Comparison of Outcomes After Arthroscopic Superior Capsule Reconstruction Versus Arthroscopic Partial Repair or Arthroscopic Debridement for Irreparable Rotator Cuff Tears

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Background: Arthroscopic superior capsule reconstruction (SCR), arthroscopic partial repair (PR), and arthroscopic debridement (DB) are valid treatment options for irreparable rotator cuff (RC) tears.

Purpose/Hypothesis: The purpose of this study was to compare clinical, functional, and radiological outcomes of arthroscopic SCR with arthroscopic PR and arthroscopic DB in patients with irreparable posterosuperior RC tears. It was hypothesized that SCR would lead to superior clinical and functional outcomes compared with PR or DB.

Study Design: Cohort study; Level of evidence, 3.

Methods: Clinical and functional outcomes of this single-center retrospective study included range of motion, strength, and the age- and sex-adjusted Constant-Murley score. Patient-reported outcome measures (PROMs) involved the quick Disabilities of the Arm, Shoulder and Hand score, the Subjective Shoulder Value, and the visual analog scale for pain. Graft and repaired tendon integrity was evaluated by magnetic resonance imaging (MRI) at 12 months of follow-up.

Results: In total, 57 patients treated with SCR (n = 20), PR (n = 17), and DB (n = 20) were included. The mean clinical follow-up was 33.8 ± 17.9 months. Preoperative clinical and functional characteristics were comparable among the 3 groups. The range of motion and clinical and functional scores of all 3 groups significantly improved from pre- to postoperatively. Postoperative PROMs showed no differences among all 3 study groups. SCR revealed significantly higher postoperative strength compared with PR ($P = .001$) and DB ($P = .004$). Postoperative MRI revealed a rerupture in 4 patients with SCR (20%). Postoperative MRI showed a rerupture in 9 patients with PR (53%). Fatty muscle infiltration of the supraspinatus and infraspinatus significantly progressed within all 3 study groups in postoperative MRI scans. No clinical and functional differences were observed between intact and reruptured PR.

Conclusion: Patients who underwent SCR had better postoperative strength recovery than patients who underwent PR or DB.

Keywords: irreparable rotator cuff tear; arthroscopy; superior capsule reconstruction; SCR; partial repair; debridement; magnetic resonance imaging; fatty muscle infiltration; repair integrity

Full-thickness rotator cuff (RC) tears are reported in about 20% of the general working population >50 years of age.[44,63] In patients >80 years of age, degenerative changes of the RC are observed in >60%.[13,37,63] Recently, increased tendon retraction and a higher amount of fatty muscle infiltration were reported to be associated with increased RC delamination.[10,57] These findings are more frequently observed in patients with large to massive RC tears involving ruptures of ≥2 tendons.[10,57] Such massive tears account for about 40% of all RC tears and are associated with a higher rerupture rate as well as poorer clinical and functional outcomes.[8,19] According to Gerber et al,[22] a RC tear is considered as irreparable if a primary repair to the tendon's anatomic footprint at <60° of glenohumeral abduction is impossible despite sufficient surgical release and mobilization of the tendon. In this case, partial repair (PR) is a viable option, with good clinical and functional results.[8,26] By restoration of the force couple and thereby improving force transmission on the humeral head, PR leads to a better joint motion.[12] On the other hand, PR can result in pathological shoulder kinematics that may favor the development of glenohumeral osteoarthritis.[48] If PR is not

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possible, debridement (DB) of the torn tendons is an accepted treatment option for patients with large to massive RC tears who have only limited functional expectations.[8,26] DB can reduce pain and improve glenohumeral range of motion; however, shoulder strength remains unchanged or may even decrease postoperatively.[21]

