Comparison of Short-term Complications Between 2 Methods of Coracoclavicular Ligament Reconstruction

A Multicenter Study

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Background: Numerous techniques have been used to treat acromioclavicular (AC) joint dislocation, with anatomic reconstruction of the coracoclavicular (CC) ligaments becoming a popular method of fixation. Anatomic CC ligament reconstruction is commonly performed with cortical fixation buttons (CFBs) or tendon grafts (TGs).

Purpose: To report and compare short-term complications associated with AC joint stabilization procedures using CFBs or TGs.

Study Design: Cohort study; Level of evidence, 3.

Methods: We conducted a retrospective review of the operative treatment of AC joint injuries between April 2007 and January 2013 at 2 institutions. Thirty-eight patients who had undergone a procedure for AC joint instability were evaluated. In these 38 patients with a mean age of 36.2 years, 18 shoulders underwent fixation using the CFB technique and 20 shoulders underwent reconstruction using the TG technique.

Results: The overall complication rate was 42.1% (16/38). There were 11 complications in the 18 patients in the CFB group (61.1%), including 7 construct failures resulting in a loss of reduction. The most common mode of failure was suture breakage (n = 3), followed by button migration (n = 2) and coracoid fracture (n = 2). There were 5 complications in the TG group (25%), including 3 cases of asymptomatic subluxation, 1 symptomatic suture granuloma, and 1 superficial infection. There were no instances of construct failure seen in TG fixations. CFB fixation was found to have a statistically significant increase in complications (*P* = .0243) and construct failure (*P* = .002) compared with TG fixation.

Conclusion: CFB fixation was associated with a higher rate of failure and higher rate of early complications when compared with TG fixation.

Keywords: acromioclavicular joint; AC joint; coracoclavicular; complications

Acromioclavicular joint disruption is one of the more common injuries in athletes and physically active individuals, accounting for 9% to 12% of all shoulder injuries.[1,26] Most of these injuries are relatively minor and can be managed non-operatively. Surgery may be indicated in the more severely injured shoulder. Unfortunately, there is no consensus on the optimal method of reconstruction, with over 151 different techniques for the operative reconstruction of the acromioclavicular (AC) joint existing in the literature.[1,4,6,11]

Historically, open operative techniques have failed to yield superior functional outcomes over nonoperative management for Rockwood grade 1, 2, and some grade 3 separations.[24] Not only have these procedures been associated with high failure rates, but surgical fixation in this area also carries with it the risk of potentially catastrophic hardware migration into adjacent vital structures.[18] The challenges and limitations of operative management have limited surgical treatment to either the most severe and symptomatic cases of instability or to the small subset of high-demand athletes.[8]

With advances in techniques and new options for fixation appearing within the past decade, the merits of operative management for symptomatic AC instability continue to be a topic of debate. Biomechanical studies have demonstrated the superior strength of various techniques for coracoclavicular (CC) reconstruction over ligamentous imbrication, repair, or nonanatomic reconstructions, such as the Weaver-Dunn procedure.[2,7,9] More recently, reports

have detailed successful application of arthroscopic techniques to perform or augment coracoclavicular reconstruction with favorable clinical results at early follow-up.[21,22,27-29] However, even these newer techniques are not without risk of complication, and several studies with midterm results demonstrate a high risk for loss of reduction (LOR).[5,12,15]

The purpose of this study was to compare early clinical outcomes and complication rates of patients treated with 2 different methods of CC ligament reconstruction. Our hypothesis was that no difference would be seen in the early clinical outcomes or complication rates between patients treated with cortical fixation buttons (CFBs) or tendon grafts (TGs).

METHODS

This study had obtained prior institutional review board approval. We performed a retrospective review of all CC ligament reconstructions between April 2007 and January 2013 at our 2 institutions. A total of 45 patients underwent surgery to address symptomatic AC joint instability during this time period. The procedures were all performed by 1 of 5 sports medicine fellowship–trained orthopaedic surgeons. CC ligament reconstructions were performed utilizing CFBs, TGs, or a combination of each. If a CFB was used, even in combination with a TG, the procedure was designated as a CFB reconstruction. When TGs were used without CFBs, these were designated as TG reconstructions.

