Clinical Sports Medicine Update

Clinical and Functional Outcomes by Graft Type in Superior Capsular Reconstruction

A Systematic Review and Meta-analysis

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Background: In recent years, superior capsular reconstruction (SCR) has emerged as a promising treatment for massive rotator cuff tears and has been performed with an array of graft options, most commonly dermal allograft and tensor fascia lata (TFL) autograft.

Purpose: To compare the clinical outcomes, functional outcomes, and complication rates after SCR performed with dermal allograft, TFL autograft, long head of the biceps tendon (LHBT) autograft, and porcine xenograft.

Study Design: Meta-analysis; Level of evidence, 4.

Methods: PubMed, Cochrane Library, and Embase were systematically reviewed for studies that enrolled ≥10 patients who underwent SCR and presented clinical outcome data at a minimum follow-up of 12 months. When available, pre- and postoperative patient-reported outcome scores and clinical examination data were extracted. Outcome data were then compared by graft type. A meta-analysis was also conducted of graft tear and reoperation rates after SCR with dermal allograft and TFL autograft.

Results: Human dermal allograft and TFL autograft were each utilized in 7 studies, LHBT autograft in 2 studies, and porcine xenograft in 1 study. Dermal allograft, TFL autograft, and LHBT autograft demonstrated comparable median (range) postoperative American Shoulder and Elbow Surgeons scores of 85.3 (77.5-89), 88.6 (73.7-94.3), and 82.7 (80-85.4), respectively. The median postoperative pain scores per visual analog scale for dermal allograft, TFL autograft, and LHBT autograft were 0.8, 2.5, and 1.4. Median postoperative forward elevation was 159.0°, 147.0°, 163.8°, and 151.4° for dermal allograft, TFL autograft, LHBT autograft, and porcine xenograft. Meta-analysis demonstrated a comparable pooled graft tear rate between TFL autograft (9%; 95% CI, 4%-16%) and dermal allograft (7%; 95% CI, 2%-13%). Similarly, the pooled reoperation rate was similar for TFL autograft (3%; 95% CI, 0%-7%) and dermal allograft (6%; 95% CI, 2%-12%). Among the 3 studies with pre- and postoperative information on pseudoparalysis, 73 of 76 (96%) patients with an intact/repairable subscapularis had a reversal of their pseudoparalysis after SCR.

Conclusion: Dermal allograft, TFL autograft, and LHBT autograft are all suitable options for SCR and demonstrate significant improvements in American Shoulder and Elbow Surgeons score, pain score per visual analog scale, and forward elevation. Moreover, dermal allograft and TFL autograft have comparable rates of graft tear and reoperation.

Keywords: SCR; rotator cuff; shoulder injury; autograft; allograft

The rotator cuff musculature, composed of 4 muscle units, acts as an active glenohumeral joint stabilizer and may be torn as a result of acute trauma or chronic tendon degeneration, leading to pain and functional impairment.[9,26,27] The treatment of rotator cuff tears poses a significant health care burden, with 270,000 annual rotator cuff repairs contributing to $3 billion in annual health care costs in the United States.[8,56,57] Moreover, impairment or pain of the rotator cuff results in >4.5 million annual physician visits in the United States.[43,47,54] Rotator cuff tears can vary from single-tendon tears to massive tears involving multiple tendons with significant tendon retraction and fatty infiltration.[7,18] Nearly 30% of all rotator cuff tears are classified as massive, and their associated treatment options have significant implications for patients and the health care system.[46,67]

Massive tears frequently result in structural failure, reduced range of motion, and significant pain. Specifically, massive tears may allow for superior migration of the humeral head with an unopposed deltoid superior force vector, shifting the fulcrum about which the shoulder

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muscles act on the arm. Arthroscopic repair of massive rotator cuff tears with concomitant procedures, such as subacromial debridement with or without acromioplasty and biceps tenotomy or tenodesis, has been shown to result in high rates of tear progression and reoperation, with only modest improvements in range of motion.[33,46,58,63] Among patients aged ≤65 years, reverse shoulder arthroplasty has its own drawbacks, with long-term complication rates as high a 50%.[13,17,19] In 2013, Mihata et al[40] introduced the technique of superior capsular reconstruction (SCR) using a tensor fascia lata (TFL) autograft to eliminate superior translation of the humeral head in relation to the glenoid. Subsequent studies utilizing dermal allograft for SCR for massive irreparable tears have also demonstrated improvements in shoulder function and lower retear rates as compared with arthroscopic rotator cuff repair with fewer complications than reverse shoulder arthroplasty.[4,12,23,51]

SCR graft options have recently expanded to include long head of the biceps tendon (LHBT) autograft, human acellular dermal allograft, and acellular dermal xenograft.[11,12,53] Although long-term outcome data are still limited for SCR, it is important to compare the short- and midterm clinical outcomes and complication rates after SCR to evaluate the effectiveness of different graft types. In a 2020 systematic review, de Campos Azevedo et al[10] identified significant clinical improvements with TFL autograft and human dermal allograft but were limited by a small sample of studies and did not reach a conclusion about the superiority of graft types. Other current systematic reviews involving SCR have been limited by the inclusion of cadaveric studies,[37] a small selection of studies,[28,60] or the failure to evaluate outcomes from the utilization of acellular porcine xenografts. The purpose of this systematic review and meta-analysis was to compare the clinical outcomes, functional outcomes, and complication rates after SCR performed with dermal allograft, TFL autograft, LHBT autograft, and porcine xenograft with a minimum patient follow-up of 12 months. We hypothesize similar clinical and functional outcomes of acellular dermal allograft, TFL autograft, and LHBT autograft with worse outcomes demonstrated by porcine xenografts.

