Clinical Outcomes of Coracoclavicular Ligament Reconstructions Using Tendon Grafts

Stephen J. Nicholas, MD, Steven J. Lee,* MD, Michael J. Mullaney, DPT, Timothy F. Tyler, MS, PT, ATC, and Malachy P. McHugh, PhD
From the Nicholas Institute of Sports Medicine & Athletic Trauma (NISMAT), Lenox Hill Hospital, New York, New York

Background: Numerous techniques for reconstruction of the coracoclavicular ligaments have been developed to treat acromioclavicular joint separations. A new, stronger method to reconstruct the coracoclavicular ligaments using semitendinosus tendon allografts has been previously described. No outcome studies have been published on this new procedure.

Hypothesis: Reconstruction of the coracoclavicular ligaments using tendon grafts produces excellent functional results.

Study Design: Case series; Level of evidence, 4.

Methods: Nine patients underwent coracoclavicular ligament reconstruction using augmented cadaveric semitendinosus tendon allografts after a grade V acromioclavicular separation. All patients were evaluated for range of motion, strength, closed kinetic chain testing, the American Shoulder and Elbow Surgeons Rating Scale, Pennsylvania Shoulder Score, the Simple Shoulder Test, and the Acromioclavicular Joint Separation Questionnaire. Preoperative and postoperative radiographs were compared.

Results: Range of motion measurements were normal in all motions except a loss of 5° ± 4° ($P < .05$) in extension. No significant strength deficits were found. Functional closed kinetic chain tests scored comparatively to standardized norms. American Shoulder and Elbow Surgeons Rating scores were 96 ± 5 out of 100; the Pennsylvania Shoulder Scale scores were 97 ± 3 out of 100; the Simple Shoulder Test scores were 11.6 ± 0 out of 12; and Acromioclavicular Joint Separation Questionnaire scores were 28 ± 3 out of 31. Subjects reported an overall subjective satisfaction of 89% ± 7%. Postoperative radiographs showed no loss of reduction of the acromioclavicular joint in any patient.

Conclusion: Outcome for coracoclavicular ligament reconstructions using augmented semitendinosus tendon grafts was excellent with full recovery of strength, minimal range of motion loss, and no clinical or radiographic loss of reduction of the acromioclavicular joint.

Clinical Relevance: This procedure provides an excellent treatment for grade V acromioclavicular separations.

Keywords: coracoclavicular (CC) ligament reconstruction; acromioclavicular (AC) separation; shoulder separation; tendon graft; distal clavicle fracture

Acromioclavicular separations (AC) and certain distal clavicle fractures (Neer type IIA and B) are common injuries. Although grade I and II AC separations are typically treated nonoperatively, some grade III, most grades greater than III, and many distal clavicle fractures are usually treated operatively. The surgical treatment of these injuries remains controversial with more than 60 operative techniques having been described.[9,11,26,27]

While both the AC and coracoclavicular (CC) ligaments stabilize the AC joint, the key anatomical structures affected for both AC separations and type II distal clavicle fractures are the CC ligaments. Several techniques to reconstruct the CC ligaments have been developed. Weaver and Dunn[34] described transferring the coracoacromial (CA) ligament into the distal end of the clavicle. Palmaris longus tendon graft to fix the clavicle to the coracoid by use of a portion of the conjoined tendon and attaching it to the clavicle or using a fascia lata has also been performed.[1,3,8,17,33,36] However, the weak initial fixation of the ligament or tendon to the clavicle and outcomes can be a problem with these techniques.[13,15,16]

*Address correspondence to Steven J. Lee, MD, Nicholas Institute of Sports Medicine & Athletic Trauma (NISMAT), Lenox Hill Hospital, 130 E. 77th Street, New York, NY 10021 (e-mail: sjleemd@aol.com).