The decision to perform open versus arthroscopic surgery was based on the primary surgeon's preference. Surgical technique did vary between the 5 surgeons involved, and this included differences in graft selection, fixation methods, and implant selection. A summary of patient demographics and specific technique modifications is included in Tables 1, 2, and 3. Of note, arthroscopic procedures were designated as such if arthroscopy was used to visualize the coracoid, assist in the reduction of the AC joint, or facilitate graft/stent passage. Also, all cases of tendon graft reconstructions utilized allograft, and the specific type of allograft used is documented in Table 3.

The incidence of complications was examined between the 2 types of procedures. We classified complications on the basis of clinical and radiographic manifestations. Major complications included symptomatic loss of reduction, which was defined by a radiographic loss of reduction (as seen on a postoperative anteroposterior [AP] radiograph) coupled with clinical symptoms of pain and dysfunction. Minor complications include asymptomatic loss of reduction (radiographic evidence of loss of reduction to approximately a Rockwood grade 2 injury without clinical symptoms),

TABLE 1
Patient Demographics[a]

	Cortical Fixation Button Group (n = 18 Patients)	Tendon Graft Group (n = 20 Patients)
Age, y, mean ± SD	33.94 ± 15.39	38.25 ± 15.67
Sex		
Male	16 (89)	18 (90)
Female	2 (11)	2 (10)
Rockwood grade		
3	7 (39)	4 (20)
4	1 (6)	1 (5)
5	10 (55)	15 (75)
Technique		
Open	2 (11)	19 (95)
Arthroscopic	16 (89)	1 (5)
Chronicity		
Acute	13 (72)	8 (40)
Chronic	5 (28)	12 (60)

[a]Data are reported as n (%) unless otherwise indicated.

superficial infections, and suture reactions. Further information gathered from the medical record included age, mechanism of injury, side of injury, sex, acute or chronic nature of injury, and length of clinical and radiographic follow-up. Exclusion criteria included loss to follow-up, age less than 18 years, and concomitant clavicular, scapular, or humeral fractures. A chronic injury was defined as any injury undergoing operative fixation 6 weeks after the initial insult.

The postoperative imaging and medical records were reviewed for each case. Radiographs were reviewed and included initial injury films, postoperative reduction films, and follow-up reduction films. A loss of reduction (LOR) was determined by reviewing immediate postoperative AP radiographs of the shoulder and measuring the CC distance. This distance was compared with subsequent postoperative radiographs at 2 weeks, 6 weeks, and 3 months after surgery. A greater than 10-mm increase in CC distance or displacement of more than 100% was deemed to be a construct failure. A CC distance of 10 mm was chosen to represent a construct failure, as intraobserver variability can vary by approximately 5 mm.[12] An LOR less than 10 mm or displacement less than 100% was deemed a subluxation or asymptomatic LOR.

Follow-up periods ranged from 3 to 32 months (mean, 6.7 months). In the instance of construct failure, time to failure and mode of failure were documented. Common failure mechanisms of CC ligament reconstruction were classified based on radiographic findings. Failure methods included coracoid fracture, clavicle fracture, and implant migration,

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TABLE 2
Summary of Cortical Fixation Button Reconstructions[a]

