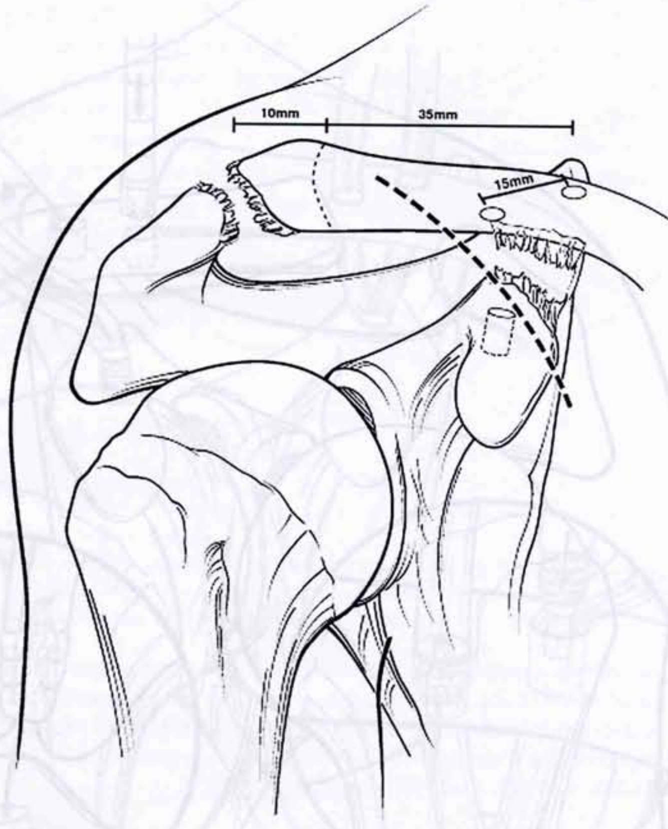

Fig 1. The distance from the lateral edge of the clavicle to the coracoclavicular ligament insertions and the width between them is drawn as well as the surgical incision site. Many surgeons commonly remove 8 to 10 mm of the distal clavicle when performing chronic acromioclavicular or coracoclavicular reconstructions.

GRAFT PREPARATION

Depending on surgeon preference, semitendinosus, anterior tibialis, allograft, or autograft can be used for this procedure. Lee and coworkers[7] found no difference in peak load-to-failure among semitendinosus, toe extensors, and gracilis tendons for reconstruction of the acromioclavicular joint. In this technique, there are two options for handling the fixation to the coracoid process. One option involves a bone tunnel interference screw type fixation, and the other option involves looping the ligament around the coracoid process.

For interference screw fixation to the coracoid process, the graft is folded in its middle and a No. 2 Fiberwire (Arthrex, Inc, Naples, FL) or a No. 2 nonabsorbable suture is placed through the doubled-over tendon graft in a Krakow type manner. One to two Krakow sutures are placed in the remaining two free ends of the graft. The graft is placed on the table in a moist sponge until the bone tunnels are prepared.

BONE TUNNEL PREPARATION IN THE CORACOID

The doubled-over portion of the graft is measured with the standard tendon-measuring device or on the handle of the Biotenodesis system (Arthrex, Inc) to determine graft size. A cannulated reamer of this size is chosen (6 or 7 mm). For fixation of the graft to the base of the coracoid process, finger palpation of both lateral and medial portions of the coracoid process and drilling into the base of it with direct visualization with a cannulated reamer guide pin is completed. A coracoid drilling guide (Arthrex, Inc) can also be used. This acts as a pipe-fitting device, fitting over the base of the coracoid process and angling the surgeon in the correct position. Once the guide pin has been inserted and confirmed by digital palpation not to be out of the coracoid process, the cannulated reamer of the specific graft size is brought in (generally 7-8 mm). This is reamed to a depth of 15 to 17 mm. Copious irrigation is used to remove any excess bone shavings from the reaming. The coracoid bone tunnel is now complete.