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A new procedure has been previously described and biomechanically tested in vitro to reconstruct the CC ligaments using tendon grafts rather than relying on the primary healing of these ligaments.[18] This has been shown in vitro to have far superior strength characteristics than suture or tape cerclage or to Weaver Dunn reconstructions. Because of its superior in vitro strength and biomechanical characteristics, this procedure should be introduced into a prospective clinical trial. The purpose of this study was to examine the clinical outcomes for CC ligament reconstructions with tendon allografts.

MATERIALS AND METHODS

Patients

Between 2000 and 2004, 9 patients (8 male, 1 female) with an average age of 41 ± 12 years underwent CC ligament reconstruction using cadaveric tendon allografts after a grade V AC separation. The allografts consisted of fresh-frozen semitendinosus tendon grafts supplied by Musculoskeletal Transplant Foundation (Edison, NJ) in accordance with the American Association of Tissue Banks standards. Six patients had chronic injuries (greater than 6 weeks), and 3 patients had acute injuries (less than 6 weeks). Patients were tested for strength, range of motion (ROM), and outcomes. Seven of the 9 patients separated their AC joint during competitive sporting activities, 1 patient was injured in a motor vehicle, and the other was injured in a construction accident. The Institutional Review Board approved the study, and all patients signed an informed consent form before testing.

Surgical Technique

A 4-cm longitudinal saber incision was made in line from the clavicle to the coracoid process. The deltotrapezial fascia was taken down subperiosteally exposing the clavicle, AC joint, and the coracoid process. The distal 1 cm of the clavicle was excised using an oscillating saw. A 4.0-mm vertical drill hole was placed into the middle third of the clavicle directly in line with and superior to the coracoid process. Both a 5-mm Mersilene suture (Ethicon, Somerville, NJ) and a semitendinosus tendon allograft were simultaneously threaded under the coracoid process. The medial limb of the tendon allograft and tape was brought into the clavicular hole from inferior to superior, then brought anterior to the clavicle and tied on the lateral side. The Mersilene tape was tied first to facilitate reduction of the clavicle to the acromion. The tendon ends were secured by tying them into a double surgical knot supplemented with side-to-side sutures using 0 Ethibond (Figure 1). The tendon graft was tensioned slightly more than that of the Mersilene tape, allowing the tendon graft to take up tension rather than the Mersilene tape. A secure closure of the deltotrapezial fascia was then performed.

Postoperative Treatment

Postoperatively, all patients wore a sling for immobilization for 4 weeks. At this time, patients were encouraged to periodically mobilize their wrist and elbow joints. Once the sling was discontinued, patients progressed with ROM and strengthening exercises accordingly, but they maintained restriction of glenohumeral extension for 8 to 10 weeks. Extension was unrestricted with activities of daily living but was not emphasized in physical therapy because this motion has been shown to cause the largest amount of stress on the CC ligaments (Lee, unpublished data, 2006).

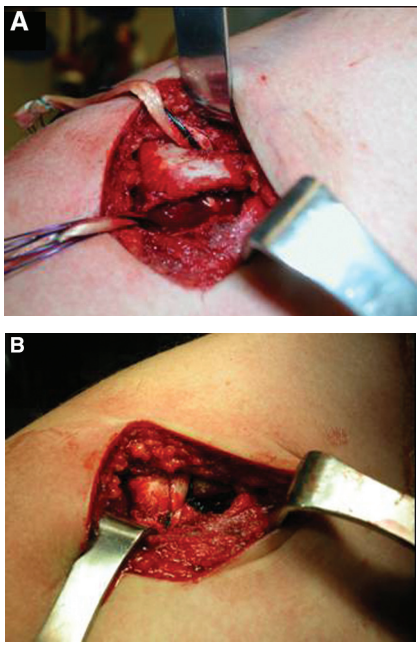

Figure 1. A, right shoulder: tendon graft and Mersilene tape passed around the coracoid and through the clavicular hole. B, tendon graft tied into a double surgeon's knot.

