Graft Healing Is More Important Than Graft Technique: Superior Capsular Reconstruction Versus Bridging Grafts—A Prospective Randomized Controlled Trial

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**Purpose:** To compare superior capsular reconstruction (SCR) versus bridging graft (BG) for massive irreparable rotator cuff tears (RCTs).

**Methods:** A prospective double-blind randomized study was conducted to compare SCR versus BG for massive irreparable RCTs. Fifty patients (mean age: 60.2 ± 6.0 years) with chronic tears (mean duration of symptoms: 5 ± 5.2 years) were intraoperatively randomized following partial repair to SCR or BG using human dermal allograft. All patients underwent standardized rehabilitation and were followed at 3, 6, 12, and 24 months clinically and radiographically. Magnetic resonance imaging were obtained at 12 months to determine graft integrity.

**Results:** At 2 years, 46 patients were available for follow-up. Mean American Shoulder and Elbow Surgeons (ASES), Western Ontario Rotator Cuff (WORC), and Quick Disabilities of the Arm, Shoulder and Hand scores were 74.8 ± 23.9, 66.0 ± 28.3, and 24.7 ± 26.1 for the SCR group, and 77.9 ± 19.9, 69.5 ± 24.5, and 25.0 ± 19.1 for the BG group, respectively, with no significant difference between groups. Magnetic resonance imaging demonstrated 18 of 24 (75%) in the SCR group and 14 of 22 (64%) in the BG group were intact at 12 months (P = .53). Patients with intact grafts compared with those with torn grafts, whether SCR or BG, had greater ASES and WORC scores at 24 months (ASES 81.0 ± 18.7 vs 65.7 ± 24.4, P = .021 and WORC 72.3 ± 24.6 vs 53.7 ± 26.7, P = .04) and greater acromiohumeral intervals on radiographs at all follow-up time points.

**Conclusions:** When performing arthroscopic reconstruction using human dermal allograft for an irreparable RCT, whether the proximal edge of the graft is attached on the glenoid bone or to the torn tendon does not significantly change short-term clinical and radiographic outcomes.

**Level of Evidence:** I, therapeutic.

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Treatment of massive irreparable rotator cuff tears (RCTs) without arthritic change in the young patient remains controversial. A variety of surgical options have been proposed, including debridement, partial repair, balloon arthroplasty, tendon transfer (e.g., latissimus dorsi transfer), or spanning the defect using graft materials (e.g., fascia lata autograft, human dermis allograft, xenograft, etc.). Although each of these procedures reportedly provide good clinical outcomes, universal success is rarely reported making treatment decisions difficult. In massive irreparable RCTs, a partial repair may be performed, leaving a residual defect in the rotator cuff. To obviate this, a variety of graft materials have been developed to “span” or “bridge” the defect between the retracted rotator cuff tendon and the greater tuberosity. Several authors have now reported short-term good results when using grafts in this manner.
An alternative option, a superior capsular reconstruction (SCR), has been introduced by Mihata et al.\(^9,10\) and has become an increasingly performed procedure. This technique does not “bridge” the tendon to the bone but alternatively uses a graft to span the defect between the superior glenoid and the greater tuberosity.\(^9,10\) Biomechanically, this presumably reconstructs the superior capsule, restores superior glenohumeral stability and prevents superior migration of the humeral head.\(^10\) Although the rotator cuff tendon defect remains, excellent short-term clinical outcomes have been reported with an increase in the acromiohumeral interval (AHI).\(^9\)

While SCR appears to be promising, its longevity is unclear and there are no comparison trials to bridging techniques. Further, some studies show high failure rates, including graft tearing.\(^11\)

The purpose of this study was to compare SCR versus bridging graft (BG) for massive irreparable RCTs. The study hypothesis was that SCR would provide superior clinical outcomes due to increased graft integrity and improved AHI.

### Methods

#### Study Design

The study was a double-blind, prospective, RCT (ClinicalTrials.gov registration #: NCT04965103) that was approved by the local institutional review board (Conjoint Health Research Ethics Board, University of Calgary. Approval #: REB 15-1787). Recruitment occurred from January 2016 to November 2018 through the senior author’s practice, and follow-up occurred through December 2020.