GRAFT FIXATION TO CORACOID PROCESS—INTERFERENCE FIT TECHNIQUE

The Biotenodesis driver is assembled and a 5.5 $\times$ 15 mm bioabsorbable Biotenodesis screw is placed on the end. A Nitonol wire is placed through the center cannulation of the screwdriver complex to shuttle the suture from the

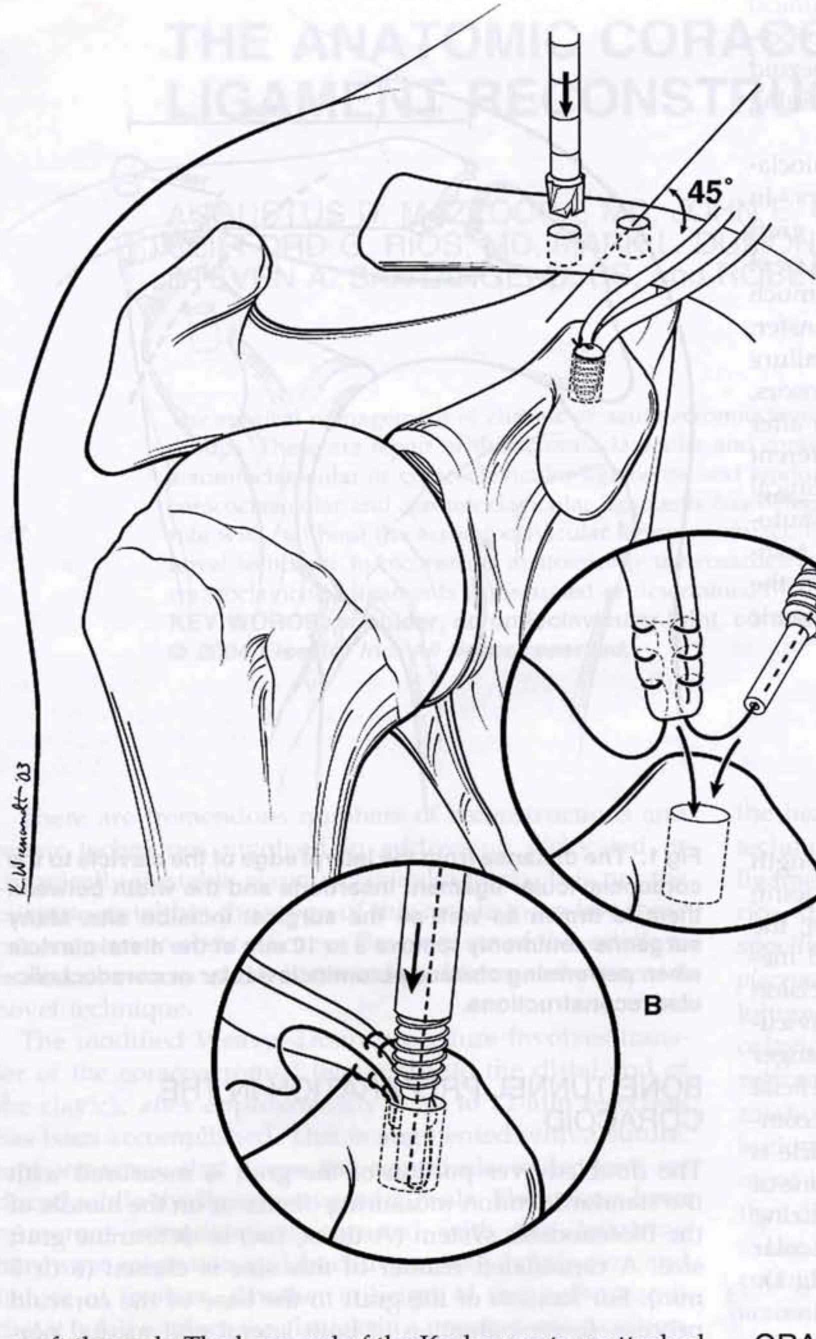

Fig 2. The bone tunnels are created with a cannulated reamer placed at a 45° angle. This allows for the appropriate orientation of the tunnels in the clavicle. The doubled-over semitendinosus graft is placed into the base of the coracoid process with a Biotenodesis screw (Arthrex Inc, Naples, FL). This allows for accurate placement and tension without drilling through the coracoid process. (A) This is a detail of the tenodesis driver being advanced up to the edge of the tendon. (B) A detail of the driver advancing the interference screw into the bone tunnel is shown.

