# Functional and Radiographic Outcomes After Allograft Anatomic Coracoclavicular Ligament Reconstruction

*Sean Baran, MD, Jeffrey G. Belisle, MD, Erin K. Granger, MPH, and Robert Z. Tashjian, MD*

**Objectives:** To analyze the functional and radiographic outcomes of anatomic coracoclavicular ligament reconstruction (ACCR) using allograft tendon without interference screw fixation.

**Design:** Retrospective nonrandomized study.

**Setting:** Level I trauma center (University Hospital).

**Patients:** Seventeen patients (mean age of 44 years) with Rockwood III through V acromioclavicular joint disruptions. Twelve of 17 patients had a primary reconstruction, including 4 patients sustaining their injuries as part of a polytrauma incident. Five of 17 patients were revisions of a previously failed acromioclavicular reconstruction procedure.

**Intervention:** Open ACCR using hamstring allograft with high-strength suture augmentation and knotted graft fixation without interference screws.

**Main outcome measures:** Clinical and patient reported outcome measures including Simple Shoulder Test, American Shoulder and Elbow Surgeons scores, and visual analog scale scores for pain and radiographic outcomes.

**Results:** The average final postoperative Simple Shoulder Test and American Shoulder and Elbow Surgeons scores were 10.8 and 80.5, respectively. The average final postoperative visual analog scale pain was 1.8. All patients demonstrated clavicle tunnel widening on final postoperative radiographs compared with immediate postoperative radiographs. The overall complication rate was 36%, with no clavicle or coracoid fractures.

**Conclusions:** Open ACCR using hamstring allograft tendon secured with a square knot and high-strength suture augmentation yields equivalent outcomes to those repairs requiring an additional interference screw. Clavicle tunnel widening predictably occurs, but the clinical significance is undetermined. It appears therefore that an interference screw is not needed. Larger comparison studies are needed.

**Key Words:** coracoclavicular ligament reconstruction, acromioclavicular joint separation, allograft hamstring, tunnel widening

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From the Department of Orthopaedics, University of Utah School of Medicine, Salt Lake City, UT.
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Reprints: Robert Z. Tashjian, MD, University of Utah Orthopaedic Center, 590 Wakara Way, Salt Lake City, UT 84108 (e-mail: Robert.Tashjian@hsc.utah.edu).

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## INTRODUCTION

Acromioclavicular (AC) joint injuries are common with an estimated 1.8 injuries per 10,000 persons per year in a general population.[1] These rates are higher among a young athletic population with an incidence of 9.2 injuries per 1000 person-years.[2–6] Despite the prevalence of these injuries, the ideal treatment strategy remains elusive. AC joint separations can be classified by the magnitude and direction of displacement according to the system originally described by Rockwood.[7] This classification system has historically dictated treatment algorithms with minor injuries, involving minimal displacement (Rockwood grades I and II), being treated nonoperatively, whereas more severe injuries with greater displacement (Rockwood grades IV–VI) are treated operatively. Initial treatment of grade III injuries has been controversial, with some advocating early surgery, while others recommend early conservative treatment.[8–14]

Early techniques of AC joint reconstruction for AC joint separations were associated with poor outcomes and significant complications. Anatomic coracoclavicular ligament reconstruction (ACCR) was initially described by Mazzocca et al[15] using clavicle bone tunnels and interference screws for clavicle graft fixation. In the last decade, ACCR has been considered a biomechanically superior technique to previously described constructs.[15] Despite short-term clinical follow-up showing generally good to excellent outcomes, the complication rate remains high with an overall rate of 39.8%.[16] Millett et al[16] noted that the risk of complications raised a red flag with respect to early surgical intervention, particularly of grade III injuries. They emphasized, however, that the risk of complications must be weighed against evidence demonstrating the potential for long-term dysfunction, resulting from scapular dyskinesis and potential rotator cuff dysfunction in patients treated nonoperatively.[17–23]