METHODS

Literature Search

This systematic review was performed in accordance with the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-analyses).[44] PubMed, Cochrane Library, and Embase databases were systematically searched for full-text journal articles in English published in the last 10 years, from January 1, 2010, to June 20, 2020. Previous systematic reviews identified through the database search were assessed for the inclusion of relevant studies (Figure 1).

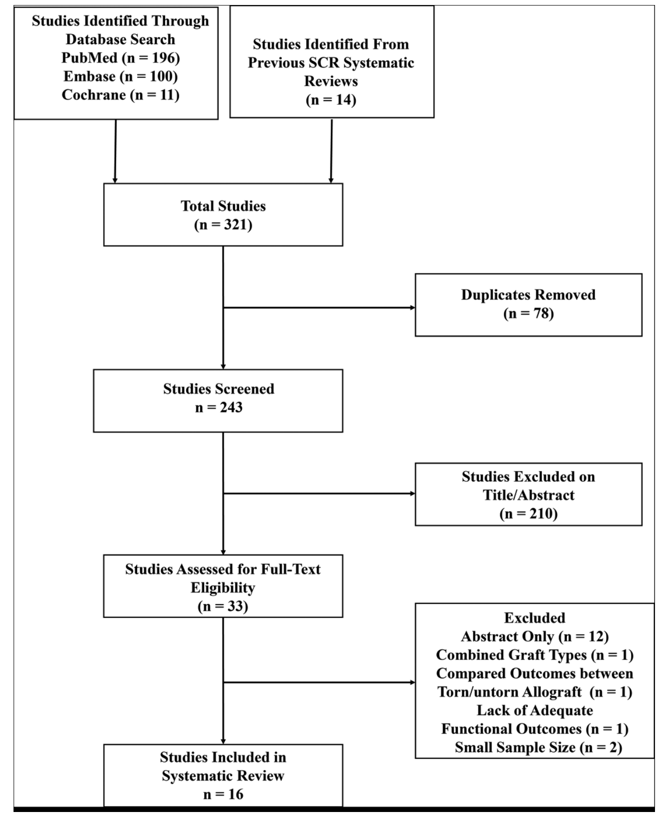

Figure 1. Study selection flowchart. SCR, superior capsular reconstruction.

PubMed was searched with the following text words: superior capsular reconstruction, superior capsule reconstruction, and ASCR. Cochrane Library was searched with the following terms among the title, abstract, and key words: superior capsular reconstruction or superior capsule reconstruction. Embase was searched with the following combinations among the abstracts and titles: (superior capsular reconstruction) OR (superior capsule reconstruction) AND graft.

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Study Selection

Full-text clinical studies, observational studies, and case series were considered for eligibility. The inclusion criteria were studies that carried out SCR in a minimum of 10 patients and included clinical outcome data with a minimum patient follow-up of 12 months. The exclusion criteria were review articles, meta-analyses, systematic reviews, case reports, cadaveric studies, studies with non-English text, studies with <10 patients, and studies lacking patient outcomes data.

Two authors screened the journal articles found through the PubMed, Cochrane Library, and Embase database search, as well as studies from previous systematic reviews, based on title and abstract to determine eligibility. The same 2 authors then assessed the full text of each eligible study for inclusion in the systematic review, with any disagreements resolved by discussion with a third author.

Data Extraction

The demographic, diagnostic outcomes, and complications data from each eligible study were extracted and inserted into predefined Excel spreadsheets. Demographic data included publication year, graft type used, patient characteristics, duration of follow-up, shoulder characteristics, and other concomitant surgery performed. Extracted clinical outcomes data were the American Shoulder and Elbow Surgeons (ASES) score, visual analog scale for pain (Pain-VAS), Constant score, and Subjective Shoulder Value (SSV). Extracted functional outcomes data comprised forward elevation, external rotation, internal rotation, and abduction. Data on complications were also extracted, such as graft tear rate, donor site morbidity, infection rate, and reoperation rate. When data were provided at multiple follow-up durations, only the data at final follow-up were included. Clinical significance in function was assessed using previously reported thresholds for ASES, Pain-VAS, Constant score, forward elevation, and external rotation.[30,45,62]

Statistical Analysis

A meta-analysis of proportions utilizing graft tear and reoperation rates in dermal allograft and TFL autograft SCR was performed, as these were the most common complications reported among all studies. The meta-analysis was conducted using a Freeman-Tukey transformation[16] (arcsine square root transformation) under the random effects model to calculate pooled estimate rates, and 95% confidence intervals were estimated with the DerSimonian-Laird estimator. The random effects model was chosen to account for differences among studies in regard to patient characteristics, surgical characteristics, and study methodology.[3] The heterogeneity analysis of the studies was represented using I^2, as an estimated percentage of error attributed to interstudy variation.[22] Following the Cochrane review handbook, values of I^2 between 0% and 40% were deemed not important; 30% to 60%, moderate heterogeneity; 50% to 90%, substantial heterogeneity; and 75% to 100%, considerable heterogeneity.[21]

