Concomitant Acromioclavicular and Coracoclavicular Ligament Reconstruction with a Duo-Figure-8 Autogenic Graft Wrapping Technique for Treating Chronic Acromioclavicular Separation

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Background: Coracoacromial ligament transfer is the traditional procedure for treating chronic acromioclavicular separation, but it is significantly inferior to ligament reconstruction according to biomechanical and clinical studies. However, ligament reconstruction carries the risk of complications of graft loosening and peri-tunnel fractures. Currently, there is no ligament reconstruction procedure optimal for preventing such complications. The purpose of this study was to describe and retrospectively analyze the clinical and radiological outcomes of a "duo-figure-8" autogenic graft wrapping technique, which was used to concomitantly reconstruct the acromioclavicular and coracoclavicular ligaments.

Methods: Preoperative, immediate postoperative, and final follow-up oputcomes were evaluated in 10 enrolled patients. Radiographic outcomes were indicated by the bilateral difference of the coracoclavicular distance (CCD) and overlapping length of the acromioclavicular joint (OLac). Quality of reduction was classified into 4 grades according to bilateral CCD difference into overreduction (< 0 mm), anatomic reduction (0–4 mm), partial loss of reduction (4–8 mm), and recurrent dislocation (> 8 mm). Clinical outcomes were evaluated using the American Shoulder and Elbow Surgeons (ASES) and Constant scores.

Results: The mean side-to-side differences for CCD were 11.9 mm (preoperative), –0.1 mm (immediate postoperative), and 3.4 mm (final follow-up); those for OLac were 9.4 mm (preoperative) and 2.7 mm (final follow-up). CCD and OLac outcomes significantly improved at final follow-up ($p < 0.05$). At the immediate postoperative stage, 6 and 4 patients had overreduction and anatomic reduction, respectively. At final follow-up, 7 and 3 patients had anatomic reduction and partial loss of reduction, respectively. The magnitude of improvement of ASES scores for patients with anatomic reduction and partial loss of reduction ($p = 0.20$) was 18.1 and 20.0, respectively. The magnitude of improvement of Constant scores in patients with anatomic reduction and partial loss of reduction ($p = 0.25$) was 19.9 and 22.3, respectively.

Conclusions: The technique yielded acceptable functional outcomes in patients with anatomic reduction or partial loss of reduction. The "duo-figure-8" wrapping method—a single autogenic tendon graft passing beneath the coracoid process with a tendon-knot fixation over the distal clavicle and looping around the acromion intramedullary—did not increase the risk of peri-tunnel fractures over the clavicle, coracoid process, or acromion.

Keywords: *Acromioclavicular joint, Joint dislocation, Ligament reconstruction*

Acromioclavicular (AC) joint injuries constitute 9% of all shoulder injuries and commonly occur in men aged 20–39 years.[1] These injuries result from a direct contusion to the shoulder, usually in high-collision sports or motorcycle accidents. Injury severity is classified according to the Rockwood classification. As per expert consensus, Rock-

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wood grade I and II injuries should be treated conservatively, and Rockwood grade IV, V, and VI injuries should be treated surgically.[2] However, no compelling guideline is available for the treatment of grade III injuries.

For acute injuries, the available surgical options include hook plate fixation and coracoclavicular (CC) looping with high-strength artificial materials and suspensory devices.[3] For chronic injuries, coracoacromial (CA) ligament transfer (the modified Weaver–Dunn procedure) is the traditional procedure, but it only provides 20%–50% stability of the native joint and is significantly inferior to tendon graft reconstruction.[4,5] According to clinical studies comparing CA ligament transfer with tendon graft reconstruction, ligament reconstruction yields superior functional results and a lower loss of reduction rate.[6,7] At present, no ligament reconstruction procedure is optimal. An emerging clinical trend of concomitant AC and CC ligament reconstruction involves resembling stabilizers in both the horizontal and vertical planes.[8-14] According to the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine upper extremity committee, in patients with a chronic AC injury, instability should be addressed in both planes by re-establishment of AC and CC ligaments.[2] However, ligament reconstruction carries the risk of complications of potential graft loosening and peri-tunnel fractures of either the clavicle or coracoid process.[15-17] For preventing above-mentioned complications, we used a "duo-figure-8" graft wrapping technique. In this technique, a single autogenic tendon graft is used to concomitantly reconstruct the AC and CC ligaments. The purpose of this study was to retrospectively analyze the clinical and radiological outcomes of the "duo-figure-8" graft wrapping technique.