Follow-up

Patients were contacted at a minimum of 1 year after surgery (range, 12-48 mo) and were scheduled for a clinical examination with the same tester. Range of motion was tested in the following planes: flexion, abduction, internal and external rotation (ER) at 90º of shoulder abduction, ER with the arm at side, and extension. Strength measurements were performed with a handheld Lafayette Manual Muscle Test System (Lafayette Instruments, Lafayette, Ind) for shoulder flexion, abduction, internal rotation (IR) at 90º of abduction, ER at 0º and 90º of abduction, and extension. Handheld dynamometry has been a well-accepted method for measuring shoulder strength in the literature. Previous studies from our institute[22,25,32] as well as our testing therapist have shown little to no difference between dominant and nondominant shoulder strength. The average of 3 repetitions for each motion was recorded. Strength measures were calculated as a percentage of the noninvolved upper extremity and categorized as a significant strength deficit at >20% deficit, equivocal strength between a 10% to 20% deficit, and normal strength at <10%.

Patients also performed a closed kinetic chain timed stability test for functional recovery.[7,10] This test was performed in

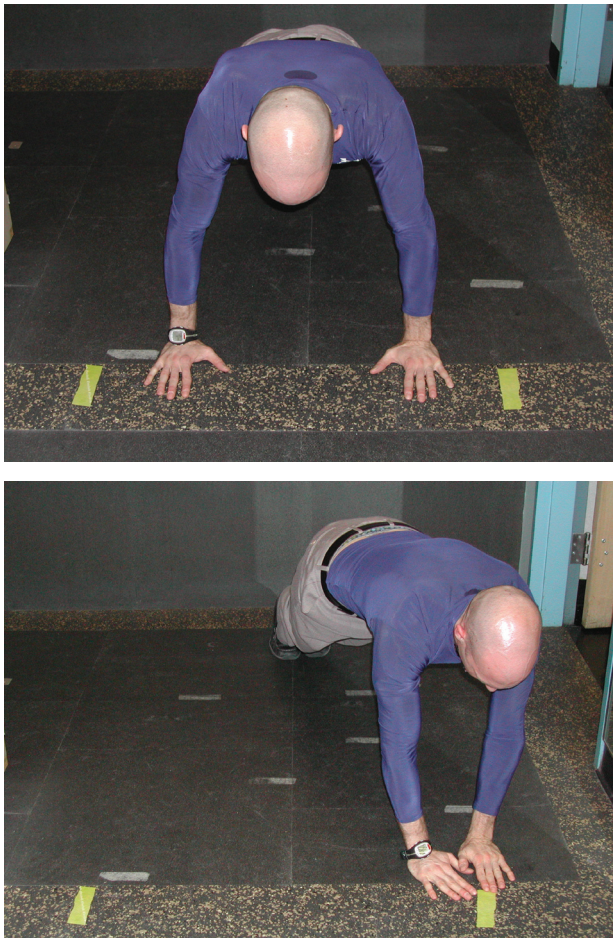

Figure 2. Closed kinetic chain testing.

the push-up position (female patients used a modified push-up position with knees in contact with the floor) with 2 lines 3 ft apart. Patients tried to touch both hands to each line as many times as possible for 15 seconds (Figure 2). One touch was counted when both hands touch one line. This test was repeated 3 times and averaged. Three values were calculated and recorded from this test: average touches, score, and power. The score was calculated by dividing the average number of touches by the patient's height (in inches). The power was calculated by taking 68% of the patient's body weight (estimated weight of trunk, head, and arms) multiplied by the average number of touches, divided by 15 seconds. Results were compared to normalized means for gender.[7,10] Patients also completed 4 outcome surveys: the AC Joint Separation Scale,[21] Pennsylvania Shoulder Score (PENN),[19] American Shoulder and Elbow Surgeons (ASES) Shoulder Scale, and the Simple Shoulder Test.[28] Finally, patients were asked their overall satisfaction with their shoulder out of 100%.