Data were collected in Excel (Microsoft Corporation) and analyzed using R Version 3.41 (R Foundation for Statistical Computing) with the metaphor package.[66]

RESULTS

Study Selection and Inclusion

Our review of the PubMed, Cochrane, and Embase databases yielded 243 unique results. Of these studies, 33 were deemed relevant upon abstract review. From these studies, 12 were excluded because they were abstract only, 1 for combining results with different graft types,[34] 1 for the study design,[42] 1 owing to a lack of adequate functional outcomes,[48] and 2 because of a small sample size.[24,68] The remaining 16 eligible studies consisted of 626 shoulders in 621 patients. Human dermal allograft was utilized in 7 studies, TFL autograft in 7 studies, LHBT autograft in 2 studies, and porcine xenograft in 1 study (Table 1). Two studies compared subgroups of patients based on preoperative shoulder condition[39,61] while 1 compared subgroups based on the type of graft used.[29] Across studies, the mean age of patients ranged from 56 to 70 years and the mean follow-up from 12 to 60 months. Eleven studies utilized postoperative imaging in all patients to assess for graft tears, while 5 used it in symptomatic patients. Ten studies examined the degree of muscle fatty infiltration of the supraspinatus, and 6 of these included only shoulders with severe fatty infiltration (Goutallier ≥3). Ten studies reported on the Hamada grade of the shoulder, and 6 of these studies also included shoulders demonstrating acetabularization (Hamada ≥3).

Studies that used intraoperative classifications of rotator cuff tears defined an irreparable tear as follows: a technically irreparable supraspinatus and infraspinatus tear,[32] a massive tear (2 fully torn tendons or a tear >5 cm) for which the supraspinatus and/or infraspinatus was unable to be repaired intraoperatively,[5,6] torn tendons that could not be repaired for unspecified reasons,[11,12,36] or most commonly when the torn rotator cuff tendon could not be reduced to the original footprint.[35,38-40] Studies that used preoperative classifications of rotator cuff tears with imaging defined an irreparable tear as follows: a massive tear (≥2 tendons) with significant retraction and/or poor tissue quality of the footprint,[2] an unspecified massive tear with fatty atrophy (Goutallier grade ≥3),[29] or a large tear (>5 cm) with significant retraction (>5 cm) and fatty infiltration (Goutallier grade ≥3).[50,53,61]

Various concomitant surgery was performed among the studies. Biceps tenotomy/tenodesis was performed in 11 studies, including 5 that routinely performed biceps tenotomy/tenodesis among the whole patient cohort.[32,35,36,50,53] Moreover, acromioplasty/subacromial decompression was performed in 9 studies, including 6 that routinely performed acromioplasty/subacromial decompression among the whole patient cohort.[29,35,38-40,53] One study occasionally performed concomitant surgery, such as anterior interval slide, posterior interval slide, distal clavicle excision, and coracoplasty.[12]

TABLE 1
Patient Demographics Across Studies in the Systematic Review[a]

Study	Age, y, Mean (Range)	No. of Patients (Shoulders)	Clinical Follow-up, mo, Mean (Range)	Imaging (%)	Graft		Supraspinatus Goutallier Grade	Hamada Grade	Subscapularis Involvement, No. (%)	
					Type	Thickness, mm			Overall	Irreparable
Makki (2020)[36]	66 (49-80)	25 (25)	24	MRI (100)	Dermal allograft				0 (0)	0 (0)
Lacheta (2020)[32]	56 (41-65)	22 (22)	25.2 (24-36)	MRI (95)	Dermal allograft	3	4		2 (9.1)	0 (0)
Burkhart (2020)[6]	64 (39-78)	41 (41)	34 (24-50)	MRI (63)	Dermal allograft	3		1-4	30 (73)	0 (0)
Hirahara (2019)[25]	63	18 (19)	25 (12-40)	US (100)	Dermal allograft	3				0 (0)
Burkhart (2019)[5]	69	10 (10)	12	MRI (100)	Dermal allograft	3		1-3	6 (60)	0 (0)
Denard (2018)[12]	62	59 (59)	17.7 (12-29)	MRI (33)	Dermal allograft	1-3	1-4	1-4	33 (56)	0 (0)
Pennington (2018)[50]	59.4 (27-79)	86 (88)	16-28	MRI (<100)	Dermal allograft	3	3-4	1-2	0 (0)	0 (0)
Takayama (2020)[61]	70.0 (61-78)	27 (27)	32.3 (24-51)	MRI (100)	TFL autograft	8.4	3-4	2-3	15 (56)	4 (15)
Kocaoglu (2020)[29]	63.6	26 (26)	30.9 (18-40)	MRI (100)	LHBT/ TFL autograft	>8	3-4			0 (0)
Lim (2019)[35]	65.3 (44-85)	31 (31)	15 (12-24)	MRI (100)	TFL autograft	>6		1-2	7 (23)	
de Campos Azevedo (2018)[11]	64.8 (47-77)	22 (22)	24	MRI (100)	TFL autograft	5-8	1-4	1-2	8 (36)	
Mihata (2018)[39]	66.2 (43-82)	88 (88)	60 (35-110)	MRI (100)	TFL autograft	6-8	2-4	1-4	35 (40)	0 (0)
Mihata (2018)[38]	66.9 (43-82)	100 (100)	48 (24-88)	MRI (100)	TFL autograft	6-8			25 (25)	2 (2)
Mihata (2013)[40]	65.1 (52-77)	23 (24)	34.1 (24-51)	MRI (100)	TFL autograft	6-8	3-4	1-4	9 (38)	0 (0)
Barth (2020)[2]	60 (47-81)	24 (24)	25 (24-29)	US (100)	LHBT autograft		1-3	1-2		
Polacek (2019)[53]	60 (45-72)	19 (20)	12	MRI (16)	Porcine xenograft	3	4			0 (0)

