



Open Anatomic Coracoclavicular Ligament Reconstruction by Modified Conjoint Tendon Transfer for Treatment of Acute High-Grade Acromioclavicular Dislocation

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Abstract: There is no ideal surgical technique for the treatment of acromioclavicular (AC) dislocations. Reconstruction of the coracoclavicular ligaments (CCLs) for the treatment of AC dislocations is evolving. Many techniques for CCL reconstruction have been described. They differ mainly in the method of fixation, number of tunnels, and graft used. The surgeon should select among hamstring autograft reconstruction, coracoacromial ligament transfer, and conjoint tendon transfer for CCL reconstruction. Early on, conjoint tendon transfer to the lateral clavicle was described for the treatment of high-grade AC dislocation. Dynamic instability occurred with poor long-term outcomes. The procedure was abandoned. Recently, proximally based conjoint tendon transfer for CCL reconstruction was described, but the technique is nonanatomic and leads to anterior displacement of the clavicle and malreduction. This article describes modified conjoint tendon transfer. The technique may yield stable, anatomic, biological reconstruction of the CCL for the treatment of acute high-grade AC dislocation. It consists of the following steps: (1) creation of clavicular holes, (2) coracoid osteotomy, (3) conjoint tendon mobilization, (4) conjoint tendon transfer and fixation to the CCL footprint on the undersurface of the clavicle, and (5) AC reduction and conjoint tendon tenodesis to the bed of the retained coracoid process.

An enormous number of surgical techniques for the treatment of acromioclavicular (AC) dislocations have been described in the literature, but no technique is ideal.¹⁻³ Many factors affect the results of the different techniques, such as the onset of interference, the approach and method of treatment, and the type of reconstruction.

Techniques for coracoclavicular ligament (CCL) reconstruction had evolved over the past several decades. The ideal technique should involve anatomic,

biological, double-bundle reconstruction; provide stable reduction; use a simple method of fixation; and carry the fewest complications, especially AC subluxation or redislocation, as well as clavicular or coracoid fractures.

Early on, conjoint tendon transfer to the lateral clavicle was described by Dewar and Barrington⁴ (1965) for the treatment of high-grade AC dislocations, creating dynamic stabilization of the lateral clavicle. However, the procedure was abandoned because of the poor long-term outcomes.⁵

Sloan et al.⁶ (2004) found that although the ultimate tensile strength of the lateral 12 mm of the conjoint tendon is less than that of the intact CCL, it is more than that of the coracoacromial ligament (CAL), and they believe that the lateral half of the conjoint tendon is a viable alternative autograft source for CCL reconstruction. More recently, Jiang et al.⁷ (2007) described proximally based conjoint tendon transfer for CCL reconstruction. However, the technique is costly and nonanatomic, changes the conjoint tendon into a single tendon for coracobrachialis attachment, and leads to anterior displacement of the clavicle and malreduction.^{6,7}

This article describes modified conjoint tendon transfer for CCL reconstruction. The technique may

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yield stable, anatomic, biological reconstruction of the CCL for the treatment of acute high-grade AC dislocation. It consists of the following steps: (1) creation of clavicular holes, (2) coracoid osteotomy, (3) conjoint tendon mobilization, (4) conjoint tendon transfer and fixation to the CCL footprint on the undersurface of the clavicle, and (5) AC reduction and conjoint tendon tenodesis to the bed of the retained coracoid process.

Surgical Technique

The operation is performed with the patient under general anesthesia and positioned in the beach-chair position with a sandbag under the scapula. The patient's arm is kept adducted. The surgeon faces the operative shoulder, and the assistant stands at the head of the patient. A lazy S-shaped skin incision is made. It starts medial and posterior to the AC joint curved medially outward the AC joint then laterally extending distally 2 to 3 cm distal to the tip of the coracoid process.

The anterior deltoid is detached from the lateral clavicle with placement of stay sutures to be repaired at the end of the procedure. The AC joint is explored. The coracoid process, conjoint tendon, torn CCL, and CAL are identified (Fig 1A).

Preparation of CCL Footprint at Clavicle

The CCL remnants are removed from the undersurface of the clavicle (Fig 1B). The CCL footprint on the

undersurface of the clavicle is debrided by a bone nibbler and burr (DePuy Synthes, Raynham, MA) to create a row bed (Fig 1C and D).

Creation of Clavicular Holes

Two holes are drilled in the clavicle; they are named after the trapezoid and conoid ligaments (Fig 2A and D). The trapezoid hole is sited anterior and 25 mm medial to the lateral end of the clavicle (Fig 2B). It is drilled by a 1.7-mm drill bit (Fig 2C). The conoid hole is sited posterior and 35 mm medial to the lateral end of the clavicle (Fig 2E). It is also drilled by a 1.7-mm drill bit (Fig 2F). After creation of clavicular holes (Fig 3A), passing suture loops are passed through (Fig 3B).