METHODS

Ethical approval was provided by the Institutional Review Board of Kaohsiung Veterans General Hospital (IRB No. KSVGH20-CT7-08). All patients signed an informed consent before the surgery. They were operated on by a single orthopedic surgeon (FTH) in Kaohsiung Veterans General Hospital, Taiwan.

Patient Enrollment
Patients were included if they (1) were aged > 18 years, (2) had a chronic (defined as > 3 months of nonoperative treatment)[16] Rockwood grade III or V AC joint injury, and (3) had undergone concomitant AC and CC ligament reconstruction with a single autogenic tendon at any time between January 2014 and November 2018. Surgical

treatment was indicated for patients with grade-III AC separation who had prolonged pain, weakness, or scapular dyskinesis after the failure of a 2-month conservative treatment.[2] However, we excluded patients with (1) a follow-up period of < 18 months, (2) concomitant upper limb injuries, or (3) a prior ipsilateral shoulder surgery. Patients who had undergone revised ligament reconstruction surgery for recurrent AC separation were also excluded.

Surgical Procedures
Concomitant AC and CC ligament reconstruction with a single autogenic tendon graft ("duo-figure-8" graft wrapping method) was performed (Fig. 1). Patients were placed under general anesthesia, and in the supine position, a bump was placed beneath the medial scapula border. The appropriate images of the AC joint were obtained by a prepositioned C-arm. The ipsilateral semitendinosus tendon was harvested in samples 4–5 mm in diameter and 20–28 cm in length. A transverse skin incision (6–8-cm long) was made along the anterior border of the distal clavicle to the anterolateral edge of the acromion. The deltotrapezial fascia was incised to expose the distal clavicle, coracoid process, and anterolateral corner of the acromion. The distal clavicle resection of 5 mm and the excision of the interposed fibrocartilaginous disc were routinely performed. Conoid and trapezoid tunnels—3.5 cm and 1.5 cm, respectively—were created medial to the lateral border of the distal clavicle. After determining the entry point of the intramedullary acromial tunnel over the lateral edge of the acromion, the pin was fixed from the entry point
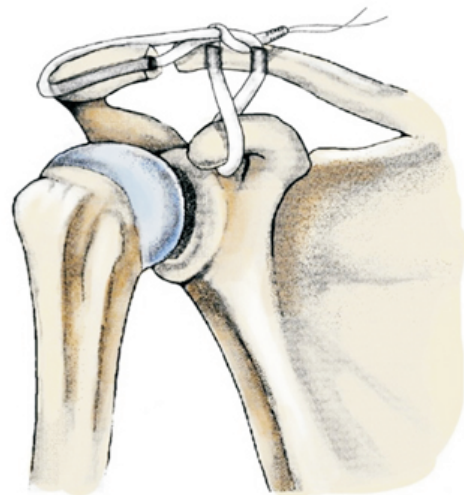

Fig. 1. Single autogenic tendon graft for concomitant acromioclavicular and coracoclavicular ligament reconstruction with the "duo-figure-8" graft wrapping method.

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through the acromion to the distal clavicle to guide the tunnel reamer and maintain the AC joint reduction (Fig. 2A). To reconstruct the CC ligament, a tendon graft was passed under the coracoid process and then through the predrilled conoid and trapezoid tunnels (Fig. 2B). After passing through the tunnels of the distal clavicle, 2 tails of the graft (the long tail through the conoid tunnel and the short tail through the trapezoid tunnel) were tied over the clavicle in an overhand configuration (the tendon-knot technique) to complete the vertical figure-8 graft wrapping (Fig. 2C). Subsequently, a No. 2 FiberWire (Arthrex, Naples, FL, USA) was sutured for additional security. The long tail of the remaining graft was introduced into the intramedullary acromial tunnel (Fig. 2D), pulled back (Fig. 2E), and then sutured upon itself with a No. 2 FiberWire over the superior aspect of the AC joint to complete the horizontal figure-8 graft wrapping (Fig. 2F). Finally, CC augmentation with a nonabsorbable, braided polyester tape (Mersilene Polyester Fiber Suture; Ethicon, Cincinnati, OH, USA) was performed to protect the tendon graft. The tape looping around the coracoid process was tied over the tendon graft superiorly on the distal clavicle.