#### Protocol

Patients were identified from referrals to the senior surgeon’s practice. Standard radiographs and secondary imaging (i.e., magnetic resonance imaging [MRI] or magnetic resonance arthrogram) were obtained to confirm the diagnosis of a massive RCT.\(^12,13\) Patients provided informed consent, underwent standardized clinical examination preoperatively by blinded examiners, then completed study outcome measures including: the American Shoulder and Elbow Surgeons (ASES) score,\(^14\) Western Ontario Rotator Cuff (WORC) index,\(^15\) and the Quick Disabilities of the Arm, Shoulder and Hand (Quick-DASH) score.\(^16\)

### Participants

Eligibility criteria are shown in Table 1.

### Interventions

Patients underwent diagnostic arthroscopy for the evaluation of the rotator cuff, biceps, and other concomitant lesions (e.g., arthritis, synovitis, labral pathologies). RCTs were assessed and documented (e.g., size of the tear, tendons involved, repairable or irreparable). Only RCTs >5 cm and/or involving complete rupture of 2 or more tendons were included. If the tear was irreparable (including partially repairable tears) following standard releases (e.g., coracohumeral ligament release, bursal, and articular release) patients were randomly assigned to 1 of 2 procedures via a sealed envelope system: “superior capsule reconstruction (SCR)” or “bridging graft (BG).” Commercially available human dermal allograft (HDA) (ArthroFLEX; Arthrex, Naples, FL) was used for both procedures, which has a reported thickness over 3 mm, and was used as a single layer. If the tear was completely repairable, the patient was excluded.

All patients underwent a standardized surgical procedure. In brief, any subscapularis pathology was addressed first (when possible) with suture anchor fixation to bone and biceps pathology (i.e., subluxation, tendinosis) was addressed with biceps tenodesis in the lower portion of the bicipital groove (i.e., suprascapular) with an interference screw fixation technique. Posterosuperior pathology was addressed next, with a subacromial smoothing and maintenance of the coracoacromial ligament. The posterior aspect of the tear (i.e., infraspinatus and teres minor) was then repaired using standardized suture anchor fixation to bone (when achievable). Due to significant retraction, a single-row repair of the anterior and posterior cuff was performed. This would thus complete the partial repair.

In patients receiving SCR, the superior aspect of the glenoid neck was debrided and 2 or 3 double-loaded anchors (3-mm Biocomposite SutureTak; Arthrex) were placed depending on the size of the medial defect. Sutures were passed through the graft in a combined simple suture and double pulley fashion.\(^17\) In patients receiving BG, 3 or 4 sutures (#2 FiberWire; Arthrex) were placed in the medial aspect of the tear

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**Table 1. Study Inclusion / Exclusion Criteria**

| Exclusion Criteria | Inclusion Criteria |
|--------------------|-------------------|
| 1. Large-to-massive rotator cuff tear (with or without subscapularis tear) that may possibly be irreparable without the use of graft materials (confirmed intraoperatively) | 1. Large-to-massive rotator cuff tear (with or without subscapularis tear) that may possibly be irreparable without the use of graft materials (confirmed intraoperatively) |
| 2. Either primary tear or retear alter previous repair | 2. Either primary tear or retear alter previous repair |
| 3. Radiographic evidence of Hamada stage 1-3\(^13\) with or without Samilson & Prieto mild osteoarthritis (<3 mm inferior osteophyte)\(^1\) | 3. Radiographic evidence of Hamada stage 1-3\(^13\) with or without Samilson & Prieto mild osteoarthritis (<3 mm inferior osteophyte)\(^1\) |

Exclusion criteria

1. Primary glenohumeral osteoarthritis: radiographic evidence of Samilson & Prieto classification moderate or greater
2. Cuff tear arthropathy: radiographic evidence of Hamada stage 4 or above
3. Inflammatory joint disease of the shoulder (e.g., rheumatoid arthritis)
4. Medical issues precluding surgery
5. Unwilling or unable to complete study outcomes
6. Workers’ compensation claim or litigation