All patients had preoperative radiographs and bilateral comparison postoperative radiographs, including clavicle, axillary, and Y views. The postoperative radiographs were performed immediately after surgery and then at 6 weeks,

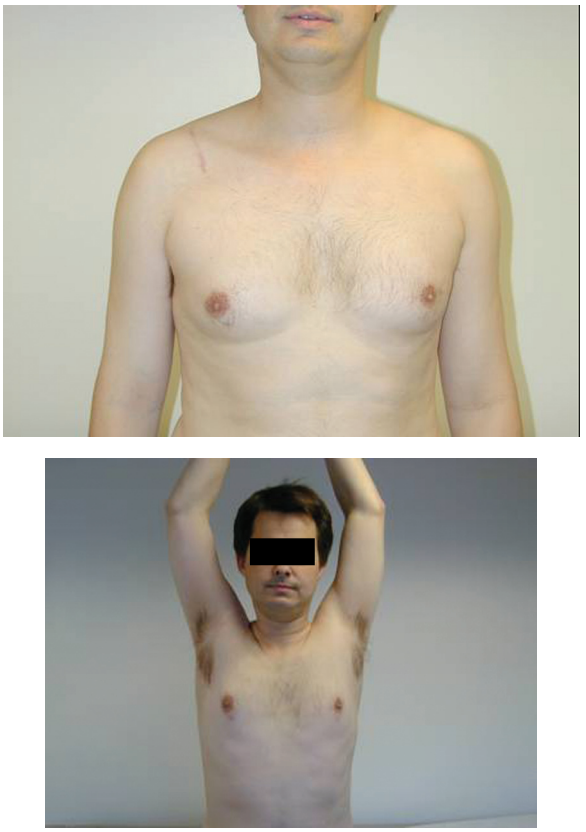

Figure 3. Clinical photographs after tendon graft reconstruction with no clinical step-off and excellent normal range of motion.

TABLE 1
Range of Motion Measurements

Position	Involved (deg)	Noninvolved (deg)	Δ
Flexion	179 ± 2	179 ± 2	0 ± 0
Abduction	179 ± 2	179 ± 2	0 ± 0
Internal rotation at 90°	66 ± 8	64 ± 10	2 ± 5
External rotation at 0°	73 ± 5	74 ± 7	1 ± 3
External rotation at 90°	101 ± 8	102 ± 10	3 ± 5
Extension	52 ± 15	56 ± 13	5 ± 4[a]

[a] $P = .003$.

3 months, and 6 months postoperatively. These were evaluated for superior, anterior, and posterior translation of the clavicle compared with the acromion using a standard ruler measured manually from the radiographs.

RESULTS

Range of motion results revealed no differences compared with the uninvolved side except for a 5° ± 4° ($P < .003$) loss of extension in the involved upper extremity (Figure 3) (Table 1). Strength measures revealed no statistically significant differences between upper extremities in all

TABLE 2
Average Strength Measurements

Shoulder Strength Tests	Involved (kg)	Noninvolved (kg)	% Difference
Flexion	12 ± 5	13 ± 5	5 ± 9
Abduction	11 ± 4	12 ± 5	5 ± 16
Internal rotation at 90°	20 ± 15	21 ± 22	4 ± 8
External rotation at 0°	16 ± 16	16 ± 17	1 ± 12
External rotation at 90°	17 ± 6	17 ± 6	0 ± 17
Extension	14 ± 5	14 ± 6	3 ± 10

TABLE 3
Categorization of Individual Strength Measurement

Shoulder Strength Tests	>20% Deficit, n	10%-20% Deficit, n	<10% Deficit, n
Flexion	1	1	7
Abduction	2	1	6
Internal rotation at 90°	1	0	8
External rotation at 0°	0	1	8
External rotation at 90°	1	1	7
Extension	0	2	7

TABLE 4
Closed Kinetic Chain Measures

	Touches		Score[a]		Power	
	Patients	Norms	Patients	Norms	Patients	Norms
Men (n = 7)	17 ± 1	14.5	0.24 ± 0.9	0.26	151 ± 1	150
Women (n = 1)	17.7	20.5	0.26	0.30	94.7	130

[a]Adjusted for height.

positions (Table 2). Of the 54 total strength measures taken (6 positions for 9 patients), only 5 (10%) had a significant strength deficit >20%, 6 (10%) had a strength deficit between 10% and 20%, whereas 43 strength measures (80%) had normal strength (deficit <10%) (Table 3).