Postoperative Management
The shoulder was protected with an arm sling for 4 weeks to ensure no tension other than that from the arm's weight. One month after surgery, patients started with passive elevation and then had active forward elevation, which was restricted to 90°. Two months after surgery, patients moved freely. Three months after surgery, if patients reported no pain and could move their shoulder relatively freely, a strengthening exercise for the shoulder joint was implemented, particularly through the use of scapular stabilizers. A return to contact sports was allowed from 6 months after the surgery.

Assessment of Radiographic and Clinical Outcomes
We reviewed the enrolled patients' charts retrospectively and collected data on their age, gender, and time from trauma to surgery. Radiographic outcomes were evaluated by comparing the bilateral CC distance (CCD) in the Zanca view (vertical translation) and the overlapping length of the acromioclavicular joint (OLac) in the modified Alexander view (horizontal translation) on a plain radiograph; preoperative, immediate postoperative, and final follow-up outcomes were evaluated. The CCD is defined as the length of a vertical line from the highest point of the coracoid process to the inferior cortex of the clavicle on the Zanca view.[18] To assess the OLac on the modified Alexander view, we employed the method of identifying the AC axis and then measuring the length from the highest to the lowest point of the overlapping area along the AC axis. In cases of complete AC separation, the overlapping length was defined to be negative and measured from the
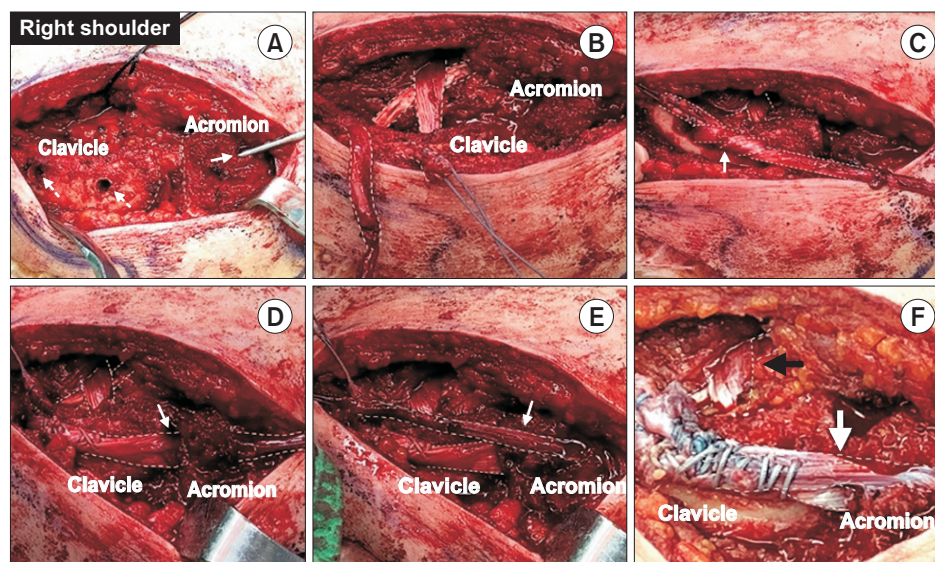

Fig. 2. Representative intraoperative images of a right shoulder. (A) Creating the conoid and trapezoid tunnels (white dotted arrow) over the distal clavicle and reducing the acromioclavicular (AC) joint with temporary guide-pin fixation via the acromion tunnel (white arrow). (B) Autogenic semitendinosus tendon passed under the coracoid process and through the predrilled tunnels on the clavicle. (C) Both tails tied over to each other: "the tendon-knot technique" (white arrow). (D) Long graft tail (white arrow) introduced into the acromial intramedullary tunnel. (E) Long graft tail (white arrow) pulled back. (F) Coracoclavicular ligament reconstruction with "vertical figure-8 graft wrapping" (black arrow); AC ligament reconstruction with "horizontal figure-8 graft wrapping" (white arrow).