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approximately 1 cm apart. These sutures were used to subsequently shuttle the graft into the subacromial space and then to secure the graft medially using a series of simple sutures. Humeral fixation was similar in both groups with 2 or 3 suture anchors (4.75- or 5.5-mm Healicoil Regenesorb; Smith & Nephew, Andover, MA) placed in the medial aspect of the humeral footprint and 2 suture anchors (4.75 mm Biocomposite SwiveLock; Arthrex) placed in the lateral tuberosity achieving a double row repair. The arm was placed in 30 degrees of abduction and neutral rotation and the size of defect (i.e., between anchors or between anchors and tendon) was measured using a specialized measuring device (SCR Guide, Arthrex). The graft was appropriately sized and shuttled arthroscopically into the subacromial space through a lateral portal. The medial and lateral aspect of the grafts were secured sequentially and then grafts were secured to the adjacent residual rotator cuff tendon anteriorly and posteriorly with a series of simple stitches as described by Wong et al. (Fig 1).5

All patients (SCR and BG) underwent a standardized rehabilitation program, including sling immobilization for 6 to 8 weeks. Passive external rotation was permitted to 0° for the first 6 weeks. At 6 to 8 weeks, progressive forward elevation was allowed in the supine position, with a progressive achievement of forward elevation in the upright position by 14 weeks. Periscapular, biceps, and triceps strengthening was permitted at 10 to 12 weeks, with no rotator cuff strengthening until a minimum 16 to 18 weeks postoperatively.

Outcomes
Patient-Reported and Structural
The primary outcome was the ASES score at 2 years. Secondary outcome measures included the WORC index, the QuickDASH score, radiographic imaging (i.e., AHI, grade of cuff tear arthropathy) at each time point, and MRI at 1 year. A 1.5-Tesla MRI was obtained and axial proton density and fat suppressed, coronal proton density, coronal turbo spin echo (TSE) T2 fat suppressed, sagittal TSE T1, and sagittal TSE T2 sequences were used to assess tissue healing. MRI was evaluated by a musculoskeletal-trained radiologist who was blinded to the patient allocation. A full-thickness defect >5 mm was used to define a retear or region that failed to heal primarily.

Sample Size
The sample size estimate was based on the minimal clinically important difference of 16 (standard deviation = 14) for the ASES score in patients treated for rotator cuff disease18 and used 2-sided α of 0.05, and 80% statistical power. The resulting sample size was 13/group; however, we inflated to 50 (25/group) to account for potential loss to follow-up and to increase clinical relevance.

Randomization
Random allocation sequence was generated and concealed by an independent research assistant using the sequentially numbered, opaque sealed envelopes system,19 and group allocation was read out by the circulating nurse once a patient was intraoperatively confirmed to be eligible.

Blinding
A study identification number without information of the assigned procedure was allocated to each patient for case identification. The patients and research assistant collecting study outcomes were blinded to the procedure throughout the study duration.

Statistical Analysis
Six outcome measures were analyzed: (1) ASES score, (2) WORC index, (3) Quick-DASH score, (4) AHI on radiographs, (5) Hamada classification on radiographs, and (6) graft integrity on MRI. For both group-wise comparisons and within-group comparisons, exact χ² tests for categorical variables and Wilcoxon rank-sum tests for continuous variables were used for statistical analyses using the SAS software, version 9.4 (SAS Institute, Cary, NC).
Results

Patient Recruitment and Demographics

Patients were recruited as shown in Figure 2. There were no differences in the baseline characteristics between BG and SCR groups (Table 2).

Clinical Outcomes

All patients underwent their assigned procedure with no intraoperative or postoperative complications except graft retear. At 2-year follow-up (mean 25 months, range 18-33 months), 46 patients (23/group) were available for follow-up.

As a whole group, there was statistically significant improvement in ASES and WORC scores from preoperative to 3-, 6-, 12-, and 24-months’ follow-up. P values ranged from P < .001 to P = .017 on these outcomes. QuickDASH was also significantly improved at each follow-up (P < .001) except for 3 months (P = .17).