Patient Sex/Age (y)	Initial Injury	Rockwood Grade	Acute vs Chronic	Coracoid Fixation Technique	Associated Pathology	Additional Fixation	No. of Clavicle Tunnel (Size, mm)	ATS Assisted	Complications
M/19	Football injury	5	Acute	Drilled	Anterior labral tear	None	1 (4.0)	Yes	Osteolysis of distal clavicle, asymptomatic LOR
M/24	Ground-level fall	3	Acute	Drilled	SLAP tear	Clavicle washer	1 (4.0)	Yes	Construct failure due to suture breakage
M/62	Fall from horse	5	Acute	Drilled	None	None	1 (4.0)	Yes	Adhesive capsulitis
M/20	Football injury	5	Acute	Drilled	None	None	1 (4.0)	Yes	Construct failure due to CFB migration
M/49	MVA	5	Acute	Drilled	None	None	1 (4.0)	Yes	Construct failure due to CFB migration
M/18	ATV accident	3	Acute	Drilled	None	None	1 (4.0)	Yes	Construct failure due to suture breakage
F/37	MVA	3	Chronic	Drilled	None	None	1 (4.0)	Yes	PDS suture granuloma
M/34	Bicycle accident	5	Acute	Drilled	SLAP tear	None	1 (4.0)	Yes	Construct failure due to coracoid fracture
M/30	Ground-level fall	5	Acute	Drilled	None	None	1 (4.0)	Yes	Construct failure due to suture breakage
M/20	Motorcycle accident	5	Chronic	Drilled	None	None	1 (4.0)	Yes	None
M/21	Fall from horse	4	Acute	Drilled	None	None	1 (4.0)	Yes	None
M/22	Football injury	3	Chronic	Drilled	PASTA, labral tear	None	1 (4.0)	Yes	None
M/18	ATV accident	5	Acute	Drilled	None	None	1 (4.0)	Yes	None
M/48	Ground-level fall	3	Chronic	Drilled	None	Weaver-Dunn	1 (4.0)	Yes	None
M/44	ATV accident	5	Acute	Drilled	RCT	None	1 (4.0)	Yes	Asymptomatic LOR
M/58	Ground-level fall	3	Chronic	Drilled	None	ST allograft	1 (6.0)	Yes	None
F/56	MVA	5	Chronic	Drilled and looped	None	ST allograft	2 (5.0)	No	Construct failure due to coracoid fracture
M/27	ATV accident	3	Acute	Drilled and looped	None	ST allograft	2 (6.5)	No	None

[a]ATS, arthroscopy; ATV, all-terrain vehicle; CFB, cortical fixation button; F, female; LOR, loss of reduction; M, male; MVA, motor vehicle accident; PASTA, partial articular-sided supraspinatus tendon avulsion; RCT, rotator cuff tear; SLAP, superior labrum anterior and posterior; ST, semitendinosus.

TABLE 3
Summary of Tendon Graft Reconstructions[a]

Patient Sex/Age (y)	Initial Injury	Grade	Acute vs Chronic	Coracoid Fixation Technique	Associated Pathology	Additional Fixation	Allograft Type	No. of Clavicle Tunnel (Size, mm)	ATS Assisted	Complications
M/18	ATV accident	3	Acute	Drilled	None	None	N/R	1 (4.0)	Yes	Asymptomatic LOR
M/32	MVA	3	Chronic	Looped	Labral tear	Nonabsorbable suture	ST	1 (5.5)	No	None
M/39	Bicycle accident	4	Chronic	Looped	Labral tear	Nonabsorbable suture	ST	1 (7.0)	No	Asymptomatic LOR
M/48	Skiing fall	3	Chronic	Looped	RCT	Nonabsorbable suture	ST	2 (6.0)	No	None
M/40	Altercation	5	Acute	Looped	None	Nonabsorbable suture	ST	2 (6.0)	No	None
F/61	Fall from height	5	Chronic	Looped	RCT	Nonabsorbable suture	Gracilis	2 (4.5)	No	None
M/60	MVA	5	Chronic	Looped	None	Nonabsorbable suture	N/R	2 (5.5)	No	None
M/33	Ground-level fall	5	Chronic	Looped	None	Nonabsorbable suture	ST	2 (5.0)	No	None
M/40	Fall from height	5	Chronic	Looped	None	Nonabsorbable suture	ST	2 (4.5)	No	Superficial infection
F/63	Fall from height	5	Chronic	Looped	None	Nonabsorbable suture	ST	2 (5.0)	No	Asymptomatic LOR
M/43	ATV accident	3	Chronic	Looped	RCT, labral tear	Nonabsorbable suture	ST	2 (5.0)	No	None
M/22	Fall from height	5	Acute	Looped	None	None	N/R	2 (5.0)	No	None
M/69	Fall from height	5	Chronic	Looped	None	None	ST	2 (N/A)	No	None
M/16	ATV accident	5	Chronic	Looped	None	Nonabsorbable suture	ST	2 (5.0)	No	None
M/23	ATV accident	5	Acute	Looped	None	Nonabsorbable suture	ST	2 (5.0)	No	None
M/25	Bicycle accident	5	Acute	Looped	None	Nonabsorbable suture	ST	2 (5.0)	No	Suture irritation
M/35	Fall from height	5	Acute	Looped	None	Nonabsorbable suture	ST	2 (5.0)	No	None
M/22	Fall from height	5	Chronic	Looped	None	Nonabsorbable suture	ST	2 (5.5)	No	None
M/30	Fall from height	5	Acute	Looped	Labral tear	Nonabsorbable suture	ST	2 (5.5)	No	None
M/46	MVA	5	Acute	Looped	None	Nonabsorbable suture	ST	2 (5.0)	No	None

