Technical Note

Distal Clavicular Augmentation with Acromioclavicular and Coracoclavicular Ligament Reconstruction in the Setting of Iatrogenic Induced Acromioclavicular Instability

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Abstract: Although chronic pain and dysfunction of the acromioclavicular (AC) joint can reliably be treated with distal clavicle excision, disruption of the local stabilizing ligamentous structures may result in iatrogenic instability of the joint. Iatrogenic AC joint instability is a rare condition caused by over resection of the distal clavicle with unintended injury to the stabilizing ligaments in the treatment of AC joint pain. Addressing postresection instability can prove to be difficult because most reconstruction techniques are intended for patients with traumatic AC joint instability with the goal of creating an anatomically stable joint. However, in the setting of iatrogenic instability, the decreased bone stock of the distal clavicle results in instability of the AC joint, especially in the horizontal plane, and may cause these techniques to fail. Thus, operative management must aim to correct both the osseous and ligamentous deficits responsible for the genesis of this instability. In this Technical Note, we describe bony augmentation of the distal clavicle with an iliac crest bone autograft for chronic iatrogenic acromioclavicular joint instability with concomitant reconstruction of the AC and coracoclavicular ligaments.

The acromioclavicular (AC) joint is a common location of pathology including instability, fracture, osteolysis, and osteoarthritis. Persistent pain and dysfunction at the AC joint are often treated with distal clavicle excision. This has been shown to be a reliable way to improve pain symptoms with low morbidity.[1-5] However, disruption of the surrounding ligaments, mainly the AC and coracoclavicular (CC) ligaments can lead to instability.

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Three main ligaments stabilize the AC joint. The AC ligament comprises superior, inferior, anterior, and posterior components that contribute to overall stability. Specifically, the superior and posterior ligaments are the strongest, and these primarily serves to provide stability in the horizontal plane. Nakazawa et al.[6] demonstrated in a 2016 study that the AC ligament could be further divided into a bundle at the superoposterior (SP) part and a bundle at the anteroinferior part of the joint. They found the SP bundle to be thicker and wider relative to the anteroinferior bundle, with the SP bundle spanning obliquely at an average $30° \pm 6°$ in relation to the AC joint surface, from the anterior part of the acromion to the posterior part of the distal clavicle.[6] The CC ligament complex consists of the conoid and trapezoid ligaments, which insert on the posteromedial and anterolateral region of the undersurface of the distal clavicle, respectively.[7] This ligamentous complex mainly serves to provide vertical stability within the AC joint. Finally, the coracoacromial ligament is a robust triangular band, connecting the coracoid process to the acromion and also contributing to vertical stability of the AC joint.[6,8,9] A quantitative anatomical study by Chahla et al.[10] demonstrated that

the coracoacromial ligament has a single consistent acromial attachment and then bifurcates into 2 distinct bundles, anterior and posterior, that separately insert on the lateral aspect of the coracoid. On average, the anterior and posterior bundles attach 10.6 mm and 24.8 mm medial and proximal to the apex of the coracoid process, respectively.[10] For the reconstruction of the AC and CC ligaments, a recent systematic review by Moatshe et al.[11] reported hook plates and K-wires having the highest rate of complications (26.3%) versus suspensory devices and synthetic ligament techniques, which had the lowest complication rates (6.2% and 4.4%, respectively). Moreover, reconstructions performed with a modified Weaver-Dunn technique were found to have the highest rates of unplanned reoperation at 5.4%.[11]

Excessive resection of the lateral end of the distal clavicle has been found to disrupt native AC articulation and creates the potential for abnormal motion and instability of the AC joint, ultimately resulting in persistent pain of the operative shoulder.[12-14] A study by Blazar et al.[12] demonstrated a significant increase in anteroposterior translation of the AC joint following either open or arthroscopic distal clavicle excision compared with the contralateral, nonoperative shoulder. Moreover, there was a strong correlation between the total anteroposterior translation and postoperative visual analog pain scores.[12] An anatomic study of the AC joint by Renfree et al.[14] reported on the amount of distal clavicle that may be arthroscopically resected without compromising the ligamentous restraints of the joint, determining that as little as 2.6 mm of the distal clavicle in males and 2.3 mm in females may violate the superior AC ligament and thus contribute to postoperative instability. Further studies[15,16] have demonstrated that AC joint stability decreases with increasing excisions and thus the current guidance recommends 5 mm of bony resection to adequately maintain maximal stability and reliably good patient outcomes.