An alternative method of fixation of the graft is to tie the ends of the graft together in a square knot after passage through the clavicle bone tunnels. Advantages of a knotted technique without screws include lower costs and potentially less graft injury from the screws. If the clinical and radiographic outcomes of a knotted graft were equivalent to an ACCR using interference screws for fixation, there might ultimately be a cost savings using the knotted graft technique. Limited clinical data are available using a knotted graft technique without interference screw fixation.[26]

The purpose of this study was to clinically and radiographically evaluate patients undergoing ACCR using free tendon allograft and high-strength suture augmentation. Our hypothesis was that a reconstructive technique using allograft fixed with a square knot, and no interference screws would have equivalent outcomes and complication rates to historically reported outcomes for ACCR with interference screw fixation. If this were true, then the need for interference screws and their associated costs must be questioned.

## Surgical Indications and Technique

In general, patients were indicated for surgery if they had a persistently symptomatic high-grade (III–V) AC joint separation that had failed a period of nonoperative management or if they had an acute grade IV or V injury and the patient elected to have early surgical reconstruction. Three grade V injuries that presented acutely were offered conservative or surgical intervention and chose acute surgical intervention. The remaining 14 patients had chronic injuries. The mean duration of symptoms before operative treatment was 772 days (range, 6–2872 days), with only the 3 patients having acute grade V injuries receiving surgical treatment before 90 days after injury. Overall, there were 6 grade III injuries, 1 grade IV injury, and 10 grade V injuries.

Patients received a general anesthetic and were placed in the beach chair position. All patients received one dose of standard preoperative antibiotics (cefazolin or clindamycin). A superior strap incision was made starting 1 cm medial to the AC joint running from just posterior to the clavicle to the level of the coracoid. Skin and subcutaneous tissues were dissected down to the deltotrapezial fascia that was incised longitudinally in line with the clavicle and then released to its undersurface. Tunnel positions for the trapezoid and conoid ligaments were planned and marked by measuring 2.5 and 4.5 cm, respectively, from the distal clavicle. Tunnels were positioned centrally in the clavicle in an anteroposterior (AP) direction to maximize bone bridges on the anterior and posterior aspects of the tunnels. A distal clavicle resection of 7 mm was performed using a sagittal saw. The tunnels were drilled sequentially with a 5.0-mm drill bit, and a passing suture was placed through each tunnel. In the first 5 cases of the series, a coracoacromial (CA) ligament transfer was added by dissecting the CA ligament free from the undersurface of the acromion, whip-stitching the free end in a Krackow fashion with #2 high-strength nonabsorbable suture (Fiberwire; Arthrex, Naples, FL), and passing the tails through two 2-mm drill holes near the end of the clavicle to be tied at the time of reduction. CA ligament transfer was abandoned after the first 5 cases because biomechanical data from Clevenger et al[31] suggested that there was no initial added biomechanical strength with the addition CA ligament transfer to the graft reconstruction.

Blunt dissection was carried down toward the coracoid, and a suture was passed from medial to lateral around the coracoid using a right angle clamp. A semitendinosus hamstring allograft between 6 and 7 mm in folded diameter (Musculoskeletal Transplant Foundation, Edison, NJ) was used. The allograft was not pretensioned. The allograft was whip-stitched at each end with #2 high-strength nonabsorbable suture (Fiberwire; Arthrex) in a Krackow fashion, and the graft, in addition to two #5 high-strength nonabsorbable strands of suture (Fiberwire; Arthrex), was passed beneath the coracoid using the passing suture. All tails were then passed through the tunnels in the clavicle using passing sutures. The clavicle was reduced with the intention to over reduce the clavicle as much as possible by pushing down on the clavicle and up on the elbow, and the two #5 nonabsorbable high-strength cerclage sutures were tied to hold the