[a]ATS, arthroscopy; ATV, all-terrain vehicle; CFB, cortical fixation button; F, female; LOR, loss of reduction; M, male; MVA, motor vehicle accident; N/A, not available; N/R, not recorded; RCT, rotator cuff tear; ST, semitendinosus.

which were identified on standard AP radiographs of the shoulder and clavicle. When LOR was identified on radiographs in the absence of fracture or implant migration, suture breakage or graft elongation was the presumed cause.

Surgical Technique

Arthroscopic Cortical Fixation Button. The patient was placed in the lateral decubitus or beach-chair position, depending on surgeon preference. An arthroscope was introduced via the standard posterior portal, and routine diagnostic arthroscopy was performed. Any concomitant intra-articular injury was addressed. An anterolateral portal was then used to identify the coracoid, and a radiofrequency ablation device was used to clear the soft tissue around the coracoid to allow for sufficient visualization.

A separate 2-cm skin incision was then made approximately 3 cm medial to the distal clavicle. Dissection was taken down sharply to the fascia, and full-thickness flaps were created. Subperiosteal dissection was carried out both anterior and posterior to the clavicle. A 2.4-mm guide pin was then drilled bicortically through the clavicle (at a distance approximately 3 cm medial to the lateral tip of the clavicle) and coracoid and visualized arthroscopically to ensure that adequate bone bridge was present in the coracoid both medially and laterally to the guide pin. C-arm confirmation was obtained, and a 4-mm reamer was drilled over the guide pin.

The CFB (TightRope; Arthrex) was then shuttled through the coracoid and clavicular tunnels. The button was flipped beneath the coracoid and visualized arthroscopically. Downward pressure was then applied on the distal clavicle to reduce the AC joint. Reduction of the AC joint was verified on fluoroscopic imaging, confirming that the clavicle was adjacent to the acromion, and then the interlaced FiberWire (Arthrex) between the 2 buttons was tightened and fixed with a knot. AC ligament repair or reconstruction was not performed during acute arthroscopic CFB reconstructions.

Tendon Graft. An incision was made 2 to 4.5 cm medial to the lateral edge of the clavicle to approximate the insertion site of the CC ligaments. Dissection was carried out down to the deltotrapezial fascia, and the fascia and the AC capsule were incised in 1 layer parallel to the long axis of the clavicle. One or 2 Kirschner wires were placed through the clavicle and directed toward the coracoid at the site of the origin of the CC ligaments (2.5 and 4 cm medial to the tip of the lateral clavicle, respectively). In cases where 1 clavicular tunnel was used, the site of the CC ligaments was approximately 3 to 3.5 cm medial to the lateral tip of the clavicle. The Kirschner wires were overreamed with a cannulated reamer of 4.5 to 6 mm based on the size of the graft. With open procedures, additional dissection was required to visualize the coracoid prior to graft shuttling. In a TG procedure performed arthroscopically, the coracoid was arthroscopically visualized and cleared of soft tissue. Graft shuttling was then performed under direct arthroscopic visualization.

The allograft was shuttled and looped around the coracoid. The ends of the graft were crossed above the coracoid and pulled through their respective clavicular drill holes in

accordance with the technique described by Carofino and Mazzocca.[3] Reduction of the AC joint was performed and verified on fluoroscopic imaging, confirming that the clavicle was adjacent to the acromion. Appropriately sized interference screws (Arthrex) were then used in the clavicular tunnels for fixation. A dynamic fluoroscopic assessment was performed after the screws were placed. If the AC ligaments were significantly disrupted, primary suture repair or reconstruction was performed. Primary suture repair consisted of a figure-of-8 repair with an absorbable suture (2-0 PDS [polydioxanone sulfate]). AC reconstruction involved draping the excess tendon graft (from the trapezoidal tunnel) posteriorly and superiorly over the AC joint and securing this with a high-strength nonabsorbable suture. A horizontal mattress suture was used to secure the graft to the periosteum and residual AC ligaments. Additional fixation of the AC and CC ligaments including sutures, interference screws, or tapes was used according to the surgeon's preference, and is listed in Table 2.