Although not a frequent entity, instability of the distal clavicle may occur in the setting of postresection. The result of this is the patient presents with horizontal instability, pain, scapular disfunction, dyskinesia of the scapula, and chronic pain. This may be further complicated by "over-resection" of the distal clavicle. Treatment of postresection instability can be difficult with most reconstruction techniques intended for patients with traumatic AC joint instability with the goal of creating an anatomically stable joint. In the setting of iatrogenic instability, the decreased bone stock of the distal clavicle may cause these techniques to fail. The reconstruction technique should address both the bone and ligamentous pathology to provide appropriate stability to the joint. In this Technical Note, we describe reconstruction of the AC and CC ligaments with a semitendinosus allograft and bony augmentation of the distal clavicle with an iliac crest bone autograft for chronic iatrogenic acromioclavicular joint instability (Video 1). This investigation was performed at the Steadman Philippon Research Institute.

Surgical Technique

Preoperative Planning and Assessment

Careful attention should be paid to a patient seen in the clinical setting with chief complaint of AC joint instability after a distal clavicle resection (Mumford procedure). A thorough evaluation of the patient's shoulder to include areas of tenderness, range of motion, neurovascular status, and strength tests should be performed. More specifically, patient's reported symptoms of instability along with any anteroposterior (AP) and/or superior-to-inferior translation of the distal clavicle with manipulation on physical and exam should be noted. Standard shoulder radiographs, AP/Grashey/scapular Y/axillary lateral views, along with clavicle AP and Zanca views can help with the diagnosis and appreciation of the position of clavicle with respect to the acromion (Fig 1 A and B). An AP view of bilateral clavicles allows comparisons of the two sides to determine the amount of prior resection and superior migration. Computed tomography (CT) scans can also be helpful to understand the amount of prior resection to plan the appropriate size and shape of iliac crest autograft to be harvested (Fig 1C).

Patients with persistent symptoms at the AC joint following distal clavicle resection and appropriate conservative measures may be considered for this technique of AC and CC reconstruction with semitendinosus tendon allograft and distal clavicle augmentation with iliac crest autograft.

Patient Positioning and Anesthesia

Regional blocks at our local institution include an interscalene indwelling nerve catheter placed as well as a single-shot Pecs2 block. General anesthesia is provided for all patients and all are transitioned to the beach chair position, paying careful attention to pad all bony prominences and neurovascular structures at risk of compression. The patient is placed in approximately 45° of inclination to allow access to the ipsilateral iliac crest; this may be modified based on the habitus of the individual patient because larger patients may need to be first placed completely supine for the iliac crest harvest for adequate exposure and then repositioned to the beach chair position for the remainder of the procedure. The operative extremity and ipsilateral iliac crest are prepped and draped in standard orthopaedic fashion. A Madded mayo band is used throughout the case to provide support to the operative arm. Repeat examination under anesthesia is performed verifying increased AP distal clavicle translation.