All patient-reported outcomes improved between the preoperative and 24-month postoperative assessments in both groups (SCR vs BG). The mean ASES, WORC, and DASH scores at 24 months postoperatively were 77.9 ± 19.9 (95% CI 69.2-86.4), 69.5 ± 24.5 (95% CI 58.9-80.1), and 25.0 ± 19.1 (95% CI 16.8-33.3) for the BG group and 74.8 ± 23.9 (95% CI 59.6-85.1), 66.0 ± 28.3 (95% CI 53.8-78.2), and 24.7 ± 26.1 (95% CI 12.8-36.6) for the SCR group, respectively, with no significant difference between groups (Table 3).

The only difference between BG and SCR groups at all time points was on the range of motion of abduction (117 ± 45° [95% CI 95-139°] vs 145 ± 26° [95% CI 132-158°]) respectively, P = .044) and forward flexion (115 ± 41° [95% CI 95-135°] vs 144 ± 26° [95% CI 132-158°]) respectively, P = .02) at 3 months.
Radiographic Outcomes
MRI demonstrated that overall graft healing was obtained in approximately 70% of patients with no significant difference between groups (Table 4). Hamada grade on standard radiographs at final follow-up is as shown. There was no significant difference in the distribution between groups (Table 4). AHI on standard radiographs improved from pre-operative to 24 months postoperative in both groups, with no significant difference between groups at any time point (Table 4).

Subgroup Analyses
Intact Versus Nonintact Grafts
To determine the effect of graft healing, patients were subdivided into intact versus return grafts. Patients with intact grafts (whether BG or SCR) had greater ASES, WORC and AHI at 24 months. Intact grafts had significantly higher AHIIs when compared to return grafts at baseline, 3-, 6-, 12-, and 24-months' postoperatively (Table 5).

Irreparable Subscapularis or Irreparable Posterior Cuff
To determine the effect of the reparability of the residual rotator cuff tendon, patients were divided into irreparable subscapularis or irreparable posterior cuff subgroups. There was no significant difference between distribution of irreparable subscapularis or posterior cuff between groups (Table 6). Both the subscapularis and the posterior cuff were irreparable in one patient in the bridging group and 2 in the SCR group (Table 2).

In general, patients with irreparable subscapularis or irreparable posterior cuff had inferior outcomes compared with those with intact or reparable tendon tears. However, this was only significant for irreparable posterior cuff tears. Patients with irreparable posterior cuff tears had significantly lower ASES and WORC scores at 24 months (Table 7).

The relationship between graft healing and an irreparable subscapularis or irreparable posterior cuff is summarized in Table 8. There was a significant decrease in healing in patients with irreparable subscapularis or irreparable posterior cuff tears (Table 8).

Discussion
The most important finding of this study was that both the SCR and BG groups improved in range of motion, patient reported outcome scores and radiographic measures following surgery in our series of irreparable RCTs. This suggests that both procedures may be reasonable options when faced with an irreparable RCT. Despite our hypothesis, SCR did not