Coracoid Osteotomy

An oblique line for the osteotomy is marked by electrocautery (Fig 4A). It extends from anterolateral to posteromedial on the coracoid process. The osteotomy is performed by a sharp osteotome (DePuy Synthes) (Fig 4B). The CAL is preserved laterally, and the neurovascular structures are protected medially. The retained part of the coracoid process is refashioned by a bone nibbler to create a socket that is deeper medially than laterally.

The conjoint tendon is tagged by No. 2 Ethibond sutures (Johnson & Johnson Medical, Diagem, Belgium) (Fig 4C) and is used for tendon mobilization and fixation. A transverse hole in the post-osteotomy

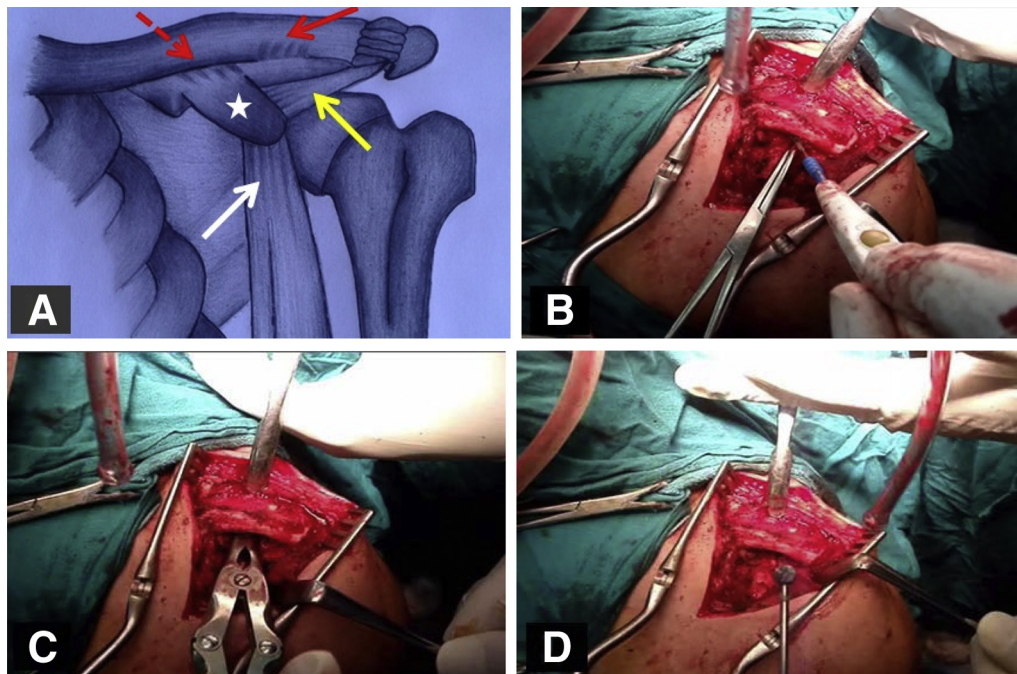


Fig 1. Preparation of footprint of coracoclavicular ligaments (CCLs) on undersurface of clavicle of left shoulder with patient in beach-chair position. (A) Coracoid process (white star), conjoint tendon (white arrow), coracoacromial ligament (yellow arrow), and torn CCL (red arrows). (B) Removal of CCL remnant from undersurface of clavicle. (C) Freshening of undersurface of clavicle by bone nibbler. (D) Freshening and rowing of undersurface of clavicle by burr.