graft through. The long end of the Krakow suture attached to the graft is placed through the cannulation portion of the Biotenodesis driver. The tenodesis driver is advanced to touch the graft tendon. This whole complex (tendon, driver, and screw complex) is placed into the previously reamed bone tunnel. The Krakow suture is usually measured to be about 15 mm in length running up and down the tendon graft. Disappearance from view of the Krakow sutures indicates that the entire length of the tendon is in the tunnel. A clamp is placed on the back portion of the teardrop handle of the driver to lock the suture in place. The screw is advanced over the driver–tendon complex, creating a secure interference screw fit (Fig 2). The clamp is released and the screwdriver complex is removed from the screw. Digital palpation confirms that the screw is flush with the bone tunnel, and by pulling on the two ends of the tendon it is confirmed that it is a secure fit. The sutures from the graft are tied together over the existing interference screw, giving both interference screw and suture anchor advantages.

GRAFT FIXATION TO CORACOID PROCESS—LOOP TECHNIQUE

To avoid placing a bone tunnel in the coracoid process, the graft can be looped around its base. Looping the graft around the base of the coracoid process can be facilitated by the use of a curved aortic cross-clamp (Stanitsky clamp) and a suture-passing device. At the same time that the graft is passed, a No. 5 Fiberwire (Arthrex, Inc) is also passed around the base of the coracoid. This will eventually become the nonbiologic fixation, reducing the clavicle to the scapula.

BONE TUNNELS IN THE CLAVICLE

It is important to make the bone tunnels in as accurate a position as possible to recreate the coracoclavicular ligament. The complex osteological measurements provided are to aid the surgeon in finding the insertions of the conoid and the trapezoid and not meant as absolute numbers. A cannulated reamer guide pin is used for placement