[a]Blank cells indicate not applicable. LHBT, long head of the biceps tendon; MRI, magnetic resonance imaging; TFL, tensor fascia lata; US, ultrasound.

Clinical and Functional Outcomes

Clinical outcomes were the ASES score (13 studies),[¶] Pain-VAS (8 studies),[2,5,6,12,25,32,35,50] Constant score (3 studies),[2,11,35] and SSV (5 studies).[2,5,6,11,12] No clinical outcome data were available for SCR with porcine xenograft. The weighted mean follow-up time was 23.2 months for dermal allograft studies, 43.2 months for TFL autograft studies, 27.2 months for LHBT studies, and 12.0 months for the porcine xenograft study. The median postoperative ASES scores for dermal allograft, TFL autograft, and LHBT autograft were 85.3, 88.6, and 82.7, respectively (Table 2). The median postoperative Pain-VAS scores for dermal allograft, TFL autograft, and LHBT autograft were 0.8, 2.5, and 1.4. The mean improvement in ASES score and Pain-VAS were clinically significant for all studies, excluding ASES in 1 study utilizing TFL.[35] Postoperative SSV was noted by 1 study for TFL autograft[11] and LHBT autograft.[2] Median postoperative SSV for dermal allograft, TFL autograft, and LHBT autograft was 83, 70, and 75, respectively. The median postoperative Constant score for TFL autograft and LHBT autograft was 64.3 and 77.0.

Functional outcomes were forward elevation (14 studies),[#] external rotation (11 studies),[**] internal rotation (8 studies),[2,11,12,29,38-40,61] and abduction (5 studies).[11,36,50,53,61] Median postoperative forward elevation was 159.0, 147.0, 163.8, and 151.4 for dermal allograft, TFL autograft, LHBT autograft, and porcine xenograft, respectively (Table 2). Median postoperative external rotation was 43.0, 40.0, and 51.4 for dermal allograft, TFL autograft, and LHBT autograft. Median postoperative abduction was 133.5, 126.8, and 149.3 for dermal allograft, TFL autograft, and porcine xenograft. All 8 studies that recorded internal rotation reported an improvement of at least 1 vertebral level, with 1 TFL autograft study[11] and 1 LHBT autograft study[2] indicating a 6-level improvement.

There was significant variability in the definition of graft failure among the studies, including 5 that did not define it. Other studies used various minimal clinically important difference (MCID) thresholds in clinical outcome measurements, such as ASES score, to determine rates of graft failure. Among studies using ASES score thresholds, 1 study defined the MCID as 11, 2 studies as 17, and 1 study as 23. Given the various definitions of graft failure and MCID thresholds, no meaningful comparison was able to be made among differences in graft failure rates.

Subscapularis Involvement

Twelve studies commented on whether the subscapularis tendon was involved, with 2 reporting an absence of subscapularis tears and 10 noting the presence of subscapularis tears. The prevalence of subscapularis tears ranged from 9.1% to 73.0% among the 10 studies that noted subscapularis involvement in their patient cohorts. Furthermore, 2 studies comprised patients with irreparable subscapularis tears with a prevalence of 2% and 15%.[38,61] Given the small number of patients with an irreparable subscapularis tear (n = 6), a subanalysis could not be performed comparing outcomes with an intact/repairable subscapularis or with an irreparable subscapularis.

Pseudoparalysis

Three studies provided pre- and postoperative outcome information for cohorts demonstrating pseudoparalysis, defined as active forward elevation <90°. One study used dermal allograft (12-month follow-up),[5] and the other 2 studies used TFL autograft (follow-up range, 24-110 months).[39,61] Patients with preoperative pseudoparalysis exhibited similar postoperative ASES scores (90.4) as compared with patients without pseudoparalysis (89) (Table 3).

[¶]References 2, 5, 6, 12, 25, 29, 32, 35, 38-40, 50, 61.
[#]References 2, 5, 6, 11, 12, 29, 35, 36, 38-40, 50, 53, 61.
[**]References 2, 5, 6, 11, 29, 35, 36, 38-40, 61.