While the superficial bursal layer represents the actual and more flexible RC tendon, the deeper ligamentous layer is in fact the more rigid glenohumeral joint capsule.[43,47,61] This deeper capsuloligamentous layer is of special biomechanical interest for glenohumeral joint stability as it counteracts the proximal migration of the humeral head.[1,33] This is also reflected in improved clinical outcomes, as higher rerupture rates are reported if the deeper capsuloligamentous layer was not integrated into the RC repair.[29] Based on these considerations, Mihata et al[43] introduced the superior capsule reconstruction (SCR) technique using a fascia lata autograft for patients with irreparable RC tears, aiming to restore the loss of superior glenohumeral joint stability. Even if the SCR represents a completely new approach for the treatment of irreparable RC tears, the significant improvements of clinical outcomes regarding pain reduction, improved range of motion, and the ability to eliminate pseudoparalysis led to a quick worldwide acceptance of this novel technique.[38-40] This can be explained, as strength restoration without impairment of shoulder kinematics can be achieved with SCR.[1,15,35,43,56] To overcome donor site morbidity, a minimally invasive harvesting technique of the fascia lata reduced autograft harvesting-related complications and showed promising clinical, functional, and radiological results in patients undergoing SCR.[3-6] Alternatively, Hirarara et al[30,31] proposed the use of an acellular dermal allograft for SCR.[16] A recently published systematic review reported good to excellent clinical outcomes in patients with irreparable RC tears undergoing SCR using a fascia lata autograft or a dermal allograft at mean short-term follow-up of 15 to 48 months.[2] Moreover, return to sport after SCR was reported in up to 100% of the cohort on the competitive and recreational levels.[38] However, long-term results on clinical and functional outcomes after SCR remain unknown.

Studies comparing PR and DB in large to massive RC tears have shown good clinical and functional outcomes for both treatment options.[9,28] The purpose of this study was to compare clinical, functional, and radiological outcomes of arthroscopic SCR with arthroscopic PR and arthroscopic DB in patients with irreparable posterosuperior RC tears. We hypothesized that SCR would lead to superior clinical and functional outcomes compared with PR and DB.

METHODS

Study Groups

The study was performed in accordance with the Helsinki Declaration and institutional review board approval was received for the protocol of this single-center retrospective study. Each patient signed written informed consent prior to any study procedures. Patients with irreparable RC tears who underwent arthroscopic SCR, PR, or DB of the shoulder between January 2012 and December 2018 and had at least 1 year of clinical and functional follow-up were included in this study. Because elevated blood sugar levels and nicotine impair tendon-to-bone healing,[20,36,49,50] patients with diabetes mellitus and a smoking history were excluded from the study. Also, patients were excluded in the case of an open surgery or revision surgery. All surgical procedures were performed by 2 fellowship-trained shoulder surgeons (W.A., P.R.H.). The surgical technique was chosen according to the surgeon's preference and ability to reconstruct. Over time, more patients underwent SCR than PR or DB.

Surgical Technique and Postoperative Rehabilitation

Superior Capsular Reconstruction

The surgical procedure has previously been described in detail.[16,30,40] All surgical procedures were performed with patients in the beach-chair position under general anesthesia and interscalene plexus blockade. DB of the tear margins, comprehensive bursectomy, subacromial decompression, opening of the rotator interval, and tenotomy of the long head of the biceps tendon (LHBT) were performed in all patients. If necessary, partial resection of the acromioclavicular joint was added. In the case of tearing of the subscapularis (SSC) tendon and/or infraspinatus (ISP) tendon, a single-row reconstruction was performed using a titanium suture anchor (5.5 mm CorkScrew FT III; Arthrex). SCR was performed using a 3-mm decellularized human dermal allograft (ArthroFLEX; LifeNet Health). The graft was fixed to the upper glenoid rim using 2

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titanium suture anchors (5.5 mm CorkScrew FT III). The arm was then positioned in 30° to 45° of abduction for humeral fixation of the SCR graft using a knotless transosseous equivalent configuration (SpeedBridge and FiberTape; Arthrex). Additionally, 3 side-to-side sutures between the ISP tendon and the dorsal margin of the SCR graft at a distance of 5 to 7 mm were performed. The rotator interval was left open.

After surgery, all shoulders were immobilized in a sling for 6 weeks. Passive mobilization was allowed from the beginning. After 6 weeks, assistive and active physical therapy without strengthening exercises or loadbearing for 12 weeks postoperatively were allowed.

PR and DB

All surgical procedures were performed with patients in the beach-chair position under general anesthesia and interscalene plexus blockade. DB of the tear margins, comprehensive bursectomy, subacromial decompression, and opening of the rotator interval were performed in all patients. A tenotomy of the LHBT was performed in all cases. If necessary, partial resection of the acromioclavicular joint was added. In case a PR of the RC was attempted, extensive tendon releases including resection of the coracohumeral ligament at the coracoid base as well as extra-articular tendon and muscle mobilization were performed. In case of tearing of the SSC tendon, a single-row refixation was performed using 1 or 2 titanium suture anchors (5.5 mm CorkScrew FT III). The ISP tendon was refixed at its footprint using 1 or 2 titanium suture anchors (5.5 mm CorkScrew FT III) to ensure reconstruction of the force couple.