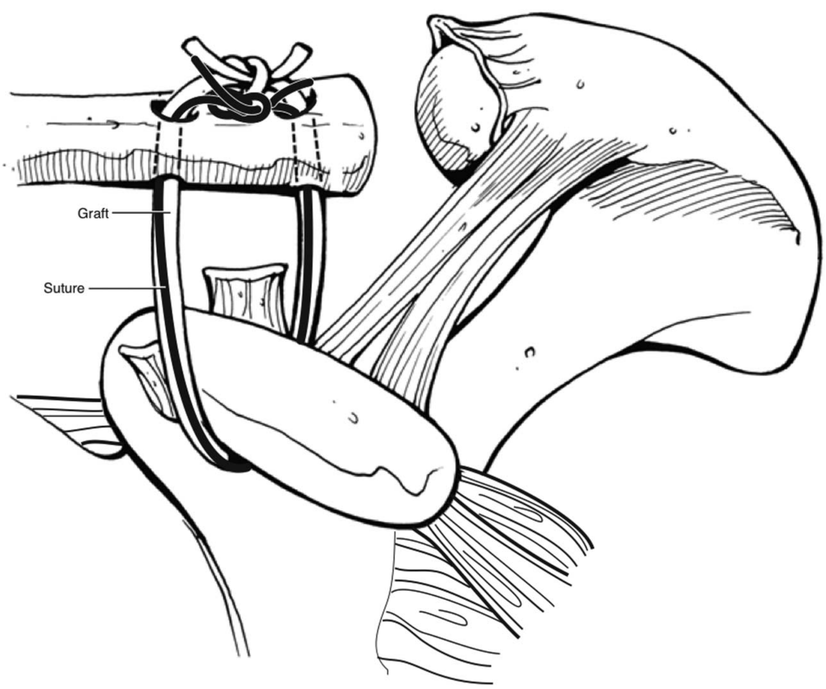


**FIGURE 1.** AC joint reconstruction using a hamstring allograft tendon graft looped under the coracoid brought up through 2 bone tunnels in the clavicle and tied in a square knot augmented with high-strength suture cerclages.

reduction. The graft was then tied on itself in a square knot. Each hitch was oversewn with two #2 high-strength nonabsorbable sutures (Fiberwire; Arthrex) using figure-of-eight stitches. The deltotrapezial fascia and AC joint capsule were repaired in a pants-over-vest fashion and imbricated (Fig. 1).

### Postoperative Rehabilitation

Patients were placed in an abduction sling for 6 weeks postoperatively allowing pendulums and elbow, wrist, and hand range of motion. At 6 weeks, the abduction sling was discontinued, and patients were allowed passive and active external rotation with the arm at the side and forward elevation limited to 90 degrees. At 9 weeks postoperatively, patients were progressed to full passive and active range of motion with a 5 pound lifting restriction. Gentle strengthening was begun at 3 months after surgery with a 20 pound lifting restriction. At 4.5 months, the lifting limit was increased to 40 pounds, and patients were released to full activities at 6 months postoperatively.

## PATIENTS AND METHODS

Between January 2007 and October 2013 at a single institution, the senior author (R.Z.T.) performed 28 ACCR procedures with free tendon allograft and high-strength suture augmentation (without interference screws) for Rockwood grade III to V AC joint disruptions. The senior author has kept a prospective surgical log of every surgical case performed since initiating practice. Seven years of logs (2007–2013) were queried to obtain the list of potential patients to include in the study. Hospital institutional review board approval was obtained before initiation of this study. Patients were routinely followed clinically for at least 1 year postoperatively. Patients failing to return for a 1-year postoperative follow-up appointment were sent a letter and contacted by phone to determine whether they had interest in returning for an evaluation. Patients were contacted again at approximately 2 years postoperatively to obtain repeat patient-reported outcome measures collected by phone, mail, or email. Incarcerated patients were excluded per University policy, leaving 24 patients available for study, and 18 of 24 (75%) patients returned for clinical evaluation and consented to inclusion in the study. One additional patient was excluded from the final analysis after sustaining a new injury to the operative shoulder resulting in a rotator cuff tear and confounding interpretation of ACCR outcomes, leaving a total of 17 patients for final analysis.