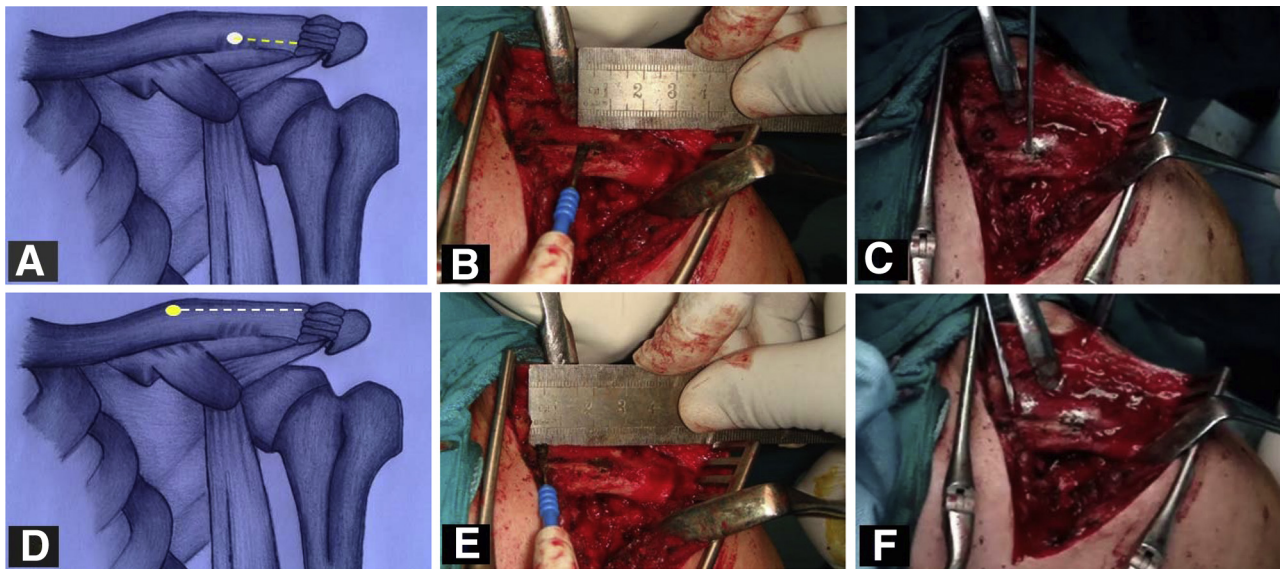


Fig 2. Creation of clavicular holes in left shoulder with patient in beach-chair position. (A) Trapezoid hole (white circle): anterior and 25 mm from lateral end of clavicle (yellow dotted line). (B) Marking of trapezoid hole: 25 mm from lateral end of clavicle. (C) Drilling of trapezoid hole by 1.7-mm drill bit. (D) Conoid hole (yellow circle): posterior and 35 mm from lateral end of clavicle (white dotted line). (E) Marking of conoid hole: 35 mm from lateral end of clavicle. (F) Drilling of conoid hole by 1.7-mm drill bit.

coracoid tip is drilled from lateral to medial using a 1.5- to 2-mm K-wire. This hole is used later for passage of the cerclage wire (Fig 4D).

Conjoint Tendon Mobilization

Careful blunt dissection of the conjoint tendon is made medially and laterally. Facial and fibrous bands are released. Upward tendon mobilization is performed. The tendon should reach the undersurface of the clavicle. Tendon mobilization is performed while the shoulder and elbow are flexed.

The lateral half of the conjoint tendon formed by the short head of the biceps tendon will represent the anterolateral bundle of the CCL (trapezoid ligament), and the medial half formed by the coracobrachialis will represent the posteromedial bundle of the CCL (conoid ligament). The musculocutaneous nerve enters the

coracobrachialis muscle at least 5 cm below the coracoid process. The medial dissection should be performed bluntly and carefully, and the tendon mobilization should be gradual and gentle.

Reduction and Fixation

No. 2 Ethibond sutures in the conjoint tendon are passed upward through the clavicular holes using passing suture loops. Then, a 1- to 1.5-mm cerclage wire is passed downward through the conoid hole on the clavicle, then to the transverse hole in the coracoid tip, and finally, upward to the trapezoid hole on the clavicle. The cerclage wire passage forms a U-shaped configuration. The coracoid tip and the conjoint tendon are internally rotated and pulled upward to the undersurface of the clavicle (Fig 4E). The AC joint is reduced, and fixation to the

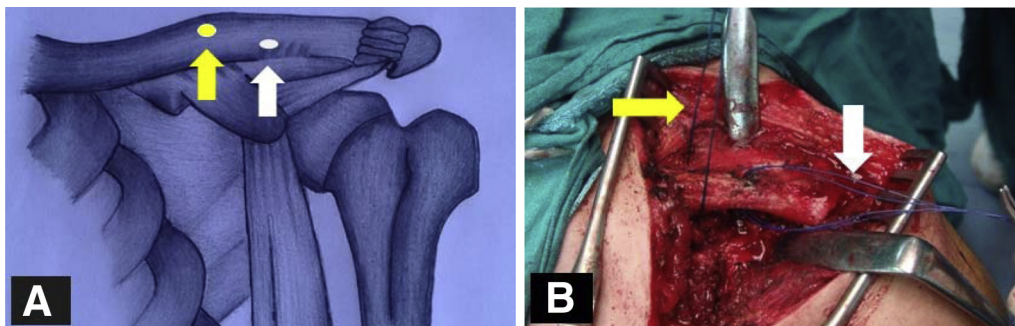


Fig 3. Clavicular holes. (A) Trapezoid hole (white circle and arrow) and conoid hole (yellow circle and arrow). (B) Passing suture loops (white and yellow arrows) are passed through the clavicular holes in the left shoulder with the patient in the beach-chair position.