| Table 2. Baseline and Intraoperative Characteristics of Whole Study Population and By Superior Capsule Reconstruction (SCR) Versus Bridging (BG) Group |
| --- |
| **Baseline characteristics** | Whole (n = 50) | SCR (n = 25) | BG (n = 25) | P Value |
| Female | 8 (16%) | 4 (8%) | 4 (8%) | |
| Male | 42 (84%) | 21 (42%) | 21 (42%) | >.90 |
| Age at surgery, y | 60.0 (sd 6.0) | 60.5 (sd 6.3) | 60.0 (sd 5.9) | .50 |
| Dominant side = involved side | 30 (60%) | 14 (28%) | 16 (32%) | .77 |
| Duration of symptoms, y | 5.18 (sd 5.2) | 3.6 (sd 2.9) | 6.7 (sd 6.5) | .11 |
| Procedure | 23 (46%) | 11 (22%) | 12 (24%) | |
| Revision | 27 (54%) | 14 (28%) | 13 (26%) | >.90 |
| Onset | 28 (56%) | 16 (32%) | 12 (24%) | |
| Traumatic | 22 (44%) | 9 (18%) | 13 (26%) | .39 |
| Hamada at baseline | |
| 1 | 23 (46%) | 13 (26%) | 10 (20%) | .67 |
| 2 | 24 (48%) | 11 (22%) | 13 (26%) | |
| 3 | 3 (6%) | 1 (2%) | 2 (4%) | |
| Acromiohumeral Interval (AHI) at baseline | 5.6 (SD 2.3) | 5.8 (SD 2.2) | 5.4 (SD 2.3) | .41 |
| Baseline American Shoulder and Elbow Surgeons Score (ASES) | 54.7 (SD 22.8) | 58.9 (SD 23.4) | 50.8 (SD 22.0) | .25 |
| Baseline Western Ontario Rotator Cuff Score (WORC) | 40.6 (SD 20.4) | 42.3 (SD 20.6) | 38.5 (SD 20.5) | .57 |
| Baseline Quick Disability of the Arm Shoulder and Hand score (QDash) | 47 (SD 23.0) | 44.9 (sd 27.4) | 49.4 (sd 18.5) | .60 |
| **Intraoperative characteristics** | |
| Graft size, cm | |
| Medial | 3.43 (SD 0.68) | 3.31 (0.68) | 3.55 (0.68) | .28 |
| Lateral | 3.17 (SD 0.71) | 3.23 (0.73) | 3.11 (0.71) | .60 |
| Anterior | 4.42 (SD 0.65) | 4.51 (0.58) | 4.32 (0.70) | .35 |
| Posterior | 4.06 (SD 0.52) | 4.19 (0.37) | 3.91 (0.61) | .03 |
| Partial repair | Yes | 47 (94%) | 24 (96%) | 23 (92%) | >.9 |
| No | 3 (6%) | 1 (4%) | 2 (8%) | |
| SD, standard deviation.
demonstrate superior outcomes to BG either clinically or radiographically in the short-term, except for range of motion in the early postoperative stage. This suggests that the previous biomechanical evidence of improved superior stability of the glenohumeral joint, achieved by SCR\textsuperscript{10} when compared with BG, did not translate to improved patient-reported outcomes.

Table 3. Postoperative Patient-Reported Outcome Measurements and Imaging Results by Whole Population and Superior Capsule Reconstruction (SCR) and Bridging (BG) Groups

