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Ten-year clinical and magnetic resonance imaging evaluation after repair of isolated subscapularis tears

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Hypothesis: The purpose was to evaluate long-term clinical outcomes and tendon structural integrity after repair of isolated subscapularis (SSC) tendon tears.

Methods: Sixty-one patients who underwent repair of isolated SSC tears were evaluated. The mean interval from symptom onset to surgery was 5.3 months. Shoulder function was investigated using the Constant score and Subjective Shoulder Value (SSV). Structural integrity of the repair and quality of the repaired tendon were assessed using magnetic resonance imaging. Independent preoperative factors affecting clinical outcomes, including patient sex, age, smoking habits, injections, dominant shoulder, profession, and tear onset (chronic vs. traumatic), were evaluated.

Results: A total of 35 patients (9 women and 26 men; mean age, 54 years) were included at the final 10-year follow-up because 21 patients were lost to follow-up and 5 underwent reoperations. The mean Constant score improved from 55.1 points preoperatively to 75.4 points postoperatively ($P = .001$). The postoperative SSV was 80.9, and the retear rate was 12.9%. Postoperative fatty infiltration increased in 26% of the patients with grades 3-4, but it was not related to lower clinical outcomes. Multivariable regression analysis revealed no correlation among the preoperative factors, including sex, age, smoking habits, injections, dominant shoulder, profession, and tear onset, and the postoperative Constant score, SSV, and tendon healing.

Conclusion: At a mean of 10 years after repair of isolated SSC tears, clinical results were satisfactory and functional improvement was maintained in the long term. Severe fatty infiltration increased with time, but it was not related to clinical outcomes and the retear rate.

The subscapularis (SSC) muscle is the largest and strongest muscle of the rotator cuff.[22,36] It has an important role in shoulder stability and function and is an anterior stabilizer of the shoulder joint.[21,32] SSC tears may present as part of a massive anterosuperior rotator cuff tear[5,34,42] or as isolated lesions.[8,15,16,31] Surgical repair of the SSC tendon is important regarding recovering internal rotation and dynamic anterior glenohumeral stability, as well as force coupling in the transverse plane.[29,30,33,37,40] However, isolated SSC tendon tears are less common, with a prevalence of only 4% among all rotator cuff lesions.[9] Because of the rarity of this injury, only a few studies have reported on the clinical results of isolated SSC tendon repair, mostly in a small number of cases.[2,3,5,19,20,24,31,36] Moreover, long-term studies of the outcome of SSC repair are sparse in the literature. Recently, Seppel et al[36] reported long-term results after repair of isolated SSC tears, with a mean follow-up period of 98.4 months. However, their series included only 17 patients in the functional evaluation, and of these, 13 (76.5%) received a magnetic resonance imaging (MRI) assessment for tendon integrity.

Fatty infiltration is an important index that reflects the quality of rotator cuff muscle, which can be evaluated using MRI or computed tomography scans.[12,18] The postoperative change in fatty infiltration after repair of SSC tendons remains controversial. Some studies reported a significant decrease in fatty infiltration of the repaired

All procedures in this study involving human participants were performed in accordance with the ethical standards of the Institutional Research Committee of Centre Hospitalier Universitaire de Strasbourg, Strasbourg, France (no. IDRCB 2013-A01788-37) and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

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SSC,[19] whereas others reported a progressive increase[28,39] or unchanged fatty infiltration at 27-38 months of follow-up.[3,11,24] Furthermore, long-term fatty infiltration changes in the repaired SSC remain unknown.

The purpose of this study was to evaluate long-term clinical outcomes and tendon structural integrity after repair of isolated SSC tendon tears. We hypothesized that the isolated SSC repair would provide satisfactory long-term functional and structural outcomes, with improvement in fatty infiltration of the repaired SSC.

Materials and methods

Study design

We retrospectively studied the records of all patients who underwent surgical repair of isolated SSC tendon tears, which had been performed in 2003 by 15 surgeons at 15 centers. The inclusion criteria were adult patients with symptomatic, confirmed isolated full-thickness tears of the SSC, who received complete tendon repair by either open or arthroscopic surgery. The exclusion criteria were partial-thickness tears, a history of shoulder surgery, partial tendon repairs, and concomitant lesions of other rotator cuff tendons. A total of 61 patients were identified and were asked to return in 2014 for clinical and radiographic evaluation at a follow-up of 10 years.

Of the original cohort of 61 patients, 21 (34.4%) were lost to follow-up and 5 (8.2%) were excluded because they had undergone a reoperation: 2 for painful retear of the SSC, 1 for infection, 1 for postoperative stiffness, and 1 for arthritis of the acromioclavicular joint. The final study cohort included 35 patients (26 men and 9 women) who had a mean age of 54 ± 7.9 years (range, 39-67 years) at the time of surgery and were examined clinically. The patients' demographic characteristics are shown in Table I. Among them, 31 have undergone an MRI examination for tendon healing assessment (Fig. 1). Of the lesions, 18 (51.4%) were found in the superior half of the SSC tendon whereas 17 (48.6%) were observed extending into the lower half of the tendon.

Table I
Patients' demographic characteristics

	Data
Age, yr	54 ± 7.9 (39.2-66.7)
Sex: M/F, n	26/9
Dominant side involved	25 (71.4)
Smokers	7 (25.9)
Previous trauma	16 (51.6)
Previous injections	10 (34.5)
Profession	
Sedentary	9 (25.7)
Light manual	12 (34.3)
Heavy manual	12 (34.3)
Repetitive	2 (5.7)

M, male; *F*, female.
Categorical variables are presented as number (percentage); continuous variables are presented as mean ± standard deviation (range).