In case of PR, shoulders were immobilized in a sling for 4 weeks. Passive mobilization was allowed from the beginning. After 4 weeks, assistive and active physical therapy without strengthening exercises or loadbearing for 12 weeks postoperatively were allowed. If solely a DB was performed, passive, assistive, and active physical therapy were allowed directly after surgery.

Clinical and Functional Evaluation

All clinical and functional assessments were performed before and at least 1 year after surgery by a single examiner (P.R.H.). Pre- and postoperative clinical and functional outcomes included range of motion using a goniometer, abduction strength at 90° of abduction and internal rotation using a spring scale, and the age- and sex-adjusted Constant-Murley score (0%, worst; 100%, best; ≥91%, excellent; 81%-90%, good; 71%-80%, satisfactory; 61%-70%, fair; ≤60%, poor).[14,66] Strength data were not normalized because of the natural discrepancy between the dominant and nondominant arms. Patient-reported outcome measures (PROMs) involved the quick Disabilities of the Arm, Shoulder and Hand (qDASH) score (0, best; 100, worst),[7] the Subjective Shoulder Value (SSV) (percentage of a 100% normal shoulder),[23] the 10-point visual analog scale (VAS) for pain (0, no pain; 10, severe pain), and the patient's satisfaction with the surgical procedure (not satisfied, fairly satisfied, moderately satisfied, satisfied, or very satisfied).

Magnetic Resonance Imaging Evaluation

Magnetic resonance imaging (MRI) scans were performed before surgery and at least 1 year postoperatively. All MRI scans were reviewed by 2 independent examiners (J.E.S., M.E.) in a blinded fashion, who were not involved in the surgical procedures, as well as by 1 radiologist experienced in the musculoskeletal field. All investigators performed 2 measurements for every MRI scan at 2 different time points. Discrepancies between investigators were identified and discussed until consensus was reached.

Preoperative tendon retraction was evaluated according to Patte[51]: grade 1 describes a tendon retraction between the greater tuberosity and the apex of the humeral head, grade 2 describes a tendon retraction between the apex of the humeral head and the upper glenoid border, and grade 3 describes a tendon retraction beyond the upper glenoid border.[51] Pre- and postoperative fatty muscle infiltration of the SSP tendon, ISP tendon, and SSC tendon were graded according to the Goutallier classification[18,24,25,64]: grade 1 describes new fatty streaks within the muscle belly, grade 2 indicates less fat than muscle, grade 3 shows the same amount of fat and muscle, and grade 4 indicates more fat than muscle. Structural repair integrity was evaluated according to Sugaya et al.[62] Since correct interpretation of repair integrity is impeded by artifacts caused by metallic suture anchors, an adapted version of the proposed classification by Sugaya et al was applied as previously reported: a tendon with homogeneous low-intensity or partial high-intensity areas and sufficient thickness was regarded as intact, a thinning of the tendon without or with only minor discontinuity on 1 image was classified as partly reruptured, and an obvious discontinuity in >1 slice was diagnosed as a rerupture.[28]

Statistical Analysis

Descriptive statistics were used to present patients' characteristics. Data distribution was assessed by visual inspection of histograms and the Kolmogorov-Smirnov test. Normally distributed continuous data were presented as mean ± SD; otherwise, data were presented as median and range. Categorical variables were described as proportion and frequency count.

Analysis of variance (parametric data) or the Kruskal-Wallis test (nonparametric data) was used to analyze differences among the 3 groups (SCR vs PR vs DB). If differences existed, pairwise comparison was performed using the independent *t* test (parametric data) or Mann-Whitney *U* test (nonparametric data) for continuous data. The Bonferroni correction was applied to correct for multiple comparisons within the outcomes. For paired comparisons (pre- and postoperative outcomes), the paired *t* test (parametric data) or Wilcoxon matched-pairs signed-rank test (nonparametric data) was applied. Categorical data were assessed using the chi-square test.