Only 7 of 8 male patients completed the closed kinetic chain testing (1 patient could not get into the test position secondary to an unrelated lower extremity problem). The average number of touches of the male patients was 14% greater than the reported normal values.[7] The average score was 8% less than that of normal values (Table 4). The average power score was comparable with that of reported normal values. Results for the closed kinetic chain testing for the only female subject revealed 14% less touches than normal, a score 16% less than reported female norms, and a power score 30% less than the reported normal values.[10] Closed kinetic chain testing norms are based on healthy college-age men and women, and it should be noted that our subjects' average age was much greater (male subjects, 40.1 ± 12; female subject, 61).

The Acromioclavicular Joint Separation Questionnaire had an average score of 28.2 ± 2 out of 31. The PENN scores averaged 97 ± 3 out of 100. This included a 28.7 of 30 on the pain portion, a 59 of 60 on the function portion, and a 9.2 of 10 on the satisfaction portion. The ASES Shoulder Scale score averaged 96 ± 5 out of 100. This included 48.9 of 50 on the pain portion and 47.1 of 50 on the function portion. The Simple Shoulder Test revealed an average score of 11.6 ± 0.3 out of 12. Subjectively patients reported their shoulder overall satisfaction rating of 89% ± 7%.

Results were similar between patients with acute and chronic injuries, but the sample size was insufficient to statistically compare outcomes (Table 5). Follow-up radiographic evaluation showed no evidence of any superior, anterior, or posterior migration compared with the opposite side in any of the patients (Figure 4). One patient was noted to have a small amount of calcifications along the pathway of the tendon graft.

TABLE 5
Individual Outcomes[a]

Patient	Age	Cause of Injury	Latest F/U, mo	Total Shoulder Strength	ROM EXT, Loss	PENN (100[b])	ASES (100[b])	Simple Shoulder Test (12[b])	AC Joint (31[b])	CKC Score % of Norms	Current Activities of Participation
1	38	Ice hockey	46	97	0	100	100	12.00	31	88	Canoe guide
2	42	Bike accident	15	93	0	91	85	12.00	28	100	Biking
3	33	Ski accident	16	96	10	99	100	12.00	31	80	Carpenter, skiing
4	41	Diving for softball	24	91	5	93	90	11.00	24	92	Softball
5	36	Fall	22	100	10	96	93	12.00	27	95	Construction
6	31	Soccer fall	20	92	5	97	98	12.00	27	100	Lifting weights, cable technician
7	63	Car accident	22	100	5	100	100	12.00	31	N/A[c]	Retired, working out
8	28	Skateboarding	24	98	5	99	100	12.00	28	100	Skateboarding
9	61	Fall	24	95	5	98	98	12.00	27	84	Golf

[a]F/U, follow-up; ROM, range of motion; EXT, external rotation; PENN, Pennsylvania Shoulder Score; ASES, American Shoulder and Elbow Surgeons Rating Scale; AC, Acromioclavicular Joint Separation Questionnaire; CKC, closed kinetic chain testing.
[b]Number signifies total possible score.
[c]Patient unable to get in test position because of recent total knee replacement.

Figure 4. Postoperative radiograph with maintained alignment 36 months after procedure.