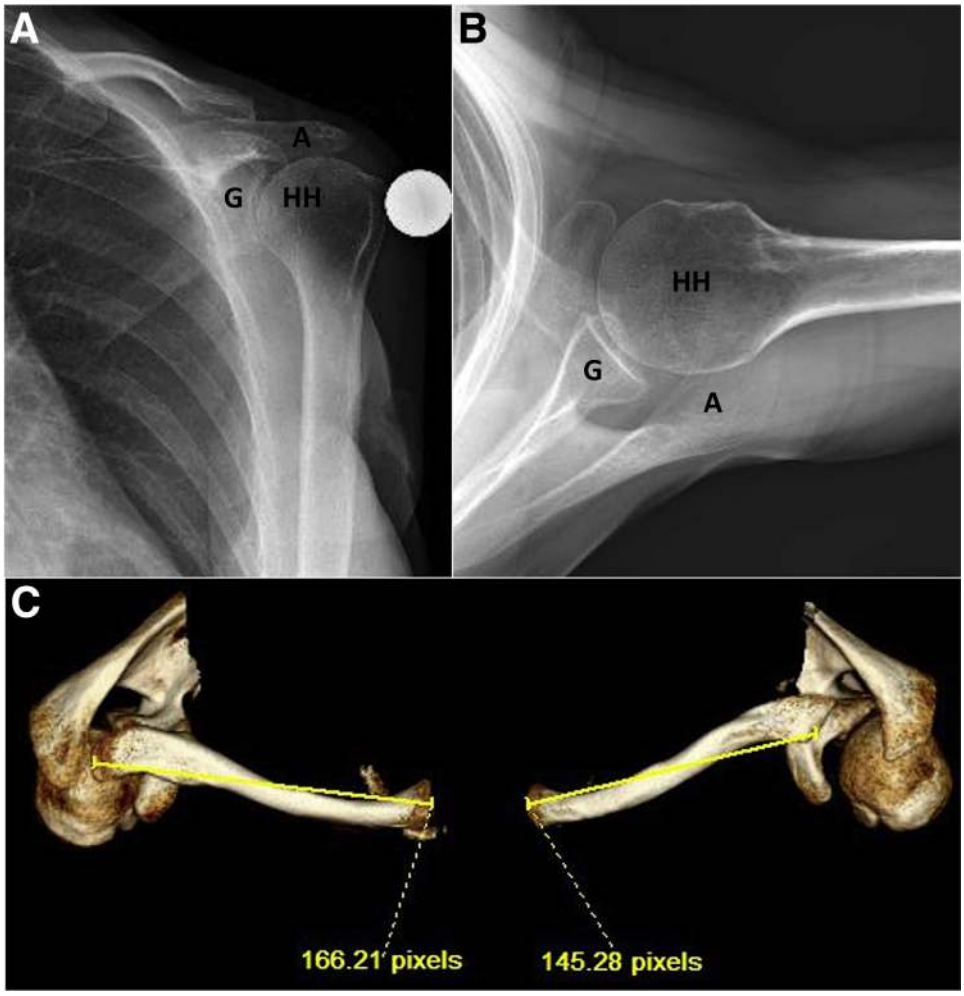

Fig 1. Preoperative standard shoulder radiographs in the (A) anteroposterior and (B) axillary lateral views can help with the diagnosis and appreciation of the position of clavicle with respect to the acromion, which can be further supplemented with (C) 3-dimensional computed tomography scans, which may be helpful in determining the amount of prior resection to plan the appropriate size and shape of iliac crest autograft to be harvested. (A, acromion; G, glenoid; HH, humeral head.)

Iliac Crest Bone Graft Harvest

With the patient in a semireclined position, a linear 4- to 5-cm incision is made 2 cm posterior to the anterior superior iliac spine. Bipolar is used to maintain hemostasis and perform a subperiosteal dissection along the crest in both a medial and lateral direction to clearly delineate the inner and outer tables of the iliac wing. Based off of preoperative planning, a tricortical graft is harvested with the use of an oscillating saw and completed with a one-quarter-inch osteotome. In the case presented, a 3 cm × 2 cm tricortical structural iliac crest graft was harvested. The graft is removed en bloc and remeasured to ensure the appropriate size graft has been harvest. The graft is then placed in a basin for security and situated on the back table for later contouring. The surgical site itself is thoroughly irrigated followed by the application of bone wax to the bleeding edges of bone to prevent hematoma formation. A block of mixed allograft bone chips with bone putty (AlloSource; Centennial, CO) is placed into the donor site. The fascia of the external obliques is primarily closed in a side-to-side fashion with the tensor fascia laterally with an No. 0-Vicryl suture in figure-of-8 fashion. The closure is completed in the usual layered fashion, the incision is dressed, and attention is then turned to the shoulder.