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lowest point of the distal clavicle to the highest point of the acromion along the AC axis (Fig. 3).[19] The quality of reduction was classified in 4 grades according to the bilateral CCD difference into overreduction (< 0 mm), anatomic reduction (0–4 mm), partial loss of reduction (4–8 mm), and recurrent dislocation (> 8 mm).[20]

Clinical outcomes were evaluated using the American Shoulder and Elbow Surgeons (ASES) score and the Constant score both preoperatively and at final follow-up.
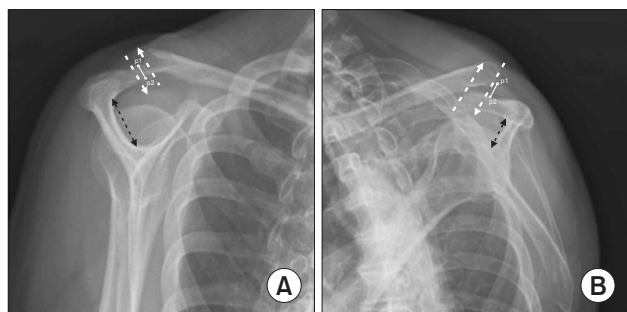

Fig. 3. Measurement of the overlapping length of the acromioclavicular joint (OLac) from modified Alexander views for type III injury (A), where the OLac is positive and measured along the acromioclavicular (AC) axis from the most superior to most inferior overlapping points (from p1 to p2), and type V injury (B), where the OLac is negative and measured at the greatest distance between the inferior cortex of the clavicle (p1) and the superior cortex of the acromion (p2) along the AC axis. The AC axis runs parallel to the line (black dotted line) that connects the most superior point to the most inferior point of the anterior cortex of the scapular spine.[19]

Statistical Analysis

Continuous variables are presented in terms of mean ± standard deviation, and categorical variables are presented in terms of frequency (%). A paired sample t-test was used to determine the difference between preoperative and postoperative outcomes (CCD and OLac side-to-side difference, ASES, and Constant scores). The clinical differences between patients with respect to anatomic reduction and partial loss of reduction after ligament reconstruction were analyzed using a Mann-Whitney U-test. Statistical significance was indicated if a p-value was < 0.05. Statistical analyses were performed using IBM SPSS ver. 20.0 (IBM Corp., Armonk, NY, USA).

RESULTS

Selected Population

From January 2014 to November 2018, 19 patients received concomitant AC and CC ligament reconstruction. Among 5 patients with a follow-up period of less than 18 months, 1 with concomitant upper-limb injuries and 1 who had received ipsilateral shoulder surgery were not enrolled. Furthermore, 2 patients who had undergone revised surgery for recurrent AC dislocation were excluded. Ten patients who had received primary ligament reconstruction surgery met the inclusion criteria. The statistics for age, sex, dislocation classification, and time from trauma to surgery are listed in Table 1. The participants' mean age was 47.0 years (range, 20–70 years), the mean time from trauma to surgery was 4.7 months (range, 3–8

Patient	Sex	Age (yr)	Follow-up (mo)	Rockwood classification	Dominant side injury	Time from trauma to surgery (mo)
1	M	63	28	V	N (left)	7
2	M	57	28	III	Y (right)	6
3	M	70	31	V	N (left)	4
4	M	46	36	V	Y (right)	3
5	M	30	28	III	Y (right)	5
6	F	32	25	V	Y (right)	3
7	M	46	24	V	N (right)	8
8	F	29	24	III	Y (right)	3
9	F	47	20	III	Y (right)	5
10	M	50	19	V	N (left)	3
Mean ± SD		47.0 ± 13.8	26.3 ± 5.1			4.7 ± 1.8

Table 1. Patient Demographics

SD: standard deviation.

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months), and the mean follow-up period was 26.3 months (range, 19–36 months). Seven patients had received surgery on their right side, whereas 3 had received it on their left side.

Outcomes

The functional and radiologic results are presented in Table 2. The mean ASES score improved from 72.2 (range, 65–80) to 91.9 (range, 88–96), and the mean Constant score improved from 67.2 (range, 60–78) to 87.8 (range, 82–92). On comparison of the preoperative and postoperative functional scores, the differences for the ASES and Constant scores were statistically significant ($p < 0.05$). Of the 10 patients, 8 (80%) had resumed exercise or returned to their previous occupation at the final follow-up.