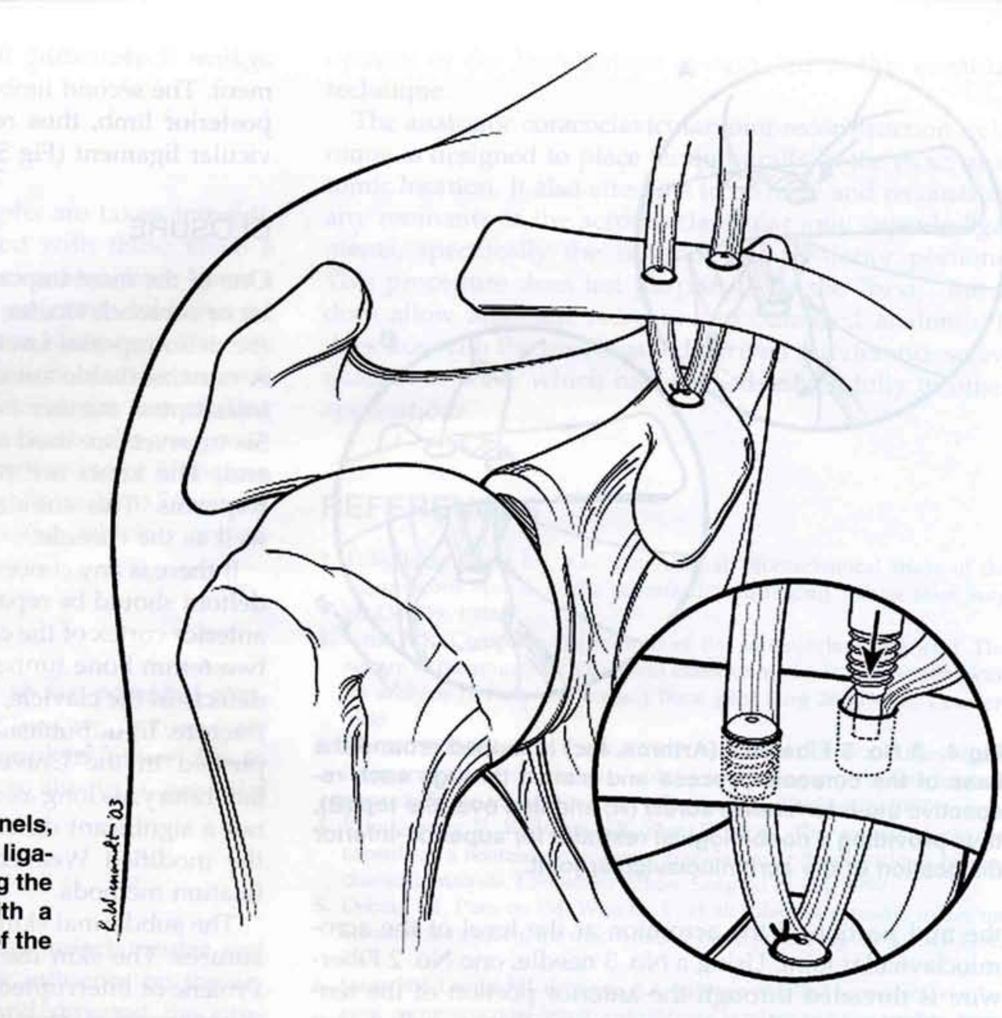

Fig 3. The orientation of the bone tunnels, one posterior recreating the conoid ligament and one in the midline recreating the trapezoid ligament, is illustrated with a screw and doubled graft in the base of the coracoid process.

of the tunnels. The first tunnel is for the conoid process, and that is roughly 45 mm away from the distal end of the clavicle in the posterior one half of the clavicle. The footprint of the conoid ligament is extremely posterior, along the entire posterior edge of the clavicle. That is why making this bone tunnel as posterior as possible is important. The guide pin is also angled approximately 45° from the direct perpendicular of the clavicle to recreate the oblique nature of the ligament. A 6- or 7-mm reamer is used to create the tunnel. Once the guide pin is inserted in the direction of the eventual bone tunnel, the reamer is placed over the guide pin and confirmation that the tunnel will be as posterior as possible without "blowing out" the posterior cortical structure of the clavicle is established. Once this is confirmed, a bone tunnel 15 to 16 mm long is created.

The same procedure is repeated for the trapezoid ligament. This is a more anterior structure than the conoid and is usually placed in the center point of the clavicle, approximately 15 mm away from the center portion of the previous tunnel. Two guide pins are used before reaming to confirm accurate placement of the tunnels. The tunnels are reamed completely through the entire width of the clavicle. Once again, copious irrigation follows to remove any bone fragments.

INTERFERENCE SCREW FIXATION OF GRAFT TO CLAVICLE

The two limbs of the biologic graft are taken and placed through the posterior bone tunnel, recreating the conoid ligament, and one from the more anterior and medial bone tunnel, recreating the trapezoid ligament. At the same time that the graft is brought through, each limb of the No. 5 Fiberwire should be brought through the respective bone tunnels as well.

Upper displacement of the scapulohumeral complex by the assistant reduces the acromioclavicular joint. A large point-of-reduction forceps placed on the coracoid process and the clavicle can assist while securing the tendon grafts. The acromioclavicular joint should be overreduced during initial fixation due to an inevitable amount of creep in the tendon graft. With complete upper displacement on the graft ensuring its tautness, a 5.5- to 15-mm bioabsorbable interference screw is placed in either the posterior or midline bone tunnels. The No. 5 Fiberwire is brought up through the cannulated process of this screw. After assessment that this is done successfully, the second screw is placed in the bone tunnel (Fig 3).

Once both grafts have been secured, the No. 5 Fiberwire is tied over the top, becoming a nonbiologic fixation for the overreduced acromioclavicular joint (Fig 4).