TABLE 2
Clinical and Functional Outcomes by Graft Type[a]

	Dermal Allograft	TFL Autograft	LHBT Autograft	Porcine Xenograft
Studies	7	7	2	1
Shoulders	263	304	38	20
Mean follow-up, mo	23.2	43.2	27.2	12.0
ASES				
Preoperative	52 (43.6-54)	38.8 (23.5-54.4)	45.6 (45-46.2)	
Postoperative	85.3 (77.5-89)	88.6 (73.7-94.3)	82.7 (80-85.4)	
Clinically significant	6 of 6	5 of 6	2 of 2	
Postoperative change	34.6 (29.9-37)	49.7 (19.3-69.4)	37.1 (35-39.2)	
Pain-VAS				
Preoperative	4.6 (4-5.8)	6	5.2	
Postoperative	0.8 (0-1.7)	2.5	1.4	
Clinically significant	6 of 6	1 of 1	1 of 1	
Postoperative change	4.1 (2.8-4.4)	3.5	3.8	
SSV				
Preoperative	36 (35-39)	33.0	41.0	
Postoperative	83 (76.3-91)	70.0	75.0	
Postoperative change	44 (41.3-55)	37.0	34.0	
Constant				
Preoperative			34.6 (17.5-51.7)	50.0
Postoperative			64.3 (63.7-64.9)	77.0
Clinically significant			2 of 2	1 of 1
Postoperative change			29.7 (12-47.4)	27.0
Forward elevation				
Preoperative	121 (27-140)	91 (67.5-136.2)	139 (135-143)	68.6
Postoperative	159 (118-167)	147 (141.4-160)	164 (162.5-165)	151.4
Clinically significant	5 of 5	6 of 7	2 of 2	1 of 1
Postoperative change	38 (27-132)	59.4 (13.0-74.0)	24.8 (22-27.5)	82.8
External rotation				
Preoperative	30 (24-37)	27.2 (13.2-38)	42 (35-49)	
Postoperative	43 (37-59)	40 (30-50.3)	51.4 (50-52.8)	
Clinically significant	2 of 3	3 of 7	1 of 2	
Postoperative change	19 (7-22)	14.0 (2-22.4)	9.4 (1-17.8)	
Abduction				
Preoperative	86.5 (70-103)	58.2 (53.2-63.1)		65.4
Postoperative	133.5 (107-160)	127 (120.7-132.9)		149.3
Postoperative change	47 (37-57)	68.7 (67.5-69.8)		83.9
Internal rotation				
Preoperative	L3	Sacrum-T11	Sacrum-T11	
Postoperative	L1	L2-T10	T12-T10	
Postoperative change	2 vertebrae	2.5 (1-6) vertebrae	3.5 (1-6) vertebrae	

[a]Values are presented as No. or median (range) unless noted otherwise. Blank cells indicate not applicable. ASES, American Shoulder and Elbow Surgeons; SSV, Subjective Shoulder Value; VAS, visual analog scale.

All cohorts of patients with preoperative pseudoparalysis had clinically significant improvements in median active forward elevation, and pseudoparalysis was reversed in 73 of 80 patients. After exclusion of patients who had an irreparable subscapularis tendon (n = 4), 73 of 76 (96%) with an intact/repairable subscapularis tendon had reversal of their pseudoparalysis after SCR.

Meta-analysis: Dermal Allograft vs TFL Autograft

Graft tear and reoperation rates after dermal allograft and TFL autograft were evaluated in a meta-analysis of proportions model. Magnetic resonance imaging (MRI) was used for postoperative imaging in 6 studies with dermal allograft, and ultrasound was used in 1 study with dermal allograft. MRI was used for postoperative imaging in 7 studies with TFL autograft. The pooled graft tear rate among the 7 studies that reported on dermal allograft was 7% (95% CI, 2%-13%) with substantial heterogeneity (I^2 = 52%) as compared with TFL autograft, which had a graft tear rate of 9% (95% CI, 4%-16%) with substantial heterogeneity (I^2 = 64%) (Figure 2). The pooled reoperation rate among the 7 studies that examined dermal allograft was 6% (95% CI, 2%-12%) with substantial heterogeneity (I^2 = 64%) as compared with TFL autograft, which had a reoperation rate of 3% (95% CI, 0%-7%) with no heterogeneity (I^2 = 7%) (Figure 3).

When evaluating complications after SCR, dermal allograft and TFL autograft had comparable rates of graft tears (7% and 9%, respectively), both of which were lower

TABLE 3
Effect of Preoperative Pseudoparalysis on Clinical and Functional Outcomes[a]

	No Pseudoparalysis	Pseudoparalysis
Studies	3	3
Shoulders	112	80
ASES		
Preoperative	47.3 (43.6-52)	35.4 (20.3-52)
Postoperative	89 (84.1-96.5)	90.4 (85.1-92.2)
Clinically significant	3 of 3	3 of 3
Forward elevation		
Preoperative	140 (135.6-142.7)	45.5 (27-67.5)
Postoperative	163.6 (161.3-167)	148.4 (141.4-159)
Clinically significant	3 of 3	3 of 3
External rotation		
Preoperative	36.4 (33.4-37)	23.45 (16.7-31.8)
Postoperative	51.6 (45.4-59)	40.5 (36.5-44)
Clinically significant	2 of 3	2 of 3

[a]Values are presented as No. or median (range). ASES, American Shoulder and Elbow Surgeons.[5,39,61]

than rates in studies utilizing porcine xenograft (15%) and 1 of the studies utilizing LHBT autograft (21%).[29] Of note, 1 study[2] utilizing LHBT autograft had a comparable graft tear rate to the pooled rate of dermal allograft and TFL autograft: 8%, 7%, and 9%, respectively. Porcine xenograft demonstrated the greatest rate of reoperation (25%) as compared with the pooled reoperation rate for dermal allograft (6%) and TFL autograft (3%). Low rates of infection were observed across all studies. No infection rates or reoperation rates were reported for LHBT autograft.