When we compared the Zanca views of bilateral clavicles, the mean side-to-side differences for CCD were 11.9 mm (range, 4.2–20.7 mm), −0.1 mm (range, −3.5–3.2 mm), and 3.4 mm (range, 1.4–5.5 mm) at the preoperative, immediate postoperative, and final follow-up stages, respectively. When we compared the modified Alexander views of bilateral shoulders, the mean side-to-side differences for OLac were 9.4 mm (range, 5.0–18.0 mm) and 2.7 mm (range, 1.0–4.6 mm) at the preoperative and final follow-up stages, respectively. The differences for CCD and OLac significantly improved at final follow-up relative to their preoperative radiographic values ($p < 0.05$).

The results for reduction quality were as follows: At the immediate postoperative stage, 6 patients exhibited overreduction and 4 patients exhibited anatomic reduction; at the final follow-up stage, 7 patients exhibited anatomic reduction (Fig. 4) and 3 patients exhibited partial loss of reduction (Fig. 5). Two of the patients with anatomic reduction at the immediate postoperative stage exhibited partial loss of reduction at the final follow-up, and 5 of the patients with overreduction at the immediate postoperative stage achieved anatomic reduction at the final follow-up. In a comparison between patients with partial loss of reduction and patients with anatomic reduction with respect to functional outcomes, we noted no significant difference in ASES ($p = 0.20$) and Constant scores ($p = 0.25$) at final follow-up (Table 3).

Complications

At final follow-up, the patients had no recurrent dislocation, peri-tunnel fracture, or donor site morbidity. Shoulder stiffness occurred in 2 patients. One underwent manipulation under general anesthesia 5 months after the index surgery, whereas the other started the aggressive stretch exercise 3 months after the index surgery.

Table 2. Functional and Radiographic Results

Patient	Preop ASES score	Postop ASES score	Preop constant score	Postop constant score	Preop CCD difference (mm)	Immediate postop CCD difference (mm)	Final follow-up CCD difference (mm)	Preop OLac difference (mm)	Postop OLac difference (mm)
1	70	90	65	89	15.4	−3.5	5.5	14.7	4.0
2	72	94	71	86	4.2	−0.5	1.5	5.0	2.0
3	73	91	65	86	20.7	3.2	5.2	18.0	4.0
4	65	92	60	86	10.6	−1.5	1.4	7.5	1.0
5	80	96	78	92	9.2	0.5	3.2	7.7	2.5
6	75	94	68	88	13.7	3.0	3.3	13.0	2.8
7	66	88	60	82	14.5	1.5	5.0	10.5	4.6
8	68	88	64	85	7.0	−0.8	2.2	5.0	2.5
9	78	94	70	92	7.8	−0.5	3.2	5.5	1.2
10	75	92	71	92	15.5	−2.0	3.0	7.5	2.0
Mean ± SD	72.2 ± 5.0	91.9 ± 2.7	67.2 ± 5.5	87.8 ± 3.4	11.9 ± 5.0	−0.1 ± 2.1	3.4 ± 1.5	9.4 ± 4.5	2.7 ± 1.2

Preop: preoperative, Postop: postoperative, ASES: American Shoulder and Elbow Surgeons, CCD: coracoclavicular distance, OLac: overlapping length of the acromioclavicular joint, SD: standard deviation.

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Table 3. Comparison of Clinical Results between Anatomic Reduction and Partial Loss of Reduction

Reduction quality	Anatomic reduction (n = 7)	Partial loss of reduction (n = 3)	*p*-value
ASES score			
Preoperative	73.3 ± 5.3	69.7 ± 3.5	
Postoperative	92.9 ± 2.5	89.7 ± 1.5	
Improvement	18.1	20.0	0.20
Constant score			
Preoperative	68.9 ± 5.7	63.3 ± 2.9	
Postoperative	88.7 ± 3.2	85.7 ± 3.5	
Improvement	19.9	22.3	0.25