ACROMIOCLAVICULAR JOINT RECONSTRUCTION

The remaining portions of the tendon graft are laid longitudinally in the direction of the acromioclavicular joint. These grafts are sutured to each other at the area overlying the interference screws for further support. A double-loaded biocorkscrew anchor (Arthrex, Inc) is placed into

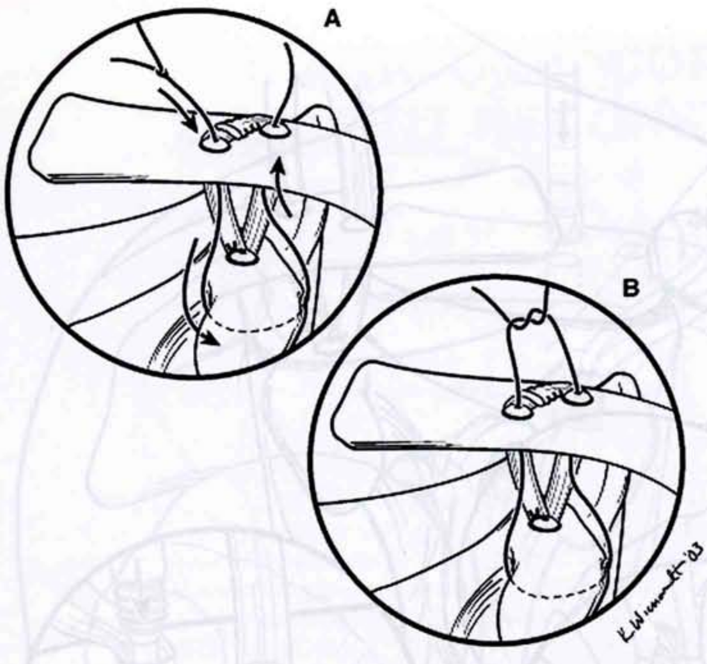

Fig 4. A No. 5 Fiberwire (Arthrex, Inc) is looped around the base of the coracoid process and placed through each respective bio-interference screw (A) and tied over the top (B), thus providing a nonbiological restraint for superior–inferior dislocation of the acromioclavicular joint.

the mid portion of the acromion at the level of the acromioclavicular joint. Using a No. 3 needle, one No. 2 Fiberwire is threaded through the anterior portion of the tendon graft in a Krakow type manner. This is pulled taut against it, recreating the superior acromioclavicular ligament. The second limb of the anchor is placed around the posterior limb, thus recreating the posterior acromioclavicular ligament (Fig 5).

CLOSURE

One of the most important concepts with acromioclavicular or coracoclavicular joint reconstruction is the closure of the deltotrapezial fascial flaps that were made previously. A nonabsorbable suture in a modified Mason-Allen type interrupted manner is placed through the deltoid fascia. Six or seven are used at this point and these are tied at the end. The knots are tied on the posterior aspect of the trapezius. This should completely obscure the grafts as well as the clavicle.

If there is any concern that this is not a secure repair, the deltoid should be repaired through small drill holes in the anterior cortex of the clavicle. Some worry exists, based on two 6-mm bone tunnels in the clavicle with further small defects in the clavicle, that this could lead to an iatrogenic fracture. In unpublished three-point bending data accomplished in the University of Connecticut biomechanics laboratory, as long as screws were in these holes there was not a significant difference in the load-to-failure between the modified Weaver-Dunn and the interference screw fixation methods.

The subdermal skin is closed with 2-0 or 3-0 absorbable sutures. The skin itself is closed with either running 2-0 Prolene or interrupted nylon everting the edge of the skin. A compression dressing is placed and the patient is placed