|                      | Whole Group | SCR         | BG          | Significance |
|----------------------|-------------|-------------|-------------|--------------|
| **ASES score**       |             |             |             |              |
| 3 mo                 | 64.2 (SD 14.3) | 65.9 (SD 14.3) | 62.5 (SD 14.5) | .35          |
| 6 mo                 | 74.1 (SD 16.1) | 71.8 (SD 15.0) | 76.0 (SD 16.9) | .24          |
| 12 mo                | 73.0 (SD 21.3) | 65.8 (SD 24.9) | 79.7 (SD 15.1) | .09          |
| 24 mo                | 76.3 (SD 21.8) | 74.8 (SD 23.9) | 77.9 (SD 19.9) | .84          |
| **WORC score**       |             |             |             |              |
| 3 mo                 | 55.8 (SD 20.2) | 55.7 (SD 22.2) | 55.9 (SD 18.6) | .90          |
| 6 mo                 | 66.5 (SD 21.1) | 66.3 (SD 23.5) | 66.2 (SD 19.4) | .80          |
| 12 mo                | 68.4 (SD 23.7) | 62.3 (SD 27.9) | 74.4 (SD 17.4) | .28          |
| 24 mo                | 67.7 (SD 26.2) | 66.0 (SD 28.3) | 69.5 (SD 24.5) | .78          |
| **QuickDASH score**  |             |             |             |              |
| 3 mo                 | 38.7 (SD 21.8) | 39.3 (SD 26.2) | 38.0 (SD 17.0) | .77          |
| 6 mo                 | 27.0 (SD 20.8) | 30.0 (SD 24.6) | 24.6 (SD 17.2) | .70          |
| 12 mo                | 24.9 (SD 21.0) | 29.1 (SD 26.4) | 20.7 (SD 13.3) | .49          |
| 24 mo                | 24.9 (SD 22.5) | 24.7 (SD 26.1) | 25.0 (SD 19.1) | .45          |
| **AHI, mm**          |             |             |             |              |
| 3 mo                 | 6.5 (SD 2.7) | 7.3 (SD 3.0) | 5.6 (SD 2.0) | .12          |
| 6 mo                 | 6.5 (SD 2.7) | 6.8 (SD 2.9) | 6.1 (SD 2.5) | .36          |
| 12 mo                | 6.6 (SD 3.0) | 7.3 (SD 2.5) | 5.9 (SD 3.4) | .35          |
| 24 mo                | 6.3 (SD 3.1) | 6.3 (SD 3.1) | 6.3 (SD 3.2) | .86          |
| **Graft healing at 12-mo MRI** | | | | .50 |
| Intact               | 32/46 (70%) | 18/24 (75%) | 14/22 (64%) |              |
| Return               | 14/46 (30%) | 6/24 (25%) | 8/22 (36%) |              |
| MRI not done         | 4/50 (8%) | 1/25 (4%) | 3/25 (12%) |              |
| **Hamada at final follow-up** | | | | >.9 |
| 1                    | 29 (58%) | 15 (30%) | 14 (28%) | |
| 2                    | 11 (22%) | 5 (10%) | 6 (12%) | |
| 3                    | 5 (10%) | 3 (6%) | 2 (4%) | |
| 4                    | 3 (6%) | 1 (2%) | 2 (4%) | |
| Missing              | 2 (4%) | 1 (2%) | 1 (2%) | |

AHI, acromiohumeral interval; ASES, American Shoulder and Elbow Surgeons Score; MRI, magnetic resonance imaging; QuickDASH, Quick Disabilities of the Arm, Shoulder and Hand score; SD, standard deviation; WORC, Western Ontario Rotator Cuff Index.

Table 4. Imaging Outcomes of Whole Study Population and Superior Capsule Reconstruction (SCR) and Bridging (BG) Groups

|                           | Whole | SCR         | BG          | Significance |
|---------------------------|-------|-------------|-------------|--------------|
| **Graft healing (assessed via 12-mo MRI)** |       |             |             |              |
| Intact                    | 32/46 (70%) | 18/24 (75%) | 14/22 (64%) | .53          |
| Return                    | 14/46 (30%) | 6/24 (25%) | 8/22 (36%) |              |
| Hamada at final follow-up |       |             |             | >.9          |
| 1                         | 29 (58%) | 15 (30%)    | 14 (28%)    | |
| 2                         | 11 (22%) | 5 (10%)     | 6 (12%)     | |
| 3                         | 5 (10%)  | 3 (6%)      | 2 (4%)      | |
| 4                         | 3 (6%)   | 1 (2%)      | 2 (4%)      | |
| Missing (n = 2)           | 2 (4%)  | 1 (2%)      | 1 (2%)      | |
| **Acromiohumeral interval (AHI), mm** |       |             |             |              |
| 3 mo                      | 6.5 (SD 2.7) | 7.3 (SD 3.0) | 5.6 (SD 2.0) | .12          |
| 6 mo                      | 6.5 (SD 2.7) | 6.8 (SD 2.9) | 6.1 (SD 2.5) | .36          |
| 12 mo                     | 6.6 (SD 3.0) | 7.3 (SD 2.5) | 5.9 (SD 3.4) | .35          |
| 24 mo                     | 6.3 (SD 3.1) | 6.3 (SD 3.1) | 6.3 (SD 3.2) | .86          |

MRI, magnetic resonance imaging; SD, standard deviation.
Alternatively, this may also indicate the importance of a partial repair.\textsuperscript{20-22} In all cases, patients underwent a “maximal” partial repair before grafting with repair of the anterior (subscapularis) and posterior cuff (infra-spinatus/teres minor) when achievable. It is possible that the clinical and radiographic improvement following surgery was the result of the partial repair and that further utilization of a graft, whether SCR or BG, was not significant enough to affect clinical outcomes. Consistent with this was the inferior clinical results demonstrated in patients who had irreparable posterior cuffs where a balanced partial repair was not achievable. Interestingly, Greiner et al. recently reported in a matched series of patients that partial repair resulted in comparable results to SCR.\textsuperscript{21}