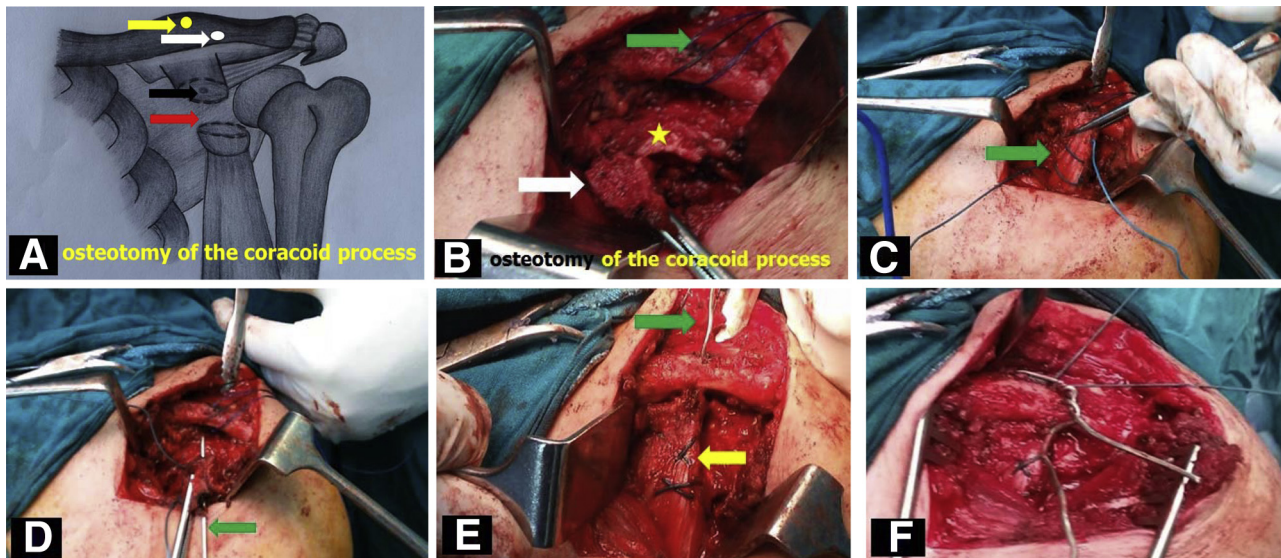


Fig 4. Osteotomy of coracoid process and conjoint tendon mobilization in left shoulder with patient in beach-chair position. (A) Osteotomy of coracoid process (red arrow), clavicular holes (white and yellow circles and arrows), and hole in coracoid bed (black arrow). (B) Osteotomy of coracoid process, post-osteotomy coracoid tip (white arrow), coracoid bed (yellow star), and retained part of coracoid process after osteotomy and passing sutures in clavicular holes (green arrow). (C) Conjoint tendon tagged by Ethibond sutures (green arrow) used for tendon mobilization. (D) Drilling hole in coracoid tip by 1.5-mm K-wire (green arrow) from lateral to medial for passage of cerclage wire. (E) Passage of Ethibond sutures first through clavicular holes using passing suture loops, followed by passage of cerclage wire from conoid hole to hole in coracoid tip to trapezoid hole (green arrow) and conjoint tendon (yellow arrow) mobilization to undersurface of clavicle. (F) Tying of sutures and cerclage wire on upper surface of clavicle after acromioclavicular reduction.

clavicle is performed with Ethibond sutures and cerclage wire (Fig 4F).

Fixation is completed (Fig 5) while the shoulder and elbow are flexed to relax the tendon. Drilling through the conjoint tendon to the coracoid bed is performed from anteromedial to posterolateral using a cannulated drill bit (Fig 5 B and C). Tenodesis of the conjoint tendon to the coracoid bed is performed with a cannulated 4-mm screw and washer (Smith & Nephew, London, England) (Fig 5 D-F).

Tenodesis is performed while the shoulder and elbow are extended to maintain tension of the conjoint tendon graft. At the end of the procedure, the deltoid and the deltotrapezial fascia are repaired. Radiologic evaluation is performed by radiography (Fig 6). Advantages of the technique are listed in Table 1, and pearls and pitfalls are shown in Table 2.

Discussion

More than 100 surgical techniques for the treatment of AC dislocations have been reported, but there is no gold-standard, ideal technique.¹⁻³ The results differ according to the onset of interference, the approach and method of treatment, and the type of reconstruction.

Early or Delayed Treatment

Early treatment allows accurate joint reduction, easy ligament identification, ligament repair or reconstruction, and joint stabilization.⁸ On the other hand, delayed treatment leads to inaccurate joint reduction, difficult ligament identification, the need for ligament reconstruction or substitution, and sometimes, the need for excision of the lateral end of the clavicle.