DISCUSSION

This comprehensive systematic review and meta-analysis demonstrated comparable ASES, Pain-VAS, and SSV scores after SCR with dermal allograft, TFL autograft, and LHBT autograft. Similar results were observed among functional outcomes. Median postoperative internal and external rotation was similar for dermal allograft, TFL autograft, and LHBT autograft, as was median postoperative abduction for dermal allograft, TFL autograft, and porcine xenograft. Additionally, comparable median postoperative forward elevation was found for all graft types. Meta-analysis also revealed an equivalent rate of graft tear and reoperation for SCR with dermal allograft or TFL autograft.

These results suggest that similar short-term clinical results may be achieved with SCR regardless of graft type, with a notable increase in shoulder function accompanied by significant pain reduction. Future studies using LHBT autograft and porcine xenograft are required to support this conclusion given the small number of existing studies involving these graft types. Despite this, the initial results of SCR with the LHBT are supported by previous biomechanical cadaveric studies demonstrating the LHBT to be effective in restoring shoulder stability.[14,20] Although biomechanical studies have not assessed the effectiveness of SCR with xenograft, cadaveric studies evaluating SCR with dermal allograft have shown excellent results.[55] SCR with xenograft may be able to provide similar restoration of shoulder function with more cost-effectiveness. However, use of the LHBT may be limited by its availability owing to anatomic variation or concomitant rupture.[31,65] One study in our systematic review found that nearly 50% of the study population had an absent LHBT with concomitant massive rotator cuff tears.[11]

Similar rates of graft tear (7% vs 9%) and reoperation (6% vs 3%) were found between dermal allograft and TFL autograft, respectively. This suggests that dermal allograft and TFL autograft demonstrate similar levels of clinical complications and rerupture rates. In comparison, porcine xenograft had much greater rates of complications, with a graft tear rate of 15%, reoperation rate of 25%, and immunologic rejection rate of 15%. As such, use of porcine xenograft is inadvisable given the large risk of clinically significant complications. Neither study evaluating LHBT autograft reported infection rates or reoperation rates.

One notable disadvantage of TFL autograft is donor site morbidity, although recent advances such as minimally invasive harvesting have reduced the rates of donor site morbidity. De Campos Azevedo et al[11] surveyed patients after SCR with minimally harvested TFL autograft with a 2-year follow-up and found that 57% of patients were bothered by the site of graft harvest. Despite significant donor site morbidity, 76% of patients indicated that improvements in shoulder function and reduction in pain compensated for the donor site morbidity, and at final follow-up 86% indicated that they would undergo the surgery again. In a study using minimally harvested TFL autograft with a 1.5-year follow-up, Ângelo and de Campos Azevedo[1] reported slightly lower functional scores of the affected thigh and associated donor site changes, such as subjective loss of strength and local complications in 7% and 13% of patients, respectively. These results suggest that donor site morbidity after TFL autograft is an important consideration when choosing graft type but should not disqualify the use of TFL autograft for SCR.

When compared with patients without preoperative pseudoparalysis, patients with pseudoparalysis demonstrated greater improvement in forward elevation and external elevation but did not attain the same levels of postoperative function. Despite this, 3 studies that reported pre- and postoperative outcomes for patients with pseudoparalysis found that it was reversed in 96% of patients with an intact/repairable subscapularis tendon upon final follow-up.[5,39,61] In a study of 27 patients with pseudoparalysis, Takayama et al[61] stated that SCR restored shoulder function in all 23 patients with a repairable subscapularis but did not restore shoulder function in any of the 4 patients with an irreparable subscapularis. This finding shows the importance of restoring the subscapularis function to better balance the shoulder during SCR for patients with pseudoparalysis. This is likely due to the fact that the subscapularis muscle plays an important role