Coracoclavicular Ligament Exposure and Preparation

After performing a diagnostic arthroscopy and addressing any additional pathology, the coracoid is exposed through a 5-cm incision in-line with the clavicle over the edge of the acromion. The dissection is continued sharply through the deltotrapezial fascia and the remaining AC joint capsule. Subperiosteal dissection is carried out anterior and posterior to expose the residual distal clavicle deficit (in this case, 25 mm). The tip of the coracoid is palpated and blunt dissection with Mayo scissors allows access to the medial and lateral aspects of the coracoid. A spot is marked with Bovie cautery 22 or 25 mm from the tip in females and males, respectively, to identify the margin of the native trapezoid ligament.[10] A 3-mm guide pin is drilled just posterior to this mark, and

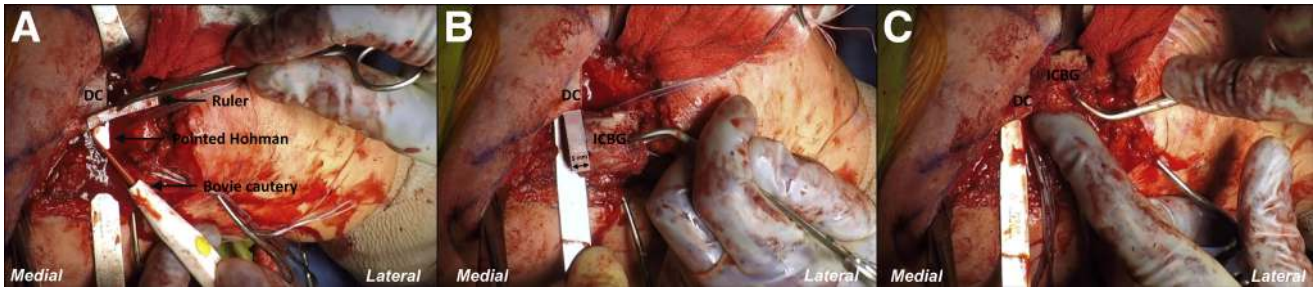

Fig 2. Left shoulder, reclined beach chair position. The length, width, and size of both the defect and step-cut is measured allowing the complementary step-cut to be created on the on both the inferior aspect of the distal clavicle and the superior aspect of the iliac crest bone graft. (DC, distal clavicle; ICBG, iliac crest bone graft.)

centered in the coronal plane, in a bicortical fashion allowing passage of a shuttling suture. A second passing suture is then passed from lateral to medial around the base of the coracoid with the use of a curved shuttling device.

Distal Clavicle Preparation

Attention is then turned to the distal clavicle defect. A new lateral border of the clavicle is cut with an oscillating saw ensuring the cut is perpendicular to the axis of the clavicle while preserving as much bone as possible. On the inferior surface of the clavicle, a 5-mm step cut is created that will be the recipient site for the iliac crest autograft. The length, width, and size of both the defect and step-cut is measured allowing the complementary step-cut to be created on the superior aspect of the iliac crest graft (Fig 2). A 4-hole lateral clavicle cluster plate (Synthes; West Chester, PA) is then placed on the superior aspect of the clavicle and preliminarily fixed with the use of a bone clamp. The graft can be easily shuttled in and out of the defect beneath the plate to allow for small medial-lateral adjustments for plate location. When the plate is in the ideal location, the graft is removed, and the plate is fixed medially through the oblong drill hole with a single 3.5-mm bicortical screw. The graft is then placed below the lateral cluster plate and clamped ensuring excellent fit and compression between the step-cuts of both the native clavicle and the graft itself. When the graft is in the ideal location, it is fixed laterally beginning with lateral compression screws followed by the use of locking screws. The remainder of the medial screw holes are then filled in compression mode to maximize compression of the graft to the native clavicle while leaving a single screw hole open just superior to the coracoid to allow the passing of a TightRope (Arthrex; Naples, FL). Intraoperative fluoroscopy is used to confirm appropriate plate placement, screw length, and reduction. Next, a 3-mm guide pin is drilled through the open hole of the plate and clavicle just superior to the central aspect of the coracoid. With the use of the previously placed shuttle suture through the