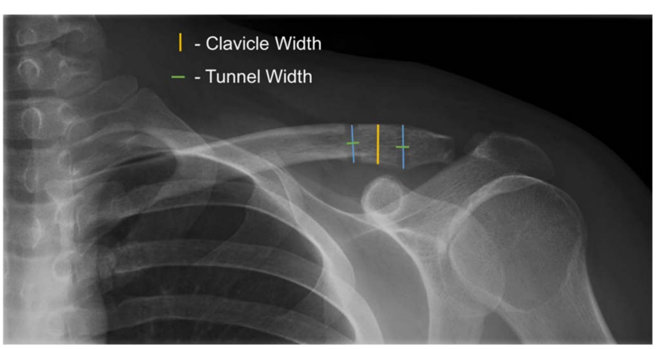


**FIGURE 2.** Tunnel widening was assessed over time by measuring the TW at the vertical midpoint of each tunnel (green line) and normalizing this to the CW midway between the tunnels to find the ratio (TW/CW). **Editor's Note:** A color image accompanies the online version of this article.

At the time of clinical follow-up, an AP and axillary radiograph were obtained, a trained research assistant performed a physical examination (range of motion using a goniometer), and the patient completed outcomes questionnaires for Simple Shoulder Test (SST), American Shoulder and Elbow Surgeons (ASES) score, and a visual analog scale (VAS) for pain. Mean duration of clinical follow-up with physical examination and radiographs was 3 years (range, 1.1–6.2 years; SD, 1.4 years). Mean duration of follow-up for patient-reported outcomes was 3.5 years (range, 1.9–6.2 years; SD 1.0 years). Demographic and surgical procedure information were recorded.

AP radiographs were reviewed for loss of reduction and tunnel width at the first postoperative visit (within 30 days of surgery) and again at final clinical follow-up. Radiographs were not obtained with a magnetic marker, prohibiting precise measurements and comparisons over time or between patients. Therefore, determination of loss of reduction was made based on the relative position of the clavicle in comparison with the acromion on sequential AP radiographs. Tunnel width (TW) was compared by normalizing the width of the tunnel at its vertical midpoint to the thickness of the clavicle directly between the tunnels (CW) (Fig. 2). This method created a ratio (TW/CW) and could then be compared between immediate postoperative AP radiographs and final postoperative AP radiographs. Measurements were made on separate occasions with 1 week between measurements using Phillips IntelliSpace PACS Enterprise 4.4 software (Philips, Andover, MA) and then averaged to arrive at the final measure. Two different orthopaedic surgeons (S.B. and J.G.B.), who were not the primary surgeon, performed the radiographic analysis. Complications were recorded as major (deep infection, loss of reduction greater than 50% of the clavicle width or fracture—coracoid or clavicle), or minor (loss of reduction less than 50% of the clavicle width).

### Statistical Methods

Differences between preoperative and postoperative patient-reported outcome scores, as well as changes in tunnel width to clavicle width (TW/CW) ratio over time were analyzed using 2-tailed paired Student *t* test. Comparisons in outcome scores among the patients undergoing primary reconstruction without polytrauma, and those with primary reconstruction after polytrauma or revision, as well as between those with and without CA ligament transfers, were made using a two-tailed, unpaired Student *t* test. Statistical significance was set at $P < 0.05$.

## RESULTS

There were 17 patients (15 male) with high-grade AC injuries (Rockwood grade III through V) who underwent

ACCR included in this study. The average age at the time the procedure was performed was 44 years (range, 28–73 years). Five (29%) procedures were revisions for failed AC reconstructions performed at other facilities, and 4 (24%) patients sustained their AC joint separation as part of a multiple trauma incident. Demographic and surgical information and injury characteristics are summarized in Table 1.