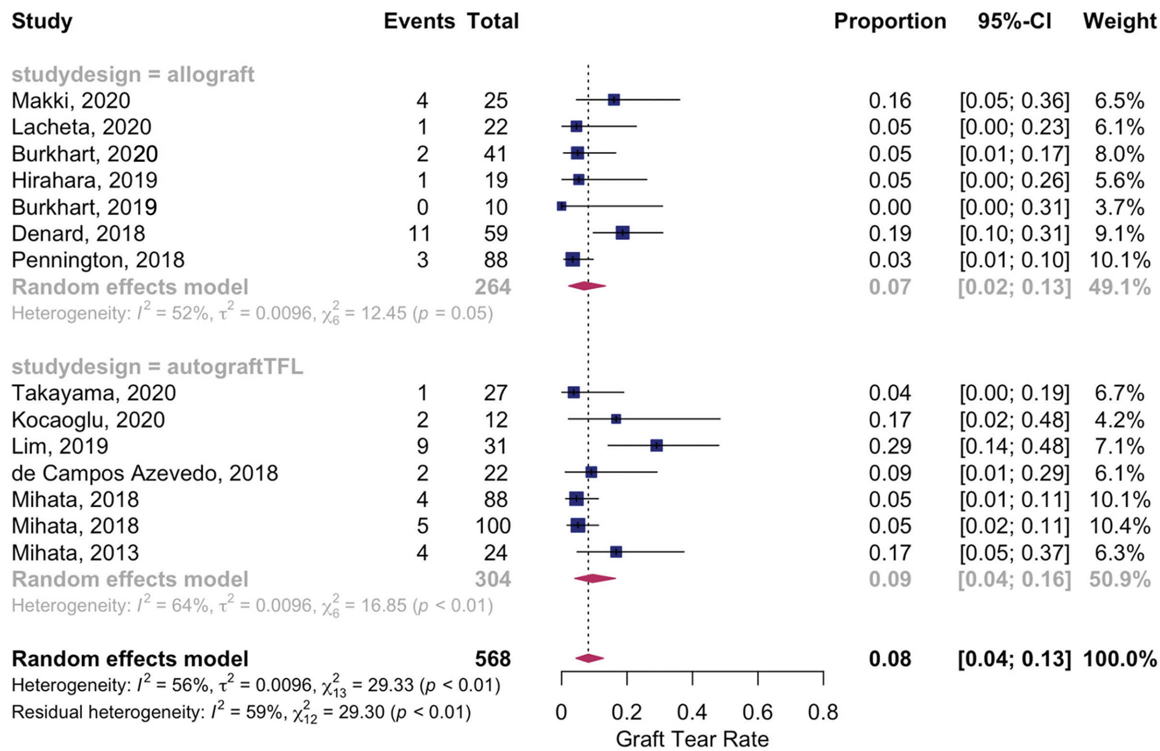

Figure 2. Forest plot of pooled graft tear rates: allograft vs tensor fascia lata autograft.

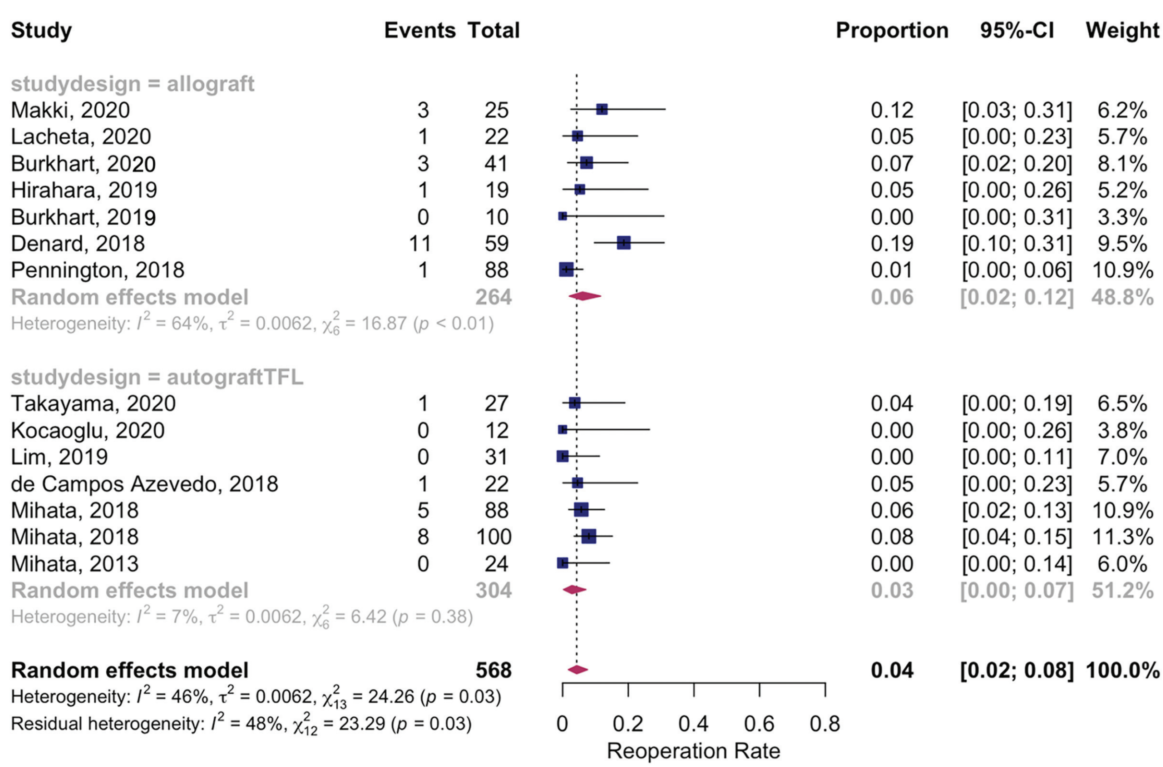

Figure 3. Forest plot of pooled reoperation rates: allograft vs tensor fascia lata autograft.

in maintaining balanced force couples, especially in the setting of rotator cuff tears.[49]

Study Limitations

This systematic review had several limitations. One important limitation was the small number of studies that used LHBT autograft and porcine xenograft. Although LHBT autograft demonstrated promising clinical and functional outcomes comparable to TFL autograft and dermal allograft, it was used in only 2 studies and did not include sufficient data on complications. Further studies with a more extensive report on complication data, such as clinical graft failure and reoperation rate, are needed to assess the stability of LHBT autograft in the case of SCR. Porcine xenograft was used in just 1 study, although the significant rate of complications and immunologic rejection suggests that xenograft should not be used in SCR. For all graft types, long-term outcome data are needed to assess the lifetime utility of SCR, including clinical outcomes and failure rates relative to other surgical options, such as reverse shoulder arthroplasty.