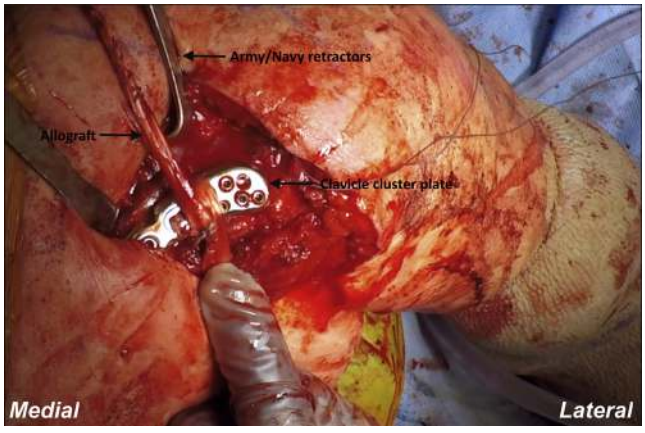

Fig 3. Left shoulder, reclined beach chair position. The lateral limb of the semitendinosus allograft passing posterior to the clavicle and the medial limb passing anteriorly are then crossed on top of the clavicle and tensioned with reduction of the acromioclavicular joint. The limbs are sewn together with high-strength SutureTape in figure-of-8 fashion (Arthrex).

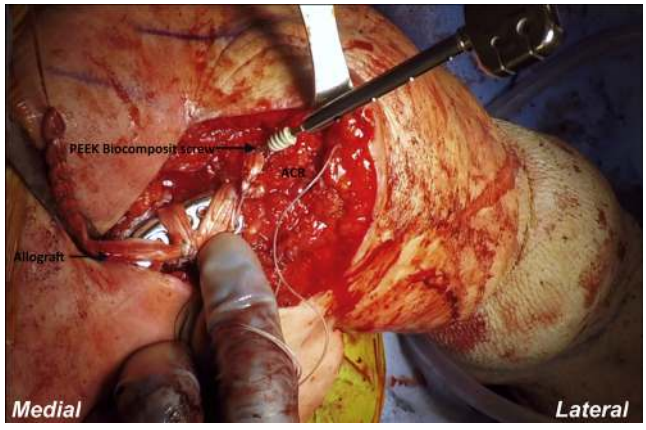

Fig 4. Left shoulder, reclined beach chair position. The lateral, posteriorly directed graft limb is shuttled through the reamed hole in the acromion in an inferior-to-superior manner. With tension on the graft, a 4-mm PEEK Biocomposite interference screw (Arthrex) is then placed to provide final fixation into the acromion with the graft preventing anteroposterior translation. (ACR, acromion.)

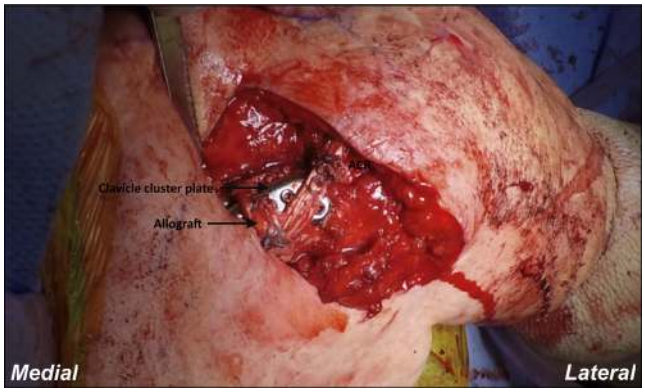

Fig 5. Left shoulder, reclined beach chair position. The remaining length of the semitendinosus allograft can be sewn back on to itself with SutureTape (Arthrex) to provide backup fixation of the final construct. (ACR, acromion.)

coracoid, the TightRope construct is passed through the base of the coracoid and then cinched down with a DogBone (Arthrex) abutting the base of the coracoid and button sitting in the plate to preliminarily reduce the clavicle.