Values are presented as mean ± standard deviation.
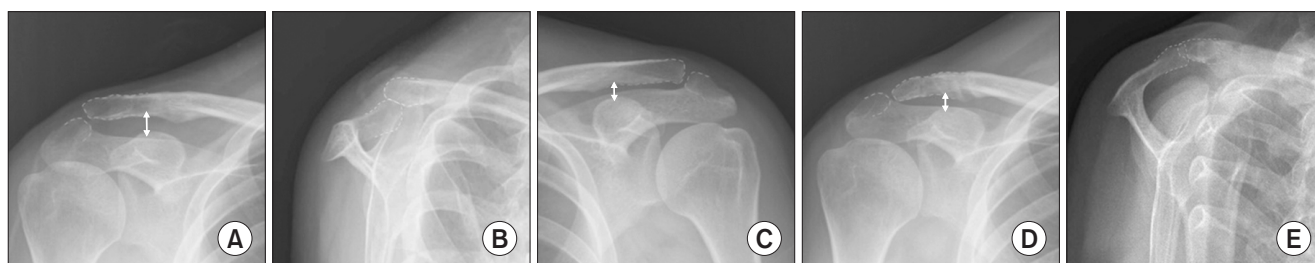ASES: American Shoulder and Elbow Surgeons.

Fig. 4. A 57-year-old male patient who underwent ligament reconstruction. (A, B) Type III injury, preoperative Zanca view and modified Alexander view. (C) Zanca view of the contralateral side. (D, E) Anatomic reduction at final follow-up. Double-headed arrows represent the coracoclavicular distance.
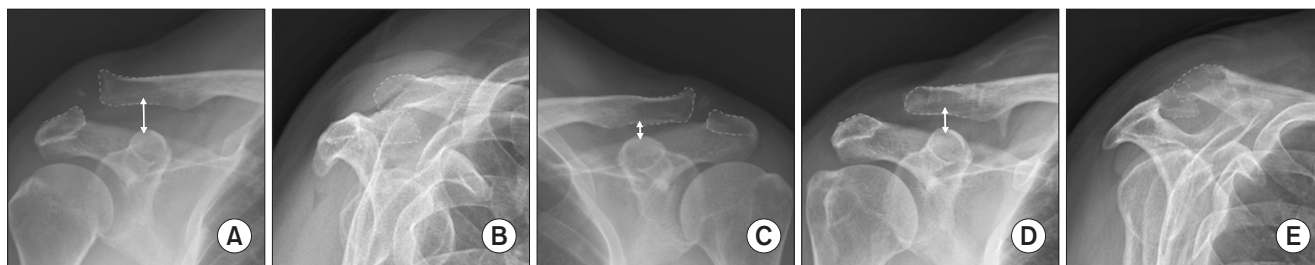

Fig. 5. A 46-year-old male patient who underwent ligament reconstruction. (A, B) Type V injury, preoperative Zanca view and modified Alexander view. (C) Zanca view of the contralateral side. (D, E) Partial loss of reduction at final follow-up. Double-headed arrows represent the coracoclavicular distance.

DISCUSSION

In this study, we noted acceptable clinical results in concomitant AC and CC ligament reconstruction using a single autogenic tendon graft; patients either had anatomic reduction or partial loss of reduction. In existing surgical techniques for ligament reconstruction, the graft for CC ligament reconstruction is fixed with an interference screw, suspensory button, or tendon-knot.[12,14,15] Several

surgeons have performed AC ligament reconstruction with a remaining tendon graft, including over-the-top suturing, the docking method, direct suturing to the trapezial fascia, and looping the acromion through the vertical tunnel or intramedullary tunnel (Table 4).[8-14] The procedure we described in this study comprises initial tendon-knot fixation for CC ligament reconstruction and subsequent combined transacromial looping into the intramedullary. None of the clinical studies on the tendon-knot technique has featured

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Table 4. Summary of Reported Surgical Techniques of CC and AC Ligament Reconstruction and Their Results