Another limitation was the heterogeneity among the clinical outcome measurement tools used after SCR. No single outcome measurement (eg, ASES score, Pain-VAS, and SSV) was used by all studies within this systematic review. Many studies reported less widely utilized outcome measurements, such as UCLA score (University of California, Los Angeles; 2 studies), SANE (single assessment numeric evaluation; 1 study), JOA score (Japanese Orthopaedic Association; 3 studies), and SPADI (Shoulder Pain and Disability Index; 2 studies). This lack of standardization within the field of shoulder surgery adds difficulty when assessing the efficacy of novel surgical procedures, and further standardization of shoulder clinical outcome scores is needed.

Graft failure was highly heterogeneous among the studies. Eight studies defined graft failure as a full-thickness tear on postoperative MRI; 3 defined graft tear as a failure to achieve an MCID; and 5 provided no definition. In addition, the studies that used clinical outcomes to define graft failure used either the ASES or the SPADI, as well as unique MCID thresholds. Given the heterogeneity of these data, we were unable to reach meaningful conclusions regarding the relative failure rates of the different graft types. Further standardization in MCID thresholds is needed to make effective comparisons among studies.

Similarly, standardization in terminology is needed. The terms "pseudoparalysis" and "pseudoparesis" lacked a standard definition, undermining the utility of the terms. Among the studies in this systematic review, pseudoparalysis was most commonly defined as active forward elevation <90°, although some studies defined it as active forward elevation <45°.[36] This general definition of pseudoparalysis may also be too broad and include a heterogeneous group of patients. For example, a patient with a painful rotator cuff tear with active forward elevation close to 90° is different from a patient with anterior-superior escape and no active forward elevation.[64] Moreover, studies have shown a difference in structural etiology for patients with active scapular plane abduction of 45° to 90° versus active scapular plane abduction <45°.[15] As such, comparisons are difficult to make across patients broadly categorized as having pseudoparalysis.

Given the novelty of this procedure, there has been significant evolution in the indications for SCR. Some studies excluded patients with pseudoparalysis[29] and included those with irreparable subscapularis tears,[38] guidelines that have since been revised. In fact, it is now accepted that an irreparable subscapularis is a contraindication to SCR because of the inability to balance force couples.[49] Moreover, there was large variability in the prevalence of subscapularis tears among the studies (0%-73.0%), and 4 studies did not comment on whether the subscapularis was torn. The variability in subscapularis involvement among the studies may have affected the outcomes in this study. Similarly, there was variability in the extent of rotator cuff pathology among the studies. Some studies included patients with more extensive arthropathy and fatty infiltration and may have been more likely to report worse outcomes than studies that included milder pathology.

Likewise, studies noted variability in the concomitant surgery performed, such as biceps tenotomy/tenodesis, acromioplasty, and subacromial decompression. These changes may have affected the outcomes of studies and limited the ability of this systematic review to effectively compare outcomes across different studies. However, biceps tenotomy/tenodesis and acromioplasty were performed in a majority of studies. As such, it is unlikely that the variation in concomitant surgery significantly affected the outcome comparisons in this study.

We assumed that no individual patient was represented in >1 study. Because 2 of the Mihata articles cited the same number of patients, some patients may have been overrepresented in our analyses.[39,41] As such, it is possible that the results of the meta-analysis for TFL autograft were skewed owing to possible overrepresentation of patients. Additionally, not all patients received postoperative imaging in 4 studies in the meta-analysis.[5,12,32,50] Despite this, we assumed that all retears were captured, since patients with better postoperative outcomes are more likely to refuse unnecessary MRI than those experiencing negative symptoms that may indicate a retear. However, this assumption may not be completely reliable, as patients may have good outcomes even with a retear and other patients may have only mild symptoms.[59] Therefore, it is possible that the rates of retear in some studies may have been affected by less postoperative imaging and thus affected the validity of the meta-analysis. Finally, we did not examine graft fixation methods, as there has been an evolution of anchor type, number, and configuration.[52]

CONCLUSION

TFL autograft, dermal allograft, and LHBT autograft for SCR demonstrate comparable short- and midterm shoulder improvement, including ASES score, Pain-VAS, and forward elevation. The rates of graft tear and reoperation were clinically similar when using dermal allograft or TFL autograft. The LHBT autograft may be preferable to avoid possible donor site morbidity associated with TFL autograft but may often be absent or torn in patients with rotator cuff pathology. Despite the robust and compelling data presented in this analysis, further study is recommended to more conclusively assess the utility of different graft types, especially with respect to LHBT autograft utilization. Long-term follow-up is also essential to determine the lifetime utility of SCR in relation to clinical outcomes and failure rates as compared with alternative surgical options such as reverse shoulder arthroplasty.

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