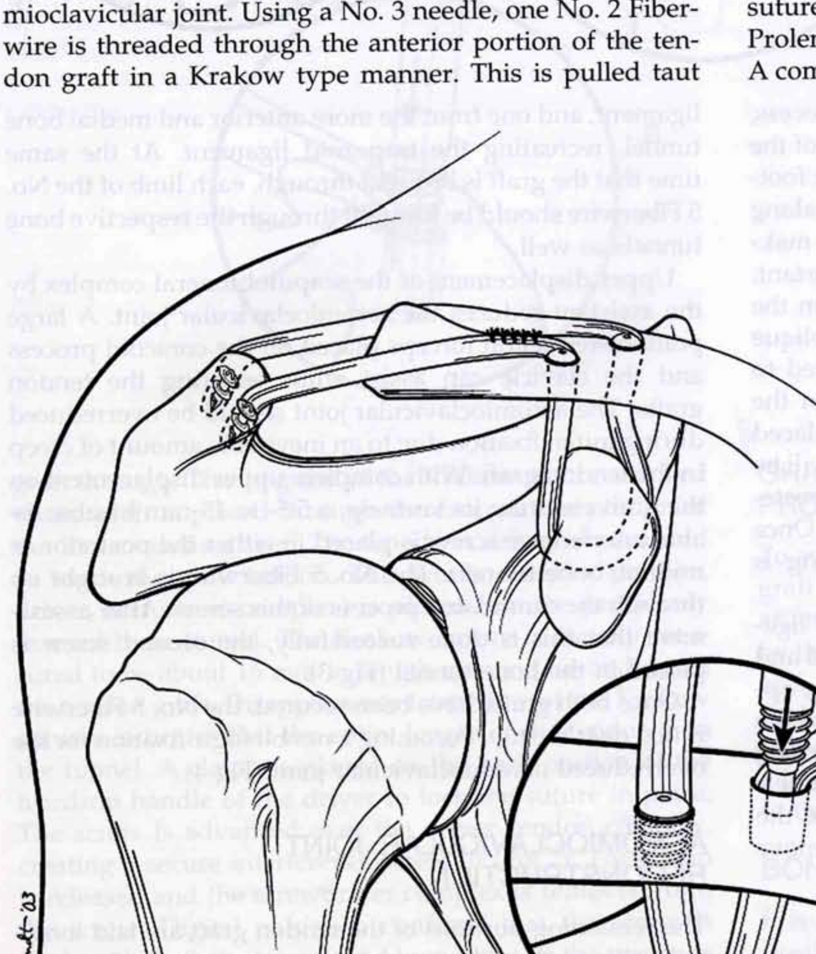

Fig 5. Recreating the superior and posterior portions of the acromioclavicular joint. The two limbs of the graft are sutured to each other medially and secured laterally with a suture anchor.

in a supportive sling with external rotation to 0° and an upward force on the arm.

POSTOPERATIVE COURSE

Zanca as well as axillary radiographs are taken immediately postoperatively and compared with those taken 6 weeks postoperatively. Pendulum exercises three times a day are started immediately. The patient is told that he will be in a sling for 6 weeks and can come out of it only during supervised therapy, which involves active assisted range of motion in all planes. However, the use of sling support is critical. From 6 to 12 weeks, the sling is generally discontinued; however, no strengthening or lifting can be done as the graft is still maturing. From 12 to 24 weeks, isometric exercises are begun. Contact athletics are allowed 6 months postoperatively.

COMPLICATIONS

Although none have been reported so far, potential complications involve infection, clavicle fracture, or osteolysis of the distal clavicle. Of course, complete failure due to nonhealing of the ligament grafts is always a potential consequence.

CONCLUSIONS

The biomechanical analyses of the acromioclavicular and coracoclavicular ligaments and their influence on the acromioclavicular joint have aided and directed the proposed operative technique.[1-5] The use of autogenous semitendinosus graft for reconstruction of the acromioclavicular joint has been reported by Jones and coworkers[6] and Lee and coworkers.[7] These studies, along with the development of the Biotenodesis system, led to this eventual technique.

The anatomic coracoclavicular joint reconstruction technique is designed to place tendon grafts in the exact anatomic location. It also attempts to provide and reconstruct any remnants of the acromioclavicular joint capsule ligaments, specifically the superior and posterior portions. This procedure does not purport to be the "best," but it does allow anatomic recreation of damaged anatomy. It does this with the previously described interference screw fixation to bone, which has worked successfully in other applications.

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