Study	Case number	CC ligament reconstruction	AC ligament reconstruction	Clinical result		Radiographic result	
				Preop	Postop	Partial loss of reduction (n)	Recurrent dislocation (n)
Choi et al. (2017)[15]	30	Auto-semitendinosus tendon-knot + cerclage suture	×	×	ASES score, 93	14	1
Baran et al. (2018)[21]	17	Allograft tendon-knot + cerclage suture	×	×	ASES score, 81	4	0
Millett et al. (2015)[17]	31	Allograft tendon-knot + cerclage suture	×	ASES score, 59	ASES score, 94	×	3
Garofalo et al. (2017)[11]	32	Auto-semitendinosus + cerclage suture	Remaining graft loop via vertical acromial tunnel	ASES score, 42	ASES score, 85	7	0
Fauci et al. (2013)[10]	20	Allograft + interference screw	Remaining graft trans-osseous suture	CS, 44	CS, 94	4	1
Jensen et al. (2013)[12]	16	Auto-gracilis tendon + suspensory button	Remaining graft loop via intramedullary acromial tunnel	×	SST, 9	4	1
Kibler et al. (2017)[13]	15	Allograft + cerclage suture	Remaining graft docking	DASH, 51	DASH, 13	×	1
Banffy et al. (2018)[8]	17	Allograft tendon + suspensory button + cerclage suture	Remaining graft over-the-top suture	ASES score, 67	ASES score, 90	×	1
Carofino and Mazzocca (2010)[9]	17	Allograft + interference screw	Remaining graft over-the-top suture	ASES score, 52; CS, 67	ASES score, 92; CS, 95	×	1
Muench et al. (2019)[14]	43	Allograft + interference screw	Remaining graft over-the-top suture	ASES score, 52	ASES, 82	×	2

CC: coracoclavicular, AC: acromioclavicular, Preop: preoperative, Postop: postperative, ASES: American Shoulder and Elbow Surgeons, CS: Constant score, SST: Simple Shoulder Test, DASH: Disability of Arm, Shoulder and Hand Score, ×: reconstruction not performed or result not mentioned in the literature.

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the use of the remaining graft for additional AC ligament reconstruction (Table 4).[15,17,21]

Our reconstruction procedure, the "duo-figure-8" graft wrapping method, aims to mimic the native AC and CC ligaments that are the major restraints of the AC joint in the horizontal and vertical planes, respectively. Choi et al.[15] conducted a case series study for isolated CC ligament reconstruction and noted complications of 47% loss of reduction and 23% recurrent dislocation. Their argument that additional AC ligament reconstruction is necessary has been supported by biomechanical studies.[22] Beitzel et al.[23] compared 4 *in vivo* AC ligament reconstruction methods (the wrapped, intramedullary, transacromion, and figure-8 methods) and found the wrapped and intramedullary methods to offer superior stability to others. Garg et al.[24] demonstrated that intramedullary AC ligament reconstruction yields a slighter anterior–posterior translation and a higher ultimate load relative to extramedullary reconstruction. Reviewing previous clinical studies of concomitant AC and CC ligament reconstruction, Jensen et al.[12] used the suspensory button with an integrated autogenic gracilis tendon for one-tunnel CC ligament reconstruction, and they also performed intramedullary AC ligament reconstruction. Similar to our results, 4 of 16 of their patients had partial loss of reduction, and the mean of the Constant scores was 84.0 in their series. Several authors have proposed the "remaining graft over-the-top suturing" method to restore the superior portion of the AC ligament that is the main restraint for anterior–posterior translation,[25] with satisfactory clinical results.[8,9,14] Accordingly, we performed intramedullary AC ligament reconstruction and sutured the remaining pulled-back graft upon itself superiorly to reinforce the superior portion of the AC ligament.

As for the correlation between clinical and radiographic outcomes, Garofalo et al.[11] reported that 22% of their patients (7 of 32) had partial loss of reduction and none had a revision surgery or a poor result. Similarly, the CC distance and functional score have not been correlated in previous studies.[16,26] Partial loss of reduction has been noted to result from graft elongation, which has occurred at either the mid-substance or the graft–screw interface during the healing period.[27,28] In a biomechanical study by Lee et al.,[5] the semitendinosus tendon had significantly greater elongation than did the native CC ligament before failure. However, the ultimate strengths of the native CC ligament and the semitendinosus tendon did not significantly differ. In our series, graft elongation was common in the healing period. We posit that the graft was sufficiently strong to maintain its integrity, which explains why no patient encountered recurrent dislocation. At final follow-up, the clinical outcomes of patients with partial loss of reduction were comparable with the anatomic reduction in our series. This finding is consistent with the aforementioned studies, which implies that the stiffness and integrity of the CC and AC connection were emphasized in functional recovery instead of reduction quality. Nevertheless, we fixed the graft in a slightly over-reduced position; 6 of 10 patients had overreduction immediately after surgery, and 5 patients achieved anatomic reduction at final follow-up. Overreduction was an alternative for reaching the anatomic position after graft union because elongation occurred in most tendon grafts during the healing period.