Furthermore, the effect of partial repair or conversely the inability to achieve a balanced partial repair (i.e., irreparable subscapularis, irreparable posterior cuff) may affect the integrity of the graft. Presumably a successful partial repair, balances the forces couples about the glenohumeral joint, reducing biomechanical loading of the graft and potentially improving healing. In the current study, an irreparable subscapularis or posterior cuff tear, correlated with a decreased healing rate of the graft whether by SCR or BG (i.e., 48% retorn). Similarly, Mihata et al.\textsuperscript{23} recently reported that patients with irreparable subscapularis tears had higher graft retear rates, smaller AHI, and less improvement in range of motion and strength. In addition, Lee et al.\textsuperscript{24} demonstrated that healing of the SCR graft was dependent on the integrity of the residual posterior remnant tissue.

Importantly, graft healing appears critical in improving patient outcomes. In patients with intact grafts, whether SCR or BG, superior clinical outcomes and AHIs were demonstrated when compared to patients with retorn grafts. While patients with intact grafts by MRI did have larger absolute AHIs, and improvements in AHIs at follow-up, they also had larger AHI measures at baseline. This potentially suggests a difference in severity of rotator cuff tearing at baseline between patients who eventually demonstrated intact versus retorn grafts. Collectively, this emphasizes the importance of patient selection, with critical analysis of the severity of rotator cuff tear and the integrity or reparability of the residual rotator cuff when a graft procedure is considered.

In addition to the residual rotator cuff, choice of graft material may be another factor affecting outcomes. Although the original description by Mihata et al.\textsuperscript{23} used autologous fascia lata, HDA was used in this study. HDA was chosen due to its availability, avoidance of donor-site morbidity, decreased surgical time, and it is currently the most commonly used material in North America.\textsuperscript{25} Although HDA can restore superior stability, previous biomechanical studies have

### Table 5. Patient-Reported Outcomes and Radiographic Acromiohumeral Intervals in Patients with Intact Versus Retorn Grafts

|                      | Intact Graft (n = 32) | Retorn Graft (n = 14) | Significance |
|----------------------|-----------------------|-----------------------|--------------|
| 24-mo ASES           | 81.0 (18.7)           | 65.7 (24.4)           | .021         |
| 24-mo WORC           | 72.3 (24.6)           | 53.7 (26.7)           | .040         |
| Absolute AHI         |                       |                       |              |
| At baseline          | 6.3 (2.2)             | 4.0 (1.6)             | .001         |
| At 3 mo              | 7.7 (2.3)             | 4.3 (2.0)             | .002         |
| At 6 mo              | 7.5 (2.4)             | 4.3 (2.0)             | .000         |
| At 12 mo             | 7.8 (2.4)             | 3.6 (2.4)             | .002         |
| At 24 mo             | 7.5 (2.4)             | 3.0 (2.4)             | .001         |
| Change in AHI        |                       |                       |              |
| Baseline – 6 mo      | 1.3 (1.8)             | 0.29 (1.0)            | .060         |
| Baseline – 12 mo     | 1.0 (1.5)             | -0.38 (1.4)           | .033         |
| Baseline – 24 mo     | 1.3 (2.0)             | -0.89 (1.4)           | .008         |

NOTE. Values reported as mean (standard deviation).
AHI, acromiohumeral interval; ASES, American Shoulder and Elbow Surgeons Score; WORC, Western Ontario Rotator Cuff Index.