AC Joint and CC Ligaments Reconstruction

The semitendinosus allograft (shaped to a 4.5-mm diameter and whip stitched on both ends with a high strength No. 2 suture) is then shuttled beneath the coracoid with the use of the previously placed shuttling suture. The lateral limb of the graft is then passed posterior to the clavicle with the aid of a hemostat. A guide pin is then drilled approximately 1 cm lateral to the newly constructed AC joint on the acromion and then over drilled with a 4.5-mm reamer. A Nitinol wire with shuttling loop is passed from superior-to-inferior through the aforementioned reamed hole of the acromion facilitating the passage of a shuttling suture. The TightRope construct (Arthrex) is retensioned with reduction of the AC joint with an inferior-based pressure on the distal clavicle. The lateral limb of the semitendinosus allograft passing posterior to the clavicle and the medial limb passing anteriorly are then crossed on top of the clavicle and tensioned with reduction of the AC joint (Fig 3). The limbs are sewn together with high-strength SutureTape in figure-of-8 fashion (Arthrex). The lateral, posteriorly directed limb is then shuttled through the reamed hole in the acromion in an inferior-to-superior manner. With tension on the graft, a 4-mm PEEK Biocomposite interference screw (Arthrex) is then placed to provide final fixation into the acromion with the graft preventing AP translation (Fig 4). If enough graft length remains, it can be sewn back on to itself with SutureTape (Arthrex) to provide backup fixation (Fig 5). The surgical site is thoroughly irrigated, and a layered closure is performed in standard fashion. Clavicle plate location and fixation may be confirmed with postoperative radiographs (Fig 6). Advantages and disadvantages, as well as pearls and pitfalls of the complete surgical technique are summarized in Tables 1 and 2, respectively.

Postoperative Rehabilitation Protocol

The patient is instructed to remain in a padded abduction sling for 6 weeks. Full passive range of motion can begin from weeks 6 through 9 after surgery followed by the initiation of active and active assist between weeks 9 and 12. Strengthening is permitted 3 months after surgery. Serial radiographs to evaluate hardware integrity and graft integration occur at weeks 2, 6, and 12 after surgery followed by a CT scan at week 16 to determine if the bone graft has healed before allowing return to full activity.

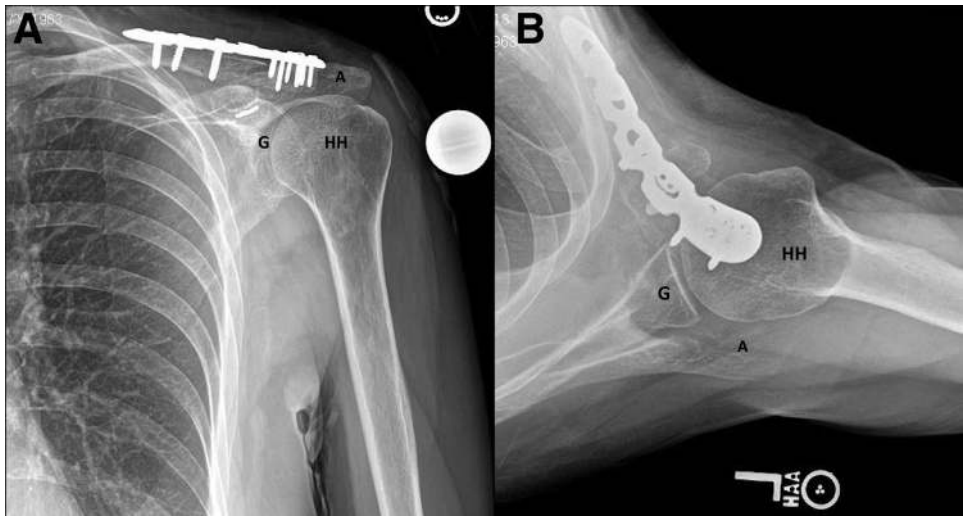

Fig 6. Left shoulder, reclined beach chair position. Clavicle plate location and fixation may be confirmed with postoperative radiographs in both the anteroposterior and axillary lateral views. (A, acromion; G, glenoid; HH, humeral head.)