Postoperative Protocol

For CFB and TG techniques, the patients were placed in an abduction sling for immobilization to protect the repair and encouraged to perform passive range of motion below 90° during the first 6 weeks. During weeks 6 through 12, passive range of motion was increased, and active range of motion was initiated once full passive range of motion could be maintained. Strength training was permitted at 12 weeks, with progression to activity as tolerated and return to sport allowed when patients demonstrated full range of motion and normal strength.

Statistical Analysis

For each cohort the rates of complications and LOR were calculated and compared using the chi-square test. Paired Student t tests were used to compare differences between demographic data. To evaluate the impact of the various preoperative independent data points on primary and secondary outcomes, multiple regression analysis was used. All reported P values are 2-tailed, with a value of <.05 indicating a statistically significant difference.

RESULTS

A total of 45 patients who had undergone a procedure for AC joint reconstruction were evaluated. Seven patients had a concomitant distal clavicle fracture and were thus excluded from the study, leaving 38 eligible patients. Eighteen patients underwent CFB reconstruction and 20 patients underwent TG reconstruction. Follow-up ranged from 3 to 32 months (mean, 6.7 months). Summaries of the CFB and TG cohorts are listed in Tables 2 and 3, respectively, and a summary of construct failures is provided in Table 4. The majority of CFB fixations were acute grade 5 separations (73% and 55%, respectively). The majority of CFB fixations were performed arthroscopically (89%). TG reconstructions were predominately chronic, grade 5

TABLE 4
Summary of Shoulders with Symptomatic Loss of Reduction After Primary Reconstruction[a]

Patient Sex/Age (y)	Initial Injury	Rockwood Grade	Chronicity	Time to Surgery, d	Failure Method	Cause of Failure	Time to Failure, d	Revision Procedure
M/24	Ground-level fall	3	Acute	28	Suture breakage	Atraumatic	60	Coracoclavicular screw
M/20	Football injury	5	Acute	34	Superior button migration	Atraumatic	35	Open TG reconstruction
M/49	MVA	5	Acute	14	Inferior button migration	Overuse	30	Declined revision surgery
M/18	ATV accident	3	Acute	20	Suture breakage	Contact Sports	120	Open TG reconstruction
M/34	Bicycle accident	5	Acute	11	Coracoid fracture	Atraumatic	83	Hook plate and TG
M/30	Ground-level fall	5	Acute	25	Suture breakage	Overuse	185	Declined revision surgery
F/56	ATV accident	5	Chronic	50	Coracoid fracture	Fall	60	Declined revision surgery

[a]ATV, all-terrain vehicle; F, female; M, male; MVA, motor vehicle accident; TG, tendon graft.

injuries (60% and 75%, respectively), and a vast majority were performed with an open technique (95%).

Fixation Technique

There were 11 complications in the 18 patients in the CFB group (61.1%). Major complications consisted of 7 construct failures resulting in loss of reduction. Minor complications included 2 cases of asymptomatic subluxation, 1 case of adhesive capsulitis, and 1 PDS suture granuloma. The most common method of failure was suture breakage, seen in 3 patients, followed by cortical button migration (n = 2) and coracoid fracture (n = 2). All reconstruction procedures demonstrated adequate reduction of the AC joint on immediate postoperative AP radiographs. Construct failures were observed between 30 and 185 days postoperatively (mean, 103.7 days).

There were 5 complications in the 20 patients in the TG group (25%), including 3 cases of asymptomatic subluxation, 1 symptomatic suture granuloma, and 1 superficial infection. All these complications were defined as minor. No construct failures were observed in the TG group.

CFB fixation was found to have a statistically significant increase in overall complications ($P = .024$) and symptomatic loss of reduction ($P = .002$) when compared with TG fixation (Table 5). Patient age, grade of injury, and chronicity of the injury were not associated with an increase in complications.