TABLE 1
Patient Data and Preoperative Radiographic Imaging Evaluation[a]

	SCR (n = 20)	PR (n = 17)	DB (n = 20)	*P*
Age, y	66.4 ± 7.1 (49-76)	67.1 ± 8.7 (54-80)	66.0 ± 7.0 (53-77)	.903[b]
Sex, female/male	14 (70)/6 (30)	7 (41)/10 (59)	10 (50)/10 (50)	.190[c]
Dominant arm affected, yes/no	19 (95)/1 (5)	15 (88)/2 (12)	16 (80)/4 (20)	.351[c]
Hamada classification[27]	1 [1-2]	1 [1-2]	2 [1-2]	.625[c]
Acromiohumeral interval distance, mm	7 ± 3 (3-14)	7 ± 2 (5-11)	7 ± 2 (4-12)	.719[d]

[a]Data are presented as mean ± SD (range), median [interquartile range], or n (%). DB, debridement; PR, partial repair; SCR, superior capsule reconstruction.
[b]Analysis of variance.
[c]Chi-square test.
[d]Kruskal-Wallis test.

Statistical significance was set at $P < .05$ (2-sided) and at $P < .017$ for Bonferroni correction if not otherwise mentioned. All data were analyzed with SPSS software (IMP Statistics Version 25; IBM Corp).

RESULTS

Patient Data

A total of 57 patients were included in this study (SCR, n = 20; PR, n = 17; DB, n = 20). No differences were observed in age, sex distribution, or whether the dominant arm was affected (Table 1).

Clinical and Functional Evaluation

Preoperative clinical and functional assessments were comparable among all 3 study groups (Table 2). Preoperative analysis of subcategories of the Constant-Murley score showed significantly higher pain for PR compared with SCR ($P = .014$) and DB ($P = .024$) (Figure 1A). The mean clinical and functional follow-up among all patients was 33.8 ± 17.9 months (range, 12-63 months). The mean clinical and functional follow-up was 12.4 ± 0.7 months (range, 12-14 months) for SCR, 40.0 ± 12.2 months (range, 24-63 months) for PR, and 46.4 ± 11.8 months (range, 25-62 months) for DB. Of all 57 patients, 4 (20%) patients who underwent SCR had revision surgery within the first year because of graft failure (range, 4-9 months after SCR) with associated pain and impaired range of motion. In all 4 revision cases, patients underwent implantation of a reverse total shoulder arthroplasty (RTSA). The 4 revisions were excluded from clinical and functional assessment.

Clinical and functional outcomes significantly improved postoperatively in all 3 study groups (Table 2). Postoperative abduction, forward flexion, and external rotation, as well as the Constant-Murley score, qDASH score, and VAS for pain score were comparable among all 3 study groups. Unrevised SCR showed significantly higher postoperative strength (6.2 ± 3.3 kg) compared with PR (2.6 ± 1.8 kg; $P = .001$) and DB (3.1 ± 2.3 kg; $P = .004$), which was also reflected by postoperative analysis of subcategories of the Constant-Murley score (Figure 1B). Postoperative SSV revealed significantly higher values for SCR (82% ± 17%) than for PR (72% ± 13%; $P = .018$). Postoperative SSV was comparable between SCR and DB. Comparing PR and DB, no differences in postoperative clinical and functional outcomes were observed. No clinical and functional differences were observed between intact and reruptured PR. The vast majority of patients were satisfied or very satisfied with their arthroscopic procedure (SCR, 94%; PR, 88%; DB, 90%).

MRI Evaluation

Postoperative MRI was available in all patients with SCR and PR. In the case of DB, postoperative MRI was available in 12 of 20 (60%) patients. The mean MRI follow-up among all patients was 12.1 ± 1.7 months (range, 4-15 months). The mean MRI follow-up was 12.4 ± 0.7 months (range, 12-14 months) for SCR, 12.8 ± 2.4 months (range, 12-15 months) for PR, and 12.2 ± 0.3 months (range, 12-13 months) for DB. MRI data are presented in Table 3.

Preoperatively, patients with PR revealed significantly lower ISP tendon retraction than those with SCR ($P = .015$) and DB ($P = .006$). Significantly higher rates of preoperative ISP fatty muscle infiltration were observed for DB compared with SCR ($P = .003$). Significantly lower rates of preoperative SSC fatty muscle infiltration were observed for SCR compared with PR ($P = .003$) and DB ($P = .008$). Fatty muscle infiltration of the SSP and ISP significantly progressed within all 3 study groups in postoperative MRI scans. Postoperative fatty muscle infiltration of the SSC remained unchanged compared with preoperative MRI scans within all 3 study groups.