Combined distal clavicle resection in chronic AC separation is necessary for the treatment of associated arthritis. Distal clavicle resection damages the AC ligament, decreases joint contact force, and greatly increases CC graft load.[25] Nonetheless, we still performed routine distal clavicle resection to reduce joint contact force and prevent further deterioration into arthritis. Kowalsky et al.[29] reported a significant increase in CC graft load after resection of the AC ligament and distal clavicle. Therefore, AC ligament reconstruction is necessary to protect the CC graft in the healing period and replace the joint contact force.

Graft failure and fractures of either the clavicle or coracoid process have been common problems after ligament reconstruction.[15-17] Clavicle fracture can occur in CC ligament reconstruction using the two-tunnel technique. It can be prevented by using a smaller tunnel, increasing the bone bridge between the two tunnels, fixing the graft without using interference screws, and improving patient compliance without early strenuous exercise.[26] We suggest that the conoid and trapezoid tunnels should be placed 20 mm apart with a maximal tunnel width of 5 mm to prevent clavicle fracture. We applied the graft beneath the coracoid process instead of through the coracoid tunnel because graft looping lowers the risk of coracoid process fracture.[9] Graft failure resulted from increased stress over the graft–screw interface.[27] Therefore, we tied two graft tails to each other on the distal clavicle without using an interference screw. This tendon-knot technique has been reported in previous studies.[15,17,21] Although graft elongation, known as cyclic creep, was greater in the tendon-knot structure than the interference screws, the former yielded better ultimate strength.[28] Furthermore, disused osteoporosis over the distal clavicle increased the graft-pullout risk, particularly with interference screw fixation.[30]

Creating the intramedullary tunnel into the acromion for the tendon-graft looping around it may bear the

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risk of acromion fracture. Jensen et al.[12] conducted AC ligament reconstruction by using this technique, and a similar surgical procedure was performed in our series. However, no patients encountered acromion fracture in either their study or our series. Owing to the morphology of the acromion, cortex blowout when creating the tunnel is a concern of surgeons. To prevent superior cortex blowout, we made a slightly oblique acromial tunnel in the superolateral-to-inferomedial direction.

For preventing excessive elongation of the tendon graft in the healing period, ideal implant augmentation after ligament reconstruction remains controversial. The surgical methods for protecting the graft have included the use of nonabsorbable tape, suture cord, suspension button, or cerclage wire.[7,8,11,21] Metal implants carry the risk of complications of skin irritation, requiring secondary surgery to remove them. Therefore, we used a nonabsorbable tape to protect the CC graft, and none of our enrolled patients underwent secondary surgery.

The present study has several limitations. The first is selection bias and weak statistical power from our retrospective research design and small sample size. The second is our follow-up with a mean of 25 months, which is insufficient for determining graft longevity and late complications. The third is our use of the ASES and Constant scores to evaluate the functional results of the AC joint. Although these scores have been used in the literature, no standard and validated scoring system exists for the AC joint. Fourth, chronic AC injury (the time from trauma to surgery over 6 weeks, 3 months, or 6 months) has no consensus on the definition. Finally, we did not directly compare concomitant AC and CC ligament reconstruction with isolated CC ligament reconstruction. Because most patients with a high-graded AC injury underwent surgery in the acute stage, we had too few chronic cases to directly compare different reconstruction techniques. To eliminate performance bias, we had only 1 surgeon conduct all ligament reconstruction procedures and all evaluations of the follow-up data.

Patients receiving concomitant AC and CC ligament reconstruction with a single autogenic tendon graft achieved acceptable functional outcomes—either anatomic reduction or partial loss of reduction—during the mid-term follow-up. The "duo-figure-8" graft wrapping method—a graft passing beneath the coracoid process with a tendon-knot fixation over the distal clavicle and looping around the acromion intramedullary—does not increase the risks of peri-tunnel fractures over the clavicle, coracoid process, or acromion.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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