Revisions

The initial surgery was classified as a failure in 7 of 18 (38.8%) patients in the CFB group. Four patients in the CFB cohort (22.2%) underwent revision surgery. Three patients in this cohort were recommended revision surgery due to symptomatic loss of reduction but declined revision surgery. A summary of surgical failures and revision surgeries is listed in Table 4. Though not a revision procedure, 1 other patient in the CFB group did develop adhesive capsulitis, necessitating an arthroscopic lysis of adhesions. There were no revision surgeries in the TG group.

Acute Versus Chronic

Twenty patients underwent surgery after an acute injury, and 18 were treated after a chronic injury. There were 11 complications (55%) in acute reconstructions and 5

TABLE 5
Summary of Coracoclavicular Ligament Reconstructions[a]

	Cortical Fixation Button Group (n = 18 Patients)	Tendon Graft Group (n = 20 Patients)	P
Type of complication			
Major	7 (39)	0 (0)	.002
Minor	4 (22)	5 (25)	.84
Total	11 (61.1)	5 (25)	.024
Complication, n			
Loss of reduction	7	0	.002
Subluxation	2	3	.818
Superficial infection	1	1	.94
Other	1	1	.94
Rockwood grade			.57
3	7 (39)	4 (20)	
4	1 (6)	1 (5)	
5	10 (55)	15 (75)	
Chronicity			.09
Acute	13 (72)	8 (40)	
Chronic	5 (28)	12 (60)	

[a]Data are reported as n (%) unless otherwise indicated.

complications (27.8%) associated with chronic reconstructions. There were 7 LORs seen in acute reconstructions and 1 LOR seen in chronic reconstructions. The chronicity of the injury did not have a statistically significant influence on increased complication or failure rate ($P = .09$).

Rockwood Grade

Utilizing the Rockwood classification, there were 11 grade 3 injuries (28.9%), 2 grade 4 injuries (5.3%), and 25 grade 5 injuries (65.8%). There were 4 postoperative complications (36.3%) associated with grade 3 injuries, 1 complication in grade 4 injuries, and 11 complications (44%) associated with grade 5 injuries. The Rockwood grade did not have a statistically significant influence on complications or failures ($P = .57$).

DISCUSSION

Overall, a high rate of complications was observed in this study group (42.1%). Symptomatic loss of reduction was

seen exclusively in CFB constructs, occurring in 7 of 18 patients (38.9%). A high rate of major (38.9%) and minor complications (22%) was seen in the CFB cohort. Of the failures, 4 elected to undergo revision surgery (22.2%). TG procedures had less overall complications (25%), and these were classified as minor complications.

The high rate of failures in our CFB cohort is noteworthy, as the majority of modern arthroscopically assisted AC stabilization procedures employ single or double CFB constructs.[10,16,21,29] The incidence of symptomatic LOR and revision surgery after arthroscopic CFB reconstruction has been quoted between 12% and 23.1%.[10,12,23] The rate of failure in our cohort of CFB reconstructions is higher (38.9%) than what was seen in previously published reports.

However, the complication profiles in these studies are similar to our findings, as were the methods of construct failure with CFBs, which included suture breakage, button migration, and coracoid fractures. Suture breakage has been quoted as the most common method of failure in several series and was the leading cause of failure in this series.[5,21]

The most likely reason for suture breakage is that the single CFB construct fails to restore the horizontal instability that is lost with disruption of the AC ligaments. Salzmann et al[21] hypothesized that a lack of dual-plane stability was to blame for single CFB failures. They theorized that single-button devices do not allow for an exact anatomic reconstruction, and the lack of horizontal stability is a likely cause of early failure.[21]

Another reason for suture breakage is the lack of biologic fixation provided by CFB. Traditional CFB techniques utilize a nonabsorbable suture without biologic fixation. Venjakob et al[29] proposed that arthroscopic CFB fixation can provide enough dual-plane stability in the immediate postoperative period to allow CC ligament healing or scar tissue formation. However, there are little data to support this, and the potential for ligament healing has been called into question, even in acute surgical repairs.[22] Scheibel et al[22] argued that biologic augmentation might be necessary in some patients presenting in the acute period, which they defined as less than 3 weeks from injury.