Of 20 patients with SCR, 4 (20%) patients revealed a rerupture with dislocation of the patch in the glenohumeral joint on postoperative MRI scans within the first year after surgery (range, 4-9 months). In 2 cases, rerupture was detected on the glenoid side, and in the other 2 cases rerupture occurred on the humeral side. Of 17 patients with PR, 9 (53%) patients revealed a rerupture on postoperative MRI scans. Significantly lower rerupture rates were observed for patients with SCR than for those with PR ($P = .032$).

TABLE 2
Preoperative and Postoperative Evaluation of Clinical, Functional, and Patient-Reported Outcome Measures[a]

				P			
	SCR (n = 16)	PR (n = 17)	DB (n = 20)	Between Groups[b]	SCR vs PR[c]	SCR vs DB[c]	PR vs DB[c]
Abduction, deg							
Preoperative	100 ± 47	103 ± 29	103 ± 43	.966	—	—	—
Postoperative	152 ± 30	143 ± 28	142 ± 30	.138	—	—	—
P (within group)[d]	**.005**	**.001**	**.002**				
Forward flexion, deg							
Preoperative	106 ± 44	111 ± 29	117 ± 42	.720	—	—	—
Postoperative	156 ± 22	149 ± 21	148 ± 28	.250	—	—	—
P (within group)[d]	**.003**	**.001**	**.002**				
External rotation, deg							
Preoperative	23 ± 20	25 ± 17	32 ± 20	.368	—	—	—
Postoperative	42 ± 19	38 ± 20	48 ± 21	.398	—	—	—
P (within group)[d]	**.029**	**.001**	**.006**				
Strength, kg							
Preoperative	0.8 ± 1.1	1.2 ± 1.4	1.3 ± 1.6	.748	—	—	—
Postoperative	6.2 ± 3.3	2.6 ± 1.8	3.1 ± 2.3	**.002**	**.001**	**.004**	.536
P (within group)[d]	**.001**	**.004**	**.001**				
Constant-Murley score[e]							
Preoperative	36 ± 18	44 ± 15	41 ± 17	.363	—	—	—
Postoperative	89 ± 19	78 ± 12	78 ± 15	.068	—	—	—
P (within group)[d]	**<.001**	**<.001**	**<.001**				
qDASH score							
Preoperative	65 ± 15	54 ± 20	62 ± 16	.228	—	—	—
Postoperative	18 ± 16	22 ± 15	23 ± 20	.724	—	—	—
P (within group)[d]	**<.001**	**<.001**	**<.001**				
SSV, %							
Preoperative	37 ± 17	34 ± 15	36 ± 12	.671	—	—	—
Postoperative	82 ± 17	72 ± 13	74 ± 15	**.036**	**.018**	.060	.317
P (within group)[d]	**<.001**	**.001**	**<.001**				
VAS pain score							
Preoperative	7 ± 1	7 ± 2	7 ± 1	.404	—	—	—
Postoperative	2 ± 2	2 ± 2	2 ± 2	.438	—	—	—
P (within group)[d]	**<.001**	**<.001**	**<.001**				

[a]Data are presented as mean ± SD. Boldface *P* values indicate statistically significant differences ($P < .05$). Dashes indicate areas not applicable. DB, debridement; PR, partial repair; qDASH, quick Disabilities of the Arm, Shoulder and Hand; SCR, superior capsule reconstruction; SSV, Subjective Shoulder Value; VAS, visual analog scale.

[b]*P* value among the 3 groups using analysis of variance (parametric data) or Kruskal-Wallis test (nonparametric data).

[c]*P* value between 2 groups using the independent *t* test (parametric data) or Mann-Whitney *U* test (nonparametric data). Significance set at $P < .017$ owing to Bonferroni correction.

[d]*P* value within a group using the paired *t* test (parametric data) or Wilcoxon matched-pairs signed-rank test (nonparametric data).

[e]Adjusted for age and sex.

DISCUSSION

In the case of irreparable RC tears, SCR, PR, and DB led to good clinical and functional outcomes at a minimum of 1 year postoperatively. Pain, range of motion, strength, the Constant-Murley score, the qDASH score, and the SSV all statistically significantly improved postoperatively in all 3 study groups. Compared with PR and DB, SCR showed significantly higher postoperative strength, which is also reflected by an increased strength subcategory of the Constant-Murley score. Also, SCR revealed a higher postoperative SSV compared with PR. However, improved clinical and functional outcomes of all 3 study groups were not reflected by postoperative MRI scans, as fatty muscle infiltration of the SSP and ISP progressed, while fatty muscle infiltration of the SSC remained unchanged. Furthermore, 20% of patients treated with SCR underwent surgical revision with RTSA within the first year after surgery, whereas patients treated with PR or DB had no revision surgery at the final follow-up.