Open or Arthroscopic Procedures

Open procedures permit accurate joint reduction, removal of the degenerated disk, and repair of the deltotrapezial fascia; they are technically easier but may result in painful prominent scarring.⁹ Arthroscopic procedures identify associated intra-articular lesions and cause less injury to the soft tissue, but their use requires a steeper learning curve.⁸

Fixation or CCL Reconstruction

Surgical techniques for fixation were associated with a high incidence of early and late postoperative complications. A 32% technical failure rate was reported after Bosworth screw fixation; a 43% rate of early postoperative complications and 32% rate of late instability were reported after tension band fixation; a 58% rate of early postoperative complications and 50% rate of late instability were reported after hook plate

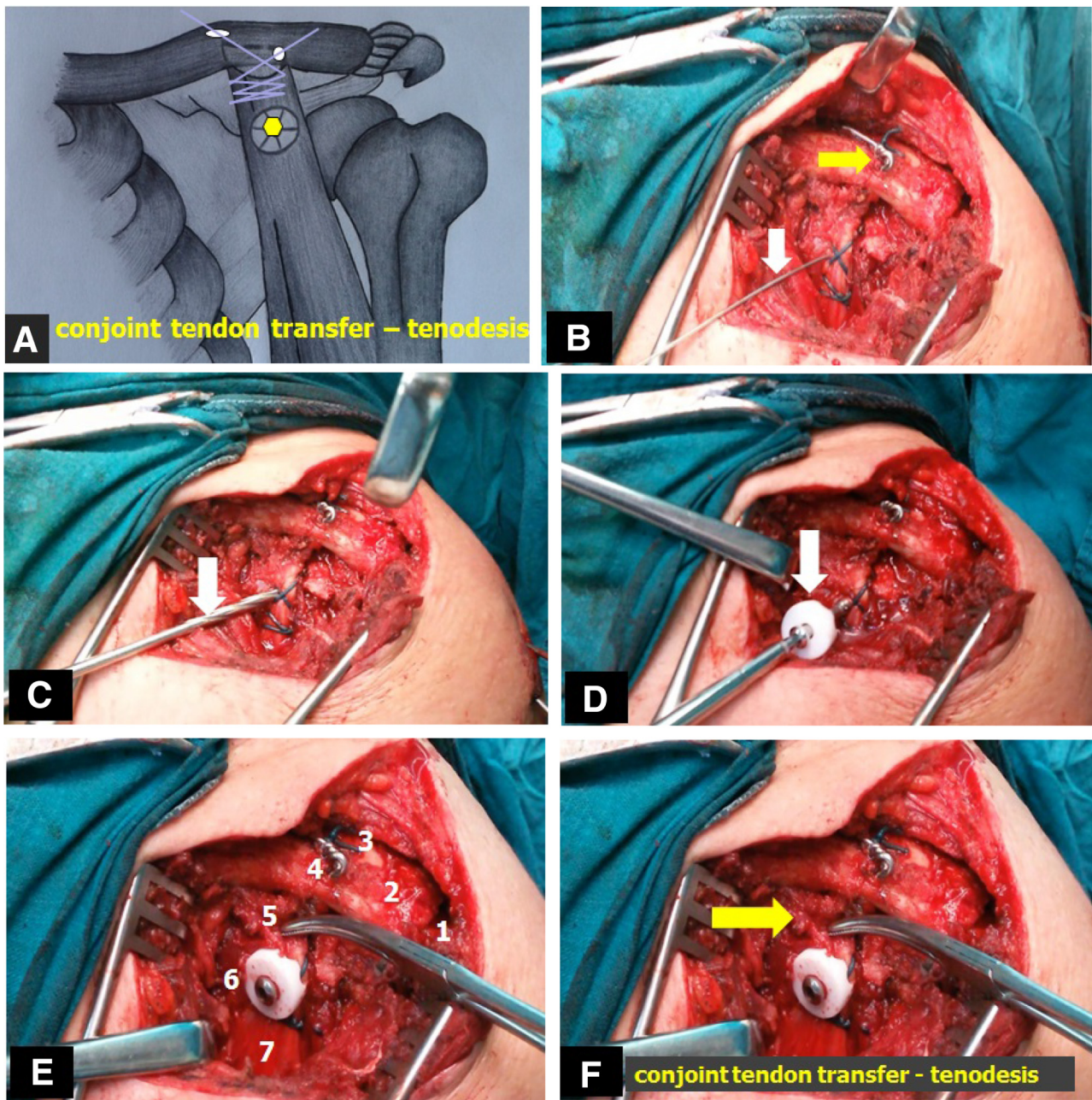


Fig 5. Conjoint tendon fixation in left shoulder with patient in beach-chair position. (A) Conjoint tendon transfer and tenodesis. Tendon transferred to clavicular holes (white ovals), tagged by Ethibond sutures (violet lines), and fixed to coracoid bed by screw and washer (black wheel and yellow hexagon). (B) Guidewire passage through conjoint tendon to coracoid bed from anteromedial to posterolateral direction (white arrow) and fixation to clavicle by Ethibond sutures and cerclage wire (yellow arrow) performed while shoulder is flexed. (C) Drilling through conjoint tendon to coracoid bed from anteromedial to posterolateral direction (white arrow). (D) Conjoint tendon tenodesis by screw and washer (white arrow) performed while shoulder is extended. (E) Final reduction and fixation, showing reduced acromioclavicular joint (1), lateral end of clavicle (2), Ethibond sutures (3), cerclage wire (4), conjoint tendon (5, 7), and screw and washer (6). (F) Conjoint tendon transfer and tenodesis for coracoclavicular ligament reconstruction, showing conjoint tendon graft (yellow arrow).

fixation; and a 17% rate of early postoperative complications and 34% rate of late instability were reported after polydioxanone suspension.^{10,11} CCL repair, reconstruction, or substitution has evolved over the past several decades.¹²⁻¹⁷

CCL Repair or Reconstruction

Open or arthroscopic, early or delayed CCL reconstruction is recommended for high-grade AC dislocation and for double disruption of the superior shoulder suspensory complex, as well as conditions associated