It could be argued that double-button CFB constructs might improve stability and provide a more anatomic reconstruction, as we only utilized single CFB constructs. The proposed benefit of double CFB constructs is that it allows for a more anatomic restoration of the CC ligament complex, as the conoid and trapezoid ligaments are reconstructed with independent devices. The role of the AC ligaments in horizontal stability of the shoulder girdle complex has been well established; however, the CC ligaments also have been shown to resist loading in the AP plane. The conoid provides restraint to anterior and superior loading, while the trapezoid ligament is a restraint to posterior loading.[2] However, other biomechanical studies have failed to show a significant improvement in stability of the double CFB constructs compared with the single CFB constructs. Beitzel et al[2] showed comparable stability in single and double CFB devices; however, the double CFB construct was found to increase the risk of coracoid fracture when stressed to failure. This was believed to be due to improved

load distribution imparted by the dual clavicular buttons, which in turn resulted in greater combined force at the coracoid tunnel and resultant fracture or cutout.[2]

Furthermore, anatomic studies have shown that the use of double CFB devices causes a significant increase in axial stiffness in cadaver subjects, and in theory, this increased rigidity could lead to shoulder stiffness and loss of mobility.[30] Recent clinical studies have also failed to show a statistically significant difference in clinical and radiographic outcomes between single and double CFB techniques.[17]

Two of the CFB failures seen in our series were due to traumatic cortical button migration. Button migration was observed at either the clavicular button or the coracoid button. In 1 case, the clavicle button migrated inferiorly through the clavicle, and in the other case, the coracoid button cut out superiorly through the coracoid. This method of failure is thought to be secondary to errant tunnel placement or small-diameter implants. Schliemann et al[23] observed inferior clavicular button migration in 11 of 63 (17.5%) patients who were treated with a single CFB technique for acute AC joint dislocation. They noted that this complication was associated with a significant LOR. They emphasized correct clavicular tunnel placement as a key in avoiding clavicular button migration.[23] The likely cause of failure in our case was due to first-generation implants, which featured a small-diameter (6.5 mm) superior button. The load concentration focused on the implant (in our case, a 6.5-mm button) is inversely proportional to the implant contact surface area. Therefore, the failure load and stiffness increase with the implant diameter.[14] Since the implementation of a wider 10-mm button, the incidence of this phenomenon has decreased in other reports.[14]

Coracoid fracture was encountered in 2 cases. Both cases of coracoid fracture were associated with a coracoid tunnel technique, in which the graft or CFB was passed through a drill hole in the coracoid. A total of 19 patients were treated with a coracoid tunnel technique in our study (18 CFB, 1 TG). In this group, there were a total of 12 complications (63.2%), of which 7 resulted in symptomatic loss of reduction.

Milewski et al[15] reported similar findings in a series of 27 anatomic CC ligament reconstructions utilizing a tendon graft with or without the addition of a CFB. Ten of 27 reconstructions utilized a coracoid tunnel; 8 complications (80%) were noted, including 2 coracoid fractures and 5 shoulders with radiographic LOR. The remaining 17 reconstructions were performed with a looped graft around the coracoid. No coracoid fractures were seen, and only 2 cases (12%) of radiographic LOR were reported. Based on their findings, they concluded that the coracoid tunnel technique was associated with an unacceptably high complication rate, and that the coracoid loop technique was preferred.

Coracoid fractures are thought to be secondary to errant tunnel placement. The mean coracoid width at the conoid and trapezoid footprint is 12.1 ± 3.3 and 13.2 ± 2.7 mm, respectively.[20] The small size of the coracoid at the level of the CC ligament footprints underscores the relative ease in which iatrogenic fracture may occur when performing an anatomic reconstruction. Establishing an exact reconstruction within the anatomic parameters of the coracoid

footprints identified by Salzmann et al[20] can also be challenging. The single CFB construct can only reproduce a single footprint on the coracoid and clavicle, and as such, it only provides restraint against superior displacement. The lack of 3-dimensional control may result in increased shear and rotational stresses at the level of the coracoid, which in turn may lead to fracture.