A recent systematic review reported good to excellent clinical outcomes with adequate pain relief and improved range of motion in patients with irreparable RC tears after SCR using a fascia lata autograft or a dermal allograft at a mean short-term follow-up of 15 to 48 months. The postoperative complication rate was 19%, with graft failure as the most common complication (13%).[2] Clinical and functional outcomes of our study were comparable to the results presented in the literature, as pain, range of motion, strength, the Constant-Murley score, and PROMs all significantly

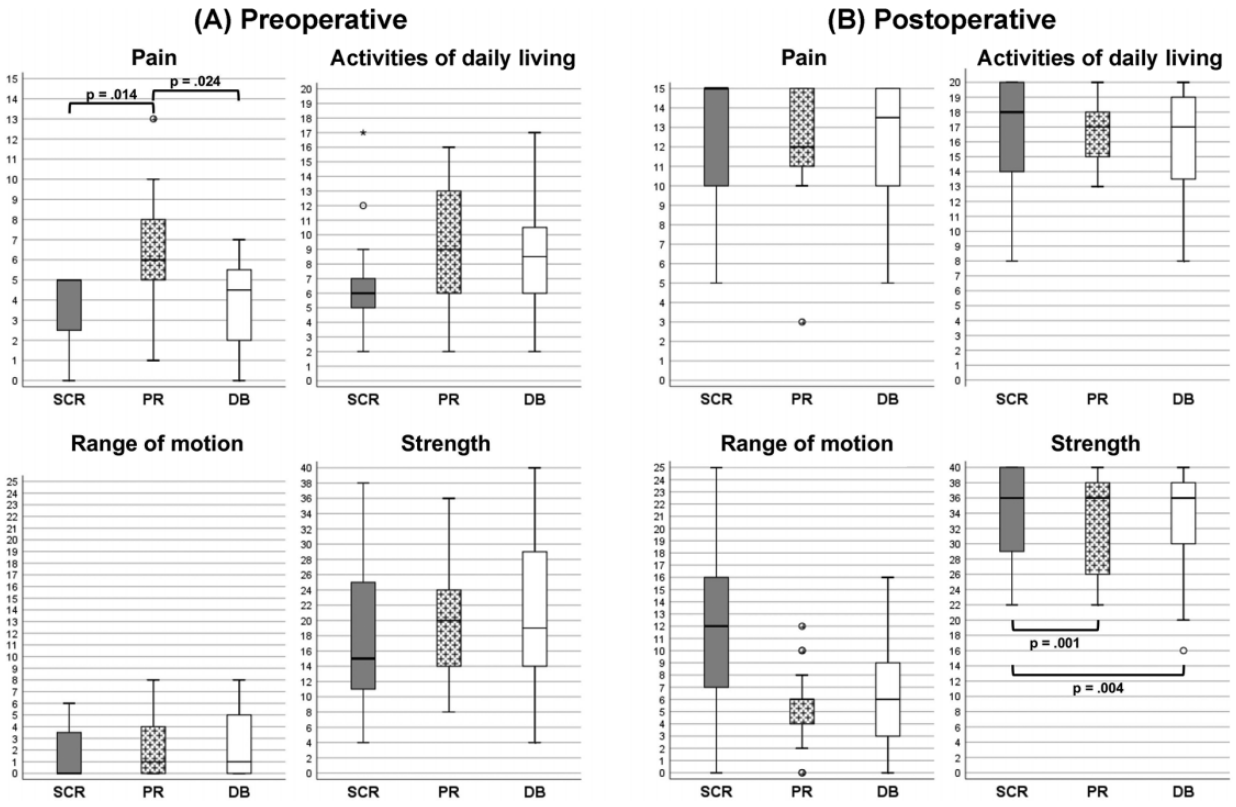

Figure 1. Subcategories of (A) preoperative and (B) postoperative age- and sex-adjusted Constant-Murley scores comparing arthroscopic superior capsule reconstruction (SCR) with arthroscopic partial repair (PR) and arthroscopic debridement (DB). Significant values are marked with brackets. Circles represent outliers, and stars represent extreme outliers.

improved postoperatively, reaching the minimal clinically important difference.[17]

Several studies have reported satisfying outcomes with improved range of motion and adequate pain relief after PR in irreparable RC tears.[9,32,34,54] Similarly, our study showed a significant pain reduction and improvement of range of motion and strength, as well as a significant improvement of PROMs after arthroscopic PR.