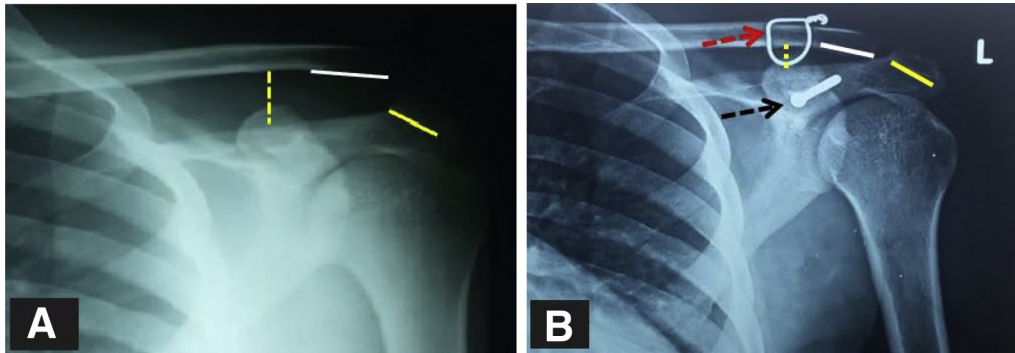


Fig 6. Radiologic evaluation. (A) Preoperative radiograph showing acromioclavicular dislocation (white and solid yellow lines) and increased coracoclavicular distance (dashed yellow line). (B) Postoperative radiograph showing acromioclavicular reduction (white and solid yellow lines), normal coracoclavicular distance (dotted yellow line), screw fixation directed posterolaterally (black arrow), and cerclage wire through clavicle (red arrow).

with soft-tissue or neurovascular injury. CCL repair is reserved for low-grade AC dislocation.⁸

Distant Graft or Local Transfer

Hamstring autograft reconstruction and fixation are costly,¹² are technically demanding, and may precipitate coracoid or clavicular fracture.^{12,15} They may be associated with distant site morbidity, graft stretching, tunnel widening,¹⁴ and infection. The Weaver-Dunn procedure,¹⁸ which entails CAL transfer, carries a risk of ongoing pain, in association with instability and recurrent subluxation, and results in only 30% of the strength and 10% of the stiffness of intact ligaments.¹⁹ It is biomechanically inferior to tendon graft reconstructions.²⁰ The conjoint tendon has better properties and greater consistency in the quality of the graft than the CAL,^{6,7,21} although it is not as strong as the native CCL; the conjoint tendon is stronger than the commonly used CAL.⁶

Sloan et al.⁶ (2004) found that the ultimate tensile strength of the intact CCL is 621 ± 209 N, that of the lateral 12 mm of the conjoint tendon is 265 ± 79 N, and that of the CAL is 246 ± 69 N. They believe that the lateral half of the conjoint tendon is a viable alternative autograft source for CCL reconstruction.

Anatomic CCL reconstruction could be performed using tendon graft passed through clavicle and coracoid tunnels using different methods of fixation; this requires many tunnels and many implants, increasing the cost and possible complications. Open anatomic CCL reconstruction using semitendinosus graft through 3 tunnels in the clavicle and coracoid in a V-shaped¹³ or figure-of-8-shaped¹⁶ configuration was described. Three interference screws¹³ or an EndoButton (Smith & Nephew) continuous loop and 1 PEEK (polyether ether ketone) screw¹⁶ were used for fixation.