Table 1. Advantages and Disadvantages

Advantages	Disadvantages
Iliac crest autograft is easily obtained and contours well to the distal clavicle	Morbidity and pain associated with iliac crest autograft must be accounted for
Acromioclavicular and coracoclavicular ligamentous reconstruction restores vertical and sagittal plane stability	Injury to neurovascular structures may occur if the drill plunges deep to the clavicle or coracoid
Decreasing acromioclavicular joint space with iliac crest bone graft reduces strain on soft-tissue reconstruction	Damage to the rotator cuff muscles or humeral head articular surface may occur if acromion tunnel is drilled too deep

Discussion

This Technical Note describes the reconstruction of the AC and CC ligament with a semitendinosus allograft and bony augmentation of the distal clavicle with an iliac crest bone autograft for chronic acromioclavicular anterior to posterior instability. The goal of the procedure is to provide stability that has been lost with over-resection of the distal clavicle. The loss of the AC and possibly the CC ligaments are reconstructed with the use of allograft to provide stability. Moreover, decreasing the AC joint space with structural bone graft reduces the strain on this soft-tissue reconstruction. This technique also places the tendon allograft in more of an AP direction at the AC joint to best stabilize this plane of motion.

Iatrogenic AC joint instability is a rare condition caused by over-resection of the distal clavicle with unintended injury to the stabilizing ligamentous structures in the treatment of AC joint pain. When instability, pain, and/or dysfunction remains despite appropriate nonoperative measures, surgical reconstruction should be considered. Previously described techniques focus on stabilization in the setting traumatic injury to the AC joint.[17,18] In a recent systematic review, Moatshe et al.[11] reported that use of hook plates and K-wires in AC reconstruction resulted in highest rates of complications, whereas the modified Weaver-Dunn procedure had the highest unplanned reoperation rates. Other techniques using soft-tissue grafts have resulted in good patient outcomes and low complication rates,[19] but these techniques do not account for significant distal clavicle bone loss.

With the AC ligaments acting as the primary restraint to AP translation and the CC ligaments providing primary restraint to superoinferior translation, both ligamentous complexes need to be considered when addressing instability. Distal clavicle excisions can easily disrupt the AC ligaments with more aggressive resections injuring the trapezoid ligament. Although the CC ligaments may not always be involved, the course of the allograft allows for additional AP restraint as the graft runs anterior and posterior to the clavicle.

In this Technical Note, we describe a novel surgical technique for reconstruction of the AC and CC ligaments with a semitendinosus allograft and bony augmentation of the distal clavicle with an iliac crest bone autograft. From our practice, this technique reliably addresses the issues of chronic AC instability after prior distal clavicle resection. Although no outcome studies have been completed for this procedure, it is believed to improve patient functionality and satisfaction in this patient population while reducing the risk of failure of other techniques.

Conclusion

Over-resection of the distal clavicle after a Mumford procedure can lead to persistent pain and morbidity drastically affecting patient's activities of daily living. To date, few surgical options have been available to address this iatrogenic pathology. This technique with the use of iliac crest autograft allows for both osseous and soft-tissue reconstruction to correct both vertical and sagittal plane instability.

Table 2. Pearls and Pitfalls

Pearls	Pitfalls
Obtaining preoperative computed tomography scan can aid in the understanding of distal clavicle insufficiency	Underappreciation of anteroposterior translation after distal clavicle excision can lead to delayed and misdiagnosis
Position the patient in 45° of inclination for access to both the hip and shoulder	Utilization of locking screws only in the lateral cluster plate will prevent compression of the graft to the native clavicle
Performing a matching step-cut on both the native clavicle and the iliac crest craft can allow for symmetric apposition	Ensure the location of the acromial based reamed hole is 1cm lateral to the AC joint to prevent iatrogenic fracture
Tensioning and then fixing of the semitendinosus allograft to allow for an oblique orientation of the graft for the AC reconstruction allows for greatest anterior to posterior motion reduction	

AC, acromioclavicular.

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