By sole removal of tendinotic tissue and surrounding synovitis in the glenohumeral joint and the subacromial bursa, as well as concomitant LHBT tenotomy, Rockwood et al[55] reported an improvement in range of motion and pain reduction in 83% of their cohort at a mean follow-up of 6.5 years. Similarly, Gartsman[21] reported a satisfaction rate of 79% in 33 patients after DB and subacromial decompression. Because lesions of the LHBT are often observed in patients with large to massive RC tears, causing pain and impingement-like symptoms,[11,26,65] additional tenotomy of the LHBT in the case of DB is indicated.[11,65] As all patients treated with DB underwent concomitant tenotomy of the LHBT, our clinical and functional outcomes after DB reflect the results from previous studies.[21,55] We observed a significant pain reduction, improvement of range of motion and strength, and increase of PROMs after arthroscopic DB.

Comparing all 3 study groups, significantly higher postoperative strength was found for the intact SCR group compared with PR and DB. Biomechanical analyses on SCR showed a decrease of proximal migration of the humeral head, thus preventing subacromial impingement and eventually preserving the acromiohumeral distance.[41,42] Also, restoration of the superior capsule leads to a normalization of superior glenohumeral translation in motion and therefore may decrease the RC retear rate and improve the clinical outcome.[1] This effect is further increased if the graft is sufficiently tensioned.[15] In a biomechanical study, Rybalko et al[56] were able to restore key biomechanical parameters of the glenohumeral joint after SCR comparable to a physiological shoulder joint motion, thus reflecting the increase of postoperative strength compared with PR or DB.

Interestingly, we observed a significantly higher SSV in patients treated with SCR compared with PR, while no differences in SSV were observed between SCR and DB. The fact that no clinical and functional differences were observed between intact and reruptured PR might be explained, as patients were actually impaired in their range of motion but were not evaluated with a painful shoulder, thus excluding them from any revision surgery. However, an impaired range of motion within the reruptured PR group might have negatively affected the SSV for PR. Nonetheless, this is just presumptive and cannot be concluded because of the small sample size.

Comparing the different graft types for SCR, Sommer et al[60] found rerupture rates between 8% and 29% in the case of autografts, with increasing numbers between 19%

TABLE 3
Preoperative and Postoperative Evaluation of Magnetic Resonance Imaging Scans[a]

				P			
	SCR (n = 20)	PR (n = 17)	DB (n = 12)	Between Groups[b]	SCR vs PR[c]	SCR vs DB[c]	PR vs DB[c]
Tendon retraction[d]							
Preoperative SSP	3 [2-3]	2 [2-3]	3 [2-3]	.063	—	—	—
Preoperative ISP	2 [2-3]	2 [1-3]	2.5 [2-3]	**.015**	**.015**	.554	**.006**
SSP fatty muscle infiltration[e]							
Preoperative	3 [3-4]	3 [1-4]	3 [3-4]	.071	—	—	—
Postoperative	4 [3-4]	4 [2-4]	4 [4-4]	.196	—	—	—
P (within group)[f]	**.014**	**<.001**	**.008**				
ISP fatty muscle infiltration[e]							
Preoperative	2 [1-4]	3 [1-4]	3 [2-4]	**.015**	.662	**.003**	.038
Postoperative	3 [2-4]	3 [1-4]	4 [3-4]	**.048**	.544	.053	.017
P (within group)[f]	**.005**	**.025**	**.046**				
SSC fatty muscle infiltration[e]							
Preoperative	1 [1-3]	3 [1-4]	2 [1-4]	**.004**	**.003**	**.008**	.475
Postoperative	1 [1-3]	3 [1-4]	2 [1-4]	**.013**	**.013**	**.010**	.908
P (within group)[f]	.083	.999	.083				

[a]Data are presented as median [interquartile range]. Boldface *P* values indicate statistically significant differences ($P < .05$). Dashes indicate areas not applicable. DB, debridement; ISP, infraspinatus; PR, partial repair; SCR, superior capsule reconstruction; SSC, subscapularis; SSP, supraspinatus.