Weaver-Dunn Procedure

The Weaver-Dunn procedure¹⁸ carries a risk of ongoing pain, in association with instability and

Table 1. Advantages of Technique

Anatomic reconstruction	
	The proximal attachment of the conjoint tendon is at the CCL footprint on the clavicle.
	The distal attachment of the conjoint tendon is near the coracoid base.
	Double-bundle reconstruction is simulated.
	Anatomic AC reduction is provided.
	No anterior displacement of the clavicle or malreduction occurs.
Open reconstruction	
	Easier identification is possible.
	Less surgical time is required.
	Good AC reduction is allowed.
	Removal of the torn or degenerated AC disk is allowed.
Early reconstruction	
	Early reconstruction could be performed for acute and chronic cases.
	Early reconstruction is better than late reconstruction.
	Early reconstruction produces better results than repair.
	A more stable reduction is provided with less failure than repair.
Conjoint tendon graft	
	The graft provides biological reconstruction.
	The graft is united at the clavicular attachment by bone-to-bone healing.
	Double-bundle reconstruction is simulated.
	The short head of the biceps represents the trapezoid ligament.
	The coracobrachialis represents the conoid ligament.
	Tenodesis at the coracoid prevents graft slipping.
	Tenodesis at the coracoid prevents dynamic instability.
	Tenodesis at the coracoid forms a static CCL reconstruction.
	Tenodesis at the coracoid preserves the function of the conjoint tendon.
	Conjoint tendon graft is a local graft and so avoids distant graft morbidity.
	Conjoint tendon graft has greater tensile strength than the CAL.
Drill holes and method of fixation	
	The drill holes are made at anatomic sites of the native CCL attachments.
	The drill holes avoid tunnel complications.
	The drill holes avoid tunnel widening and loosening.
	The drill holes avoid clavicular or coracoid fracture.
	The method of fixation is simple and inexpensive.
	The method of fixation gives stable reduction.
	The method of fixation avoids interference screw fixation.
	The method of fixation avoids biological reactions.

AC, acromioclavicular; CAL, coracoacromial ligament; CCL, coracoclavicular ligament.

Table 2. Surgical Steps, Pearls, and Pitfalls

Surgical Step	Pearls	Pitfalls
Open dissection	A lazy S-shaped incision allows easy access to the AC joint, lateral clavicle, and coracoid process.	A saber-cut incision needs excessive retraction to access to AC joint, lateral clavicle, and coracoid process.
	Detachment of the anterior deltoid allows easy access to the undersurface of the clavicle and the conjoint tendon. Stay sutures in the surgically detached deltoid are important and are used for reattachment at the end of the procedure.	Deltoid splitting leads to a difficult approach and deltoid damage. Neglecting deltoid repair decreases the deltoid strength and power of shoulder flexion.
	Exploration of the AC joint is important to remove or debride the intervening disk.	The neglected torn intra-articular disk is a source of postoperative pain.
Preparation of CCL footprint at clavicle	Debridement and removal of soft tissues from the undersurface of the clavicle should be performed.	If this preparation of the CCL footprint at the clavicle is not performed, nonunion between the transferred coracoid tip and the undersurface of the clavicle may occur.
	Freshening and decortication create a row surface that is important for healing.	
Clavicular holes	The sites of the clavicular holes (2.5-3.5 cm medial to the lateral end of the clavicle) are made at the anatomic sites of attachment of the native CCL.	Improper sites lead to nonanatomic reconstruction.
	The number of clavicular holes (2 holes) simulates double-bundle reconstruction, and a bone bridge between them is important for suture and wire tightening and fixation.	Making 1 hole eliminates the double-bundle concept, and there is no bone bridge on which to perform fixation. Making more than 2 holes is not needed and weakens the clavicle.
	A small diameter of the hole avoids clavicular fractures.	A larger diameter of the hole may precipitate clavicular fractures.
	The position of the clavicular holes (1 anterior and 1 posterior) allows internal rotation of the attached coracoid tip.	Two holes on 1 line leads to a nonanatomic bundle attachment.
	The loops of the passing sutures are at the undersurface of the clavicle to pass the Ethibond sutures from below upward.	If the loops of the passing sutures are at the upper surface of the clavicle, this leads to false passage of the Ethibond sutures from below upward.
Coracoid osteotomy	A sharp osteotome is used to perform easy osteotomy.	If the osteotome is not sharp enough, this may lead to coracoid fracture.
	The osteotomy extends from anterolateral to posteromedial; this gives a long surface at the coracoid tip for attachment to the undersurface of the clavicle.	Limited osteotomy of the coracoid tip gives a small surface for attachment.
	The osteotomy creates a socket that is deeper medially than laterally and has 2 borders. The socket embraces the tendon between its borders, which allows easy fixation and tenodesis. The deeper the socket, the nearer to the coracoid base and the more anatomic the reconstruction.	If the osteotomy is straight, the surface of the bed will be flat and away from the coracoid base; this provides less anatomic attachment.
	A hole is drilled in the tip from lateral to medial and used for passage of the cerclage wire from medial to lateral.	Drilling in the tip from medial to lateral is difficult.
Conjoint tendon mobilization	Blunt careful dissection is performed.	Overzealous dissection may injure the musculocutaneous nerve.
	Mobilization is performed with the elbow and shoulder flexed to relax the tendon.	Tendon mobilization is difficult if the elbow and shoulder are extended.
Reduction and fixation	The Ethibond sutures are passed first, followed by the cerclage wire.	The reverse is difficult.
	The cerclage wire is passed in a U-shaped manner through the conoid hole, then to the transverse hole in the coracoid tip, and finally, through the trapezoid hole on the clavicle.	Changing this order makes the passage difficult.
	Fixation to the clavicle is performed by Ethibond sutures and cerclage wire while the shoulder and elbow are flexed.	If the shoulder and elbow are extended, the tendon will be very tight during mobilization.
	Drilling through the conjoint tendon to the coracoid bed is performed from an anteromedial to posterolateral direction using a cannulated drill bit.	If not, the screw may be loose.
	The tenodesis is performed while the shoulder is extended to maintain tension of the conjoint tendon graft.	If the shoulder and elbow are flexed, the tendon will be lax with less tension.
	The coracoid tip and the conjoint tendon are internally rotated and pulled upward to the undersurface of the clavicle.	Upward traction without internal rotation produces a less anatomic reconstruction.