## Clinical and Radiographic Outcomes

Range of motion measures as performed on repeat clinical examination an average of 2.9 years after surgery were available for 16 patients. Mean active forward elevation was 156 degrees (range, 115–170 degrees; SD 17 degrees), and mean external rotation was 60 degrees (range, 40–90 degrees; SD 12 degrees). The 5 patients undergoing revision reconstruction had mean active forward elevation and external rotation of 153 degrees (range, 120–170 degrees; SD 20 degrees) and 60 degrees (range, 60–90 degrees; SD 13 degrees), respectively. In the primary reconstruction group, the 4 patients having sustained their AC separation as part of a polytrauma incident had mean active forward elevation and external rotation of 148 degrees (range, 115–170 degrees; SD 23 degrees) and 57 degrees (range, 45–68 degrees; SD 10 degrees), respectively compared with the non–polytrauma primary reconstruction group in which 7 of 8 patients had final range of motion measurements of 162 degrees (range 150–170 degrees; SD 9 degrees) and 56 degrees (range 40–70 degrees; SD 11 degrees). No statistical significance was found between any of the groups for final range of motion ($P > 0.05$).

On radiographic analysis, 4 patients (3 with CA ligament transfer) experienced <50% loss of reduction between 2 and 6 months postoperatively, and no further treatment was rendered. The average ratio of tunnel width to clavicle thickness on the immediate postoperative radiograph was 0.42 (SD, 0.09) for the lateral tunnel, which increased to 0.57 (SD 0.13) at final radiographic follow-up ($P = 0.007$). Similarly, for the medial tunnel, the average ratio was 0.44 (SD, 0.08) immediately postoperatively, increasing at final follow-up to 0.59 (SD 0.12) ($P = 0.003$). Medial tunnel widening was noted in 15 patients, and lateral tunnel widening was noted in all 17 patients.

**TABLE 1.** Demographic and Injury Characteristics, Surgical Information

| | |
|---|---|
| Patient Demographics | |
| No. shoulders | 17 |
| Men | 15 |
| Mean age, y (SD) | 44 (16.4) |
| Injured shoulder | |
| Right | 5 |
| Left | 12 |
| Rockwood grade | |
| III | 6 |
| IV | 1 |
| V | 10 |
| CA ligament transfer | 5 |
| Timing of surgery | |
| Greater than 90 d after injury | 14 |
| Less than 90 d after injury | 3 |
| Revision procedures (original failure) | |
| Failed Rockwood screw | 2 |
| Single tendon graft with interference screw in clavicle and coracoid | 1 |
| Permanent suture/button fixation | 1 |
| Concomitant polytrauma | |
| Distal clavicle fracture | 2 |
| Bilateral sternoclavicular joint dislocations | 1 |
| Pelvic trauma | 1 |

## Patient-Reported Outcomes and Comparisons

Patient-reported outcome data were available at a mean follow-up of 3.5 years (range, 1.9–6.2 years; SD 1.0 years). Table 2 summarizes the SST, ASES, and VAS scores. The average SST score was 10.8 (SD, 1.7) for the entire cohort. Excluding the patients with polytrauma, 10 of 14 patients had normal or near-normal scores of 11 or 12. The mean ASES score of the entire cohort was 80.5 (SD, 20.4). Nine patients had ASES scores greater than 90, with the majority of lower scores occurring in revision or in patients with polytrauma. There was no statistically significant difference in outcome scores when comparing the non–polytrauma primary reconstruction group to the revision cohort or those sustaining a polytrauma injury. Similarly, no significant difference in SST ($P = 0.41$), ASES ($P = 0.20$), or VAS pain ($P = 0.07$) was detected comparing those with and without CA ligament transfer.