### Table 7. Patient-Reported Outcomes for Patients With Irreparable Posterior Rotator Cuff and Repaired/Intact Posterior Rotator Cuff

|                      | Posterior Cuff Repaired or Intact (n = 33) | Posterior Cuff Irreparable (n = 17) | P Value |
|----------------------|-------------------------------------------|-------------------------------------|---------|
| 24-mo ASES           | 81.9 (SD 18.3)                            | 65.8 (SD 24.5)                      | .01     |
| 24-mh WORC           | 72.9 (SD 25.3)                            | 57.9 (SD 25.8)                      | .04     |

ASES, American Shoulder and Elbow Surgeons Score; SD, standard deviation; WORC, Western Ontario Rotator Cuff Index.

### Table 6. Reparability of Subscapularis and Posterior Cuff, By Superior Capsular Reconstruction (SCR) and Bridging Graft (BG) Groups

|                      | Subscapularis | Posterior Cuff |
|----------------------|---------------|---------------|
| BG                   | 23 repaired or intact (92%) | 18 repaired or intact (72%) |
| SCR                  | 2 irreparable (8%) | 7 irreparable (28%) |
|                      | 18 repaired or intact (72%) | 15 repaired (60%) |
|                      | 7 irreparable (28%) | 10 irreparable (40%) |

P = .14 P = .55

### Table 8. Graft Integrity Versus Intact or Reparable Subscapularis and Posterior Cuff Versus Irreparable Subscapularis and/or Posterior Cuff

|                      | Intact or Reparable Subscapularis and Posterior Cuff | Irreparable Subscapularis and/or Posterior Cuff |
|----------------------|------------------------------------------------------|-----------------------------------------------|
| Gift intact (n = 32) | 21 (84%)                                             | 11 (52%)                                     |
| Gift retorn (n = 14) | 4 (16%)                                              | 10 (48%)                                     |
| Total (n = 46)      | 25                                                   | 21                                            |

P = .027.
demonstrated that it does not restore superior stability as well as fascia lata. Furthermore, graft thickness may play a role. Thicker grafts, whether using fascia lata, or HDA, significantly improved superior translation and subacromial contact when compared with thinner grafts.

While our results are similar to the recent SCR case series using HDA for both clinical and radiographic outcomes, graft healing rates of HDA are in general, inferior to the reported rates of fascia lata by Mihata et al. In the longest-term follow-up case series of the original SCR patients with fascia lata autograft, Mihata et al. reported a 90% healing rate. However, in a systematic review of clinical SCR studies, the authors concluded that SCR using both fascia lata autograft and HDA can lead to improvement in clinical and radiologic outcomes. Although the retear rate appeared lower in fascia lata autografts, the current literature was heterogeneous and difficult to compare. Even though graft healing is essential, patients with return grafts do not necessarily perform poorly and the same graft was utilized in both the SCR and BG groups. In addition, the results of BG were in fact comparable not only to the SCR group in our study but also to previous reports of BGS. Further studies are needed to determine the ideal graft properties (e.g., material, thickness, etc.) for each procedure.

The strength of the current study include that it was a prospective, blinded, randomized trial using the same HDA for both groups. In addition, we utilised both clinical and radiologic outcomes with a high percentage of follow-up. Although there are potential limitations listed below, we believe this study still provides high-level, valuable evidence when comparing different surgical procedures for patients with irreparable rotator cuff tears.

Limitations

First, even though both patients and the evaluator were blinded, it was impossible to blind a surgeon for the procedures. Second, the graft used in this study was HDA, which as discussed above, while commonly used is different in its characteristics from fascia lata autograft. Third, only short-term follow-up was available and therefore the mid and long-term outcomes are unclear with respect to patient reported outcomes, radiographic outcomes (i.e., retear rates), and the development of cuff tear arthropathy. Fourth, it would have been ideal to add a partial repair only group; however, this would have increased the number of patients significantly and it may have been more difficult to recruit patients. Importantly, the size of the graft utilized was similar to previous case series of both SCR and BG. Fifth, we did not register our trial on clinicaltrials.gov prior to initiating recruitment in early 2016, though we have registered it retrospectively.

Conclusions

When performing arthroscopic rotator cuff reconstruction using human dermal allograft for an irreparable RCT, whether the proximal edge of the graft is attached to the glenoid bone or the torn tendon does not significantly change short-term clinical or radiographic outcomes.

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