AC, acromioclavicular; CCL, coracoclavicular ligament.

recurrent subluxation, and results in only 30% of the strength and 10% of the stiffness of intact ligaments.¹⁹ The mean laxity after reconstruction was 42 mm in the horizontal plane and 14 mm in the vertical plane compared with 8 mm and 3 mm, respectively, in intact ligaments²² and could be augmented by either autograft or synthetic suture material.^{3,22} This procedure could be performed in an arthroscopically assisted or all-arthroscopic manner.^{23,24}

Dewar and Barrington Procedure

The Dewar and Barrington procedure⁴ has been used for the treatment of acute and chronic injuries, with better results in younger patients. However, reports of residual joint aching led to the procedure being abandoned because of poor long-term outcomes.⁵ The procedure includes conjoint tendon transfer to the lateral clavicle. It creates dynamic stabilization of the lateral clavicle. Transfer of the tendon either directly or together with the tip of the coracoid is performed.²⁵ The procedure carries the risk of over-tightening the coracoclavicular space, subsequent fracture of the coracoid,²³ nonunion of the transferred coracoid, loss of fixation, or screw breakage, and it may be associated with injury to the musculocutaneous nerve.^{26,27}

Jiang Technique

Jiang et al.⁷ (2007) performed proximally based conjoint tendon transfer for CCL reconstruction. They retained the origin of the tendon and divided its lateral half distally and then reversed the tendon and implanted it into the lateral end of the clavicle. Fixation was performed with No. 2 Ethibond sutures with suture anchors for augmentation.^{6,7}

Conjoint Tendon Transfer and Tenodesis

The technique is based on anatomic and biological reconstruction. It creates an anatomic clavicular footprint, favored by bone-to-bone healing. It also creates a nearly anatomic coracoid footprint. It applies the double-bundle concept, in which the short head of the biceps represents the anterolateral bundle and the coracobrachialis represents the posteromedial bundle of the CCL. It provides secure stable fixation.

The technique is performed using small clavicular and coracoid holes and hence is not associated with fractures or tunnel widening. It is performed by a simple and inexpensive method of fixation and provides good tension of the local graft with no effect on the function of the conjoint tendon. It preserves the CAL and is not associated with distant graft-site morbidity.

The technique is performed in acute cases with early reconstruction. Early operative treatment for grade III through V dislocations may result in better functional and radiologic outcomes, with a reduced risk of infection and loss of reduction compared with delayed surgery.²⁸

CC ligament reconstruction for the treatment of acute AC joint dislocation results in successful long-term clinical and radiographic outcomes.²⁹ The disadvantage of this technique is violation of the deltoid, which can be avoided by gentle dissection and good closure.

Video 1 shows our technique for open anatomic CCL reconstruction with modified conjoint tendon transfer for the treatment of acute high-grade AC dislocation of the left shoulder with the patient in the beach-chair position through a lazy S-shaped incision. **Video 1** shows the steps of the technique: (1) open dissection, (2) preparation of the CCL footprint on the undersurface of the clavicle, (3) creation of clavicular holes, (4) coracoid osteotomy, (5) conjoint tendon mobilization, (6) conjoint tendon transfer and fixation to the CCL footprint on the undersurface of the clavicle, and (7) AC reduction and conjoint tendon tenodesis to the bed of the retained coracoid process.

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