## Complications

Two of 17 patients had a complication requiring return to the operating room, one for graft failure and the second for deep infection. In the first case, a primary reconstruction without CA ligament transfer had an atraumatic failure with >100% superior displacement of the clavicle at 2 months postoperatively. This was initially treated with of nonoperative measures, but the patient returned for a reconstruction at 3 years postindex procedure, secondary to persistent symptoms. The second patient presented with deep infection 3 months after revision reconstruction after failed acute AC reduction with a suture/cortical button technique at an outside facility. Multiple irrigation and debridement procedures and distal clavicle resection for osteomyelitis were required. There were 4 additional patients (2 primary reconstructions without polytrauma, 1 primary reconstruction with polytrauma, and 1 revision reconstruction) with less than 50% loss of reduction discovered on radiographs between 2 and 6 months postoperatively. All these patients were asymptomatic and required no further treatment. There were no postoperative clavicle or coracoid process fractures. Overall, there was a 12% rate of major complications (2 patients returning to the operating room, one for infection and the other for complete graft disruption) and a 24% rate of minor complications (<50% loss

**TABLE 2.** Postoperative Outcome Measures

| | Overall | Nonpolytrauma* | Polytrauma* | Revision |
|---|---|---|---|---|
| SST score | 10.8 (1.8) | 11.4 (1.1) | 9.8 (2.9), $P = 0.62$ | 10.9 (1.6), $P = 0.88$ |
| ASES score | 80.5 (20.4) | 86.3 (19.7) | 72.0 (26.5), $P = 0.53$ | 78.2 (17.7), $P = 0.87$ |
| VAS pain | 1.8 (2.0) | 1.3 (1.9) | 2.1 (2.7), $P = 0.25$ | 2.4 (1.9), $P = 0.80$ |

Polytrauma and revision reconstructions were compared with the non–polytrauma reconstructions, and *P* values are listed.
Data are presented as mean (SD) unless otherwise noted.
*Primary reconstruction.

of reduction on follow-up x-rays) for an overall complication rate of 36%.

## DISCUSSION

AC joint reconstruction may be considered acutely for grades IV, V, and VI separations and for grade III separations in manual laborers and competitive athletes, or in a chronic grade III to VI separations failing a trial of conservative treatment.[8–14] Despite biomechanical and clinical evidence in support of AC joint reconstruction, complications remain common.[16,24] In our series of patients with a mean 3.5 years follow-up using allograft tendon with knotted graft fixation and high-strength suture augmentation, we have demonstrated excellent overall patient-reported outcomes with few major complications. Functional outcome scores are comparable with previously reported series using interference screws as well as a small series of patients using a knotted graft as reported by Nicholas et al[16,25–27] Similarly, both major and minor complication rates are comparable with previously reported data.[16,28,29] Tunnel widening was present almost universally in the current series and has not been previously reported in a series of patients after ACCR without interference screw fixation. Consequently, widening is not necessarily associated with the type of fixation but rather the presence of a tendon graft passed through holes in the clavicle.

There is biomechanical evidence to support the surgical technique used. Tashjian et al[30] examined AC joint reconstruction using hamstring allograft looped beneath the coracoid in cadaveric shoulders and compared clavicular-side fixation with polyethyl ethyl ketone (PEEK) interference screws, square-knot in the graft, and side-to-side repair of the graft. The authors found superior ultimate strength with the square-knot technique. It should be noted in the current series that 5 of the patients did have a concomitant CA ligament transfer. CA ligament transfer was purposefully abandoned part way through the study period, given evidence from Clevenger et al[31] that CA ligament transfer does not improve time-zero biomechanical strength over tendon reconstruction with high-strength suture augmentation.