It is important to note that all patients in this study who were treated with a CFB fixation device demonstrated complete reduction on postoperative radiographs. LOR occurred between 30 and 185 days postoperatively, suggesting that the CFB may afford a suitable initial fixation but it is prone to early failure, owing to its inferior biomechanical properties, its inability to resist relatively normal stresses in the rehabilitation period, and lack of biologic augmentation.

Only minor complications were seen with tendon graft reconstructions, and these included asymptomatic loss of reduction (n = 3), superficial infection (n = 1), and suture granuloma formation (n = 1). The complication rate of tendon graft reconstructions in this study was comparable to that seen in other studies utilizing a similar TG technique (25% vs 28.2%).[12] We did not observe any overt failures, although 3 of 20 (15%) patients demonstrated asymptomatic loss of reduction on follow-up radiographs. This rate of asymptomatic graft loosening is higher than previously published reports of 5.9%.[31]

Common modes of failure reported for TG reconstructions include graft elongation, graft rupture at the interference screw/graft interface, clavicle fracture, or coracoid fracture.[25] Although no failures were observed in this study, we did see instances of asymptomatic LOR. The most likely cause of asymptomatic LOR in our patients was due to graft elongation, which is a commonly observed complication of TG constructs. Mazzocca et al[13] demonstrated a change in graft length of 1.9 ± 0.94 mm when constructs were cycled to 70 N for 3000 cycles, whereas Tashjian et al[25] noted a 1.1-mm change in graft length after 1100 cycles.

The difference in graft elongation between allograft and autograft in CC ligament reconstructions has not been extensively studied. Milewski et al[15] found a similar rate of complications and construct failures when comparing allograft and autograft CC reconstructions. Further biomechanical and clinical studies are needed to determine the effect of graft source on loosening and failure.

Interestingly, there were no clavicle fractures seen in our cohort. Recent studies utilizing similar TG techniques have reported clavicle fracture rates between 18% and 20%.[12] In the present study, clavicular tunnel size varied from 4.5 to 7 mm, and a dual clavicular tunnel technique was routinely used. The origins of the conoid and trapezoid ligaments were utilized as an anatomic footprint for the placement of clavicular tunnels, in accordance with the biomechanical studies of Rios et al.[19] The fact that we experienced no clavicle fractures is perhaps due to the strict anatomic location of the clavicular drill holes in this cohort and the use of small (4.5 mm) tunnels and interference screws. Milewski et al[15] reported on clavicle fractures seen with anatomic CC ligament reconstruction. Their recommendations included minimizing clavicle tunnel diameter, allowing at least 25 mm between clavicle tunnels, and placing the lateral clavicle tunnel at least 10 to 15 mm from the lateral edge of the clavicle.[15]

We found no statistically significant difference in complications with regard to chronicity (acute or chronic), patient age, or type of injury (Rockwood 3, 4, or 5). There was an increased complication rate observed in arthroscopically assisted procedures, but the overwhelming majority of these procedures were CFB reconstructions. Due to the inherent differences in constructs, we are unable to draw any conclusions regarding the complication rates in open versus arthroscopic CC ligament reconstructions.

This study has several weaknesses. First, this study lacks validated outcome measures. The primary outcome measures we investigated were early complications; most notably, those that resulted in a loss of reduction. Subjective outcome measures were defined in terms of construct maintenance or construct failure. We commonly observed an asymptomatic LOR (equivalent to a Rockwood grade 2 AC separation) in the postoperative period, yet this finding was not adversely associated with loss of function or persistent pain. A second weakness is the lack of uniform follow-up seen in our patient population. Follow-up ranged from 3 to 32 months. Further studies and more long-term follow-up will be needed to assess for maintenance of reduction and overall patient satisfaction. However, due to the large number of complications and early revisions seen in some of our cohorts, we feel the short-term follow-up is adequate as a definitive endpoint (ie, LOR) was achieved. The retrospective nature of this study, the lack of randomization, and lack of standardized surgical technique are other potential weaknesses of this study.

CONCLUSION

The use of a CFB led to an unacceptably high rate of overall complications (61.1%) and major complications (39%) in CC ligament reconstructions. The use of looped TGs was also associated with a high rate of minor complications (25%). Although current techniques for CC ligament reconstruction continue to evolve, further improvements in surgical techniques are needed to ensure reproducible results with a low rate of complications.

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