[b]*P* value among the 3 groups using the Kruskal-Wallis test (nonparametric data).

[c]*P* value between 2 groups using the Mann-Whitney *U* test (nonparametric data). Significance set at $P < .017$ owing to Bonferroni correction.

[d]Tendon retraction according to Patte.[51]

[e]Fatty muscle infiltration according to the Goutallier classification.[18,24,25,64]

[f]*P* value within 1 group using Wilcoxon matched-pairs signed-rank test (nonparametric data).

and 70% for allografts, respectively. In our study group, we observed 20% reruptures within the SCR group. As all patients were treated with a decellularized human dermal allograft, graft failure in our study group is within the lower range according to the abovementioned recent systematic review.[60]

Within the PR group, we observed a rerupture rate of 53%. However, no revision surgery was performed in the PR group at the latest follow-up. This high failure rate of RC repair stands in line with previous studies. Berth et al[9] observed sonographically verified reruptures in 11 of 20 (55%) PRs at a mean follow-up of 2 years. Mori et al[45] reported reruptures in 10 of 24 (41.7%) PRs at a mean midterm follow-up of 3 years and in 13 (54.2%) cases after a mean follow-up of 8 years. Still, similar to Heuberer et al,[28] the high rerupture rate reported in our study was not reflected by clinical and functional outcomes at short- to midterm follow-up periods, since there were no differences between an intact PR and verified reruptures. Nevertheless, a biomechanical investigation observed abnormal shoulder kinematics after PR, which may increase the development of glenohumeral osteoarthritis, eventually leading to inferior clinical and functional outcomes at long-term follow-up.[48] After a mean follow-up of 8 years, Mori et al[45] observed significantly inferior clinical and functional outcomes in the case of a PR rerupture with a concomitant increase in fatty muscle infiltration and osteoarthritis development.

Another viable treatment option for irreparable RC tears is RTSA.[53] As the primary indication for RTSA is an irreparable RC tear with the presence of significant osteoarthritis,[59] 2 studies have reported on significant improvements of PROMs in patients undergoing RTSA in the case of irreparable RC tears without osteoarthritic changes.[46,58] However, because of an increased complication rate after RTSA, the indication of primary RTSA, especially in patients with concomitant pseudoparalysis, must be carefully chosen, as arthroscopic procedures show comparable midterm results to RTSA. Furthermore, as component loosing after RTSA is the main cause of failure over time, primary RTSA in patients <65 years of age must be carefully weighed.[52,53]

The management of irreparable posterosuperior RC tears is still a challenge, as treatment strategies should be individually tailored to demands and expectations of the patient. Joint-preserving procedures such as the SCR succeed in restoring glenohumeral biomechanics and function. However, they should be reserved for the nonosteoarthritic shoulder and patients with higher physical demands, as postoperative recovery and rehabilitation of the shoulder are challenging and time-consuming. However, this prolonged recovery and rehabilitation after SCR is clinically beneficial, as the intact SCR is associated with improved postoperative strength compared with PR and DB. Nevertheless, long-term clinical, functional, and radiological data are still missing.[53] Also, because the costs for SCR clearly exceed the ones for PR and DB, cost analyses relative to clinical outcomes are needed to determine the overall

value of SCR. In the nonfunctional shoulder, with or without osteoarthritic degeneration, arthroscopic PR or arthroscopic DB led to satisfying clinical and functional outcomes.[53]

Limitations

This study has several limitations. First, the retrospective design with its relatively short follow-up is a potential source of selection bias to this investigation. This can be reflected by preoperative MRI scans, as patients with PR revealed significantly lower ISP tendon retraction than patients with SCR and DB, and significantly higher rates of preoperative ISP fatty muscle infiltration were observed for DB compared with SCR. Also, the different clinical and functional follow-up periods among all 3 study groups, as well as the exclusion of patients who underwent revision surgery, are a potential source of bias, as differences between the study groups might have been veiled. It must be noted that strength measurement was solely performed on the affected shoulder; therefore, no normalization to the uninvolved shoulder was done. Moreover, because of the small sample size, the results must be interpreted with caution.

CONCLUSION

Results from the present study showed that SCR, PR, and DB are valid treatment options for irreparable RC tears. Nevertheless, SCR led to a better clinical outcome regarding postoperative strength recovery.

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