The current series had a major complication rate of 12%. The overall complication rate, including those patients with asymptomatic graft stretch resulting in <50% clavicle displacement, was 36%, which is consistent with recent reports after ACCR.[16] Importantly, we did not observe any postoperative clavicle or coracoid fractures. Risk of coracoid fracture has been reported with various ACCR techniques,[32,33] and this was minimized in our series by looping the graft around the coracoid instead of drilling through the coracoid. On the clavicular side, Dumont et al[34] demonstrated no difference in clavicle load to failure for 5-mm tunnels with and without 5.5-mm PEEK interference screws in a Sawbones model. Although our knotted graft technique may minimize the risk of clavicular fractures, Carofino and Mazzocca did not report any clavicle fractures in their series of patients with PEEK screw fixation.[25] In the current series, 5-mm tunnels were used in the clavicle, and this is at the lower end of the spectrum of tunnel size that has been associated with clavicle fractures according to multiple recent studies.[34–38]

We found a statistically significant increase in the clavicle tunnel width between the immediate postoperative and final radiographs for both the medial and lateral tunnels. Yoo et al[28] reported a single case of "severe" tunnel widening in which tunnels drilled at 4.5 mm had increased to over 11 mm by 10 months postoperatively after ACCR with semitendinosus autograft without interference screw fixation. More recently, in a series of patients undergoing ACCR with autograft hamstring tendon fixed with PEEK (8 patients) or bioabsorbable (17 patients) interference screws, the authors noted tunnel widening in 20 of 25 patients.[39] They found no association of tunnel widening with screw type, and tunnel widening was not predictive of AC joint stability or of Constant, Disabilities of the ARM, Shoulder and Hand, or VAS pain scores at the final follow-up[40–42] Further study is required to determine the clinical implication of tunnel widening in AC joint reconstruction, as well as strategies to potentially prevent widening.

Clinical outcomes after ACCR have been reported in multiple studies with various techniques. These results have been generally good to excellent. Nicholas et al,[26] Tauber et al,[43] Carofino and Mazzocca,[25] and Millett et al[16] have independently reported mean ASES scores of 92–96 with 6–46 months follow-up after primary ACCR procedures. Average SST scores with similar follow-up after primary ACCR range from 9 to 11.9.[25,26,29] In a revision cohort of 12 patients undergoing ACCR with autogenous tendon, patients had generally good-to-excellent results with mean Constant score of 76.4.[27] In our series of patients, the mean SST score was 10.8 (SD, 1.7), and the mean ASES score was 80.5 (SD, 20.4). The lower scores were predominantly isolated to the patients with polytrauma and those undergoing revisions. No statistically significant difference in outcome scores was found comparing non–polytrauma primary reconstructions to polytrauma primary reconstructions and revision reconstructions, or between patients with and without CA ligament transfer; however, the number of patients is small. It has been established that patients with polytrauma sustaining even low-grade injuries have worse disease-specific and general health outcomes than isolated AC injuries.[44] The inclusion of revision and patients with polytrauma, as well as tabulation of final outcomes scores including those in patients having major complications likely contributes to the comparably lower SST and ASES scores as well as their large SD. VAS scores for pain were all acceptable at the final follow-up and consistent with VAS pain scores previously reported in the literature.[29,45–48]

There are several limitations to this study consistent with those in previously published reports on ACCR. First, the wide range of techniques and outcome measures reported in AC joint treatment makes cross-study comparison difficult. Second, the retrospective nature of the study and limited sample size, as well as those patients lost to follow-up, may bias our findings. Third, ASES, SST, and VAS scores, although commonly reported in the literature on AC joint injuries, have not been validated for that use. Fourth, inclusion of patients who have sustained a polytrauma accident or who are undergoing a revision procedure may be viewed as a weakness, but it is representative of the population treated at a Level I center. Fifth, although similar to previously published reports, the number of patients in the study is small and limits statistical comparison among groups secondary to power. The method for calculation of tunnel width was developed due to lack of standardized markers and has variability and some degree of error. Also, inter- and intra-observer agreement were not performed to validate the measure.

In conclusion, ACCR with allograft hamstring tendon and knotted graft fixation results in generally good-to-excellent outcomes at the final follow-up. Complication rates, both major and minor, are significant but consistent with previous studies evaluating ACCR. Consequently, graft fixation without interference screws seems to offer cost savings without compromise of clinical results. Larger prospective, randomized studies, will be needed to determine the validity of this statement.

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