DISCUSSION

More than 60 techniques have been described for the operative treatment of AC separations and distal clavicle fractures.[9,26,27] Techniques that have focused on fixing the AC joint have been associated with serious complications and have not resulted in satisfactory results.[20,23] Those treatments that address the CC ligaments have been associated with better outcomes, as it is now well established that the CC ligaments offer the primary restraint to vertical stability of the AC joint. These techniques such as direct suture repair, suture and suture anchor cerclage, coracoclavicular screws, or some combination of these techniques rely on holding the relationship between the coracoid and clavicle for a long enough period of time to allow for primary healing of the CC ligaments.[2,4,10,14,24,31]

Whether this allows for true healing approaching the strength of the native CC ligaments is debatable. If the CC ligaments do not heal, eventually all these static fixation techniques described will likely fail over time. These techniques are also not satisfactory for the treatment of the chronically injured CC ligaments. Because of these limitations, techniques to reconstruct the CC ligaments have been developed, including use of local tissue such as the coracoacromial ligament or conjoined tendon or free tendon grafts.[5,29,34] These methods have previously suffered from weak initial fixation strength and suboptimal outcomes.[30,35] Previous studies have shown that Weaver Dunn reconstructions have failed at an average of 70 N compared with 641 N for the native CC ligaments.[18]

We have previously shown in vitro that tendon graft reconstructions using hamstring tendons have significantly superior strength characteristics than CA ligament transfers, suture, or tape cerclage. These tendon graft reconstructions failed at an average of 618 N, which was not statistically different than the native CC ligaments. A key finding was the method of fixation of the tendon grafts: the tendon graft itself was tied into a double surgeon's knot. Using this method, these tendon grafts did not fail at the fixation sites but failed midsubstance through the tendon itself.[18]

Others have subsequently confirmed the biomechanical advantage of using tendon grafts in vitro. Costic et al[6] recently described a similar repair technique, differing slightly in that 2 separate 6-mm clavicular holes and a 7-mm coracoid hole were used. Grutter et al[12] recently tested a biomechanical cadaveric construct reconstructing not only the CC ligaments but also the superior AC ligaments using tendon grafts. This study also differed in that they used 2 separate 4.5-mm drill holes in the clavicle and a 4.5-mm drill hole in the coracoid process. They found the flexor carpi radialis graft to be of sufficient strength to withstand the forces seen by the native AC joint, but they noted that a hamstring tendon graft would be their choice in clinical practice.

We chose not to make an additional drill hole in the clavicle or in the coracoid process to minimize the possibility of pathologic fracture, especially because these reconstructions were performed mostly on a highly active and athletic population. To more accurately reproduce normal anatomy, however, we recommend placing the lateral limb of the tendon graft anterior to the clavicle while the medial limb is placed through the clavicular hole. This arrangement does not seem to be significantly different than that reproduced with 2 separate clavicular holes. We also have not found any evidence for migration in the anterior and posterior planes, obviating the need to repair the superior AC ligaments when a secure deltotrapezial repair has been performed.

Jones et al[16] described a case report using a semitendinosus tendon graft to salvage a previous coracoacromial ligament transfer, although the technique used was slightly different from ours. To our knowledge, this is the first study that has followed a series of patients after hamstring tendon graft reconstruction of the CC ligaments. This study showed excellent outcomes after tendon graft reconstruction of the CC ligaments. Patients reported significant relief of pain, return of normal strength and function, negligible loss of motion, and no loss of reduction on postoperative radiographs. Subjective and standardized outcome measures showed high satisfaction rates. This particular patient population is older than most AC joint separation patients (2 patients >60 y); however, as evident in Table 5, all patients returned to their previous occupation or sport.

Based on several in vitro biomechanical studies,[6,12,13,15,18] a pilot case report study,[16] and now this series of patients, hamstring tendon graft reconstructions appear to offer a viable alternative for the treatment of operable AC separations. This technique offers a strong biological reconstruction that should be able to respond to stresses and strains and does not interrupt the normal healing of the native CC ligaments. It does not require hardware removal, can be used for both acute and chronic injuries, and is relatively simple to perform.

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