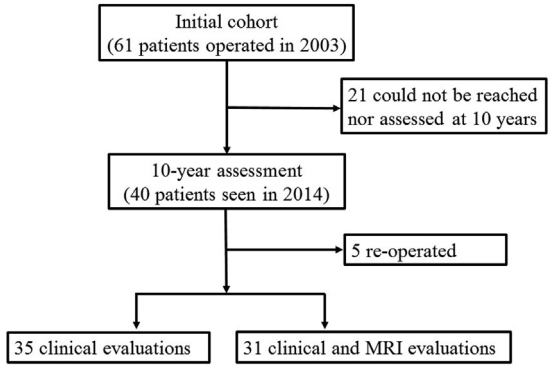

Figure 1 Flowchart detailing inclusion and exclusion of patients. *MRI*, magnetic resonance imaging.

Surgical techniques

The repair was performed in an open manner (deltopectoral) in 26 shoulders (74.3%) and arthroscopically in 9 shoulders (25.7%). Biceps tenodesis or tenotomy was performed in 24 shoulders (69%) and 3 shoulders (9%), respectively. All tendons were repaired using a single row of suture anchors. All repairs were "watertight" at the end of the intervention.

Postoperative rehabilitation

After surgery, the arm was supported in a sling with the arm at the side. All patients followed the same rehabilitation protocol, with passive motion exercises initiated on the first postoperative day and, when possible, hydrotherapy after skin healing. To ensure the integrity of the SSC repair, active internal rotation was prohibited for 6 weeks. At the same time, passive external rotation was restricted to 0°. Active shoulder motion was allowed after 6 weeks. Patients were not allowed to perform any strengthening or strenuous work for 6 months after the surgical procedure. Light sports and demanding activities were allowed after 6 months.

Postoperative evaluation

The 35 patients in this study cohort were evaluated clinically using the Constant score[7] and Subjective Shoulder Value (SSV).[14,17] The Constant score was assessed before surgery and at final follow-up. The subgroup of 31 patients who underwent radiographic assessment was evaluated using frontal and sagittal radiographs with the arm in neutral rotation following the imaging protocol described by Walch et al.[41] In these patients, MRI scans were used to assess tendon healing, according to the Sugaya classification,[38] and fatty infiltration, according to the Goutallier classification[18] modified by Fuchs et al.[12] Muscle atrophy was graded on a T1-weighted magnetic resonance image in the oblique-sagittal plane using the 4-point scale (0, none; 1, mild; 2, moderate; and 3, severe) proposed by Warner et al.[42] The radiographs were used to grade glenohumeral arthritis, following the classification described by Samilson and Prieto,[35] and the subacromial space, as described by Walch et al[41] (considered pathologic if ≤6 mm). The MRI protocol included (1) T2-weighted fat-suppression sequences (non–proton density–weighted) in the oblique-coronal, oblique-sagittal, and transverse planes, including the entire scapula, which were used to analyze tendon healing, and (2) T1-weighted sequences in the transverse and sagittal planes, which were used to analyze fatty infiltration and muscle conditions.

Each MRI scan was interpreted by 3 observers, including a senior radiologist, a senior surgeon, and a junior surgeon, all of whom were blinded to patient information. To determine intraobserver and interobserver agreement, each observer repeated his or her readings after an interval of 3 weeks. The Cohen κ statistic test revealed good intraobserver agreement ($\kappa = 0.71$) and moderate interobserver agreement ($\kappa = 0.56$) for the Goutallier classification[18] modified by Fuchs et al.[12] The κ statistic test showed good intraobserver agreement ($\kappa = 0.74$) and moderate interobserver agreement ($\kappa = 0.68$) for the Sugaya classification of tendon

healing. In view of unsatisfactory agreement for some variables, discrepancies in classification or grading were discussed by the observers to reach a consensus.

Statistical analysis

Descriptive statistics were used to summarize data. For non-Gaussian quantitative data, between-group differences were evaluated using the Mann-Whitney *U* test. Categorical data were analyzed using the Pearson χ^2 test or Fisher exact test. Univariable and multivariable linear (for Constant score and SSV) and ordinal (for Sugaya type) regression analyses were performed to identify factors associated with the outcomes. $P < .05$ was considered significant.

Results

In the final study cohort of 35 patients, complications were noted in 2 shoulders (6%), which included 1 infection and 1 frozen shoulder. In the 35 shoulders evaluated clinically, the mean total Constant score improved from 55.1 ± 18.1 points (range, 24-92 points) preoperatively to 75.4 ± 17 points (range, 42-97 points) at 10 years ($P < .001$). The subscores showed a marked improvement when compared with the scores preoperatively. The pain subscore improved from 6.4 ± 2.3 points (range, 2-12 points) preoperatively to 12.5 ± 3.2 points (range, 5-15 points) at 10 years ($P < .001$); activities of daily living, from 10.5 ± 3.3 points (range, 4-16 points) to 16.8 ± 4.3 points (range, 5-20 points; $P < .001$); range of motion, from 28.1 ± 8.8 points (range, 10-40 points) to 34.1 ± 5.5 points (range, 20-40 points; $P < .001$); and strength, improved from 9.9 ± 7.5 points (range, 0-25 points) to 12 ± 6.6 points (range, 2-24 points; $P = .05$). The mean postoperative SSV was 80.9 ± 20.3 (range, 10-100) (Table II).

Of the 31 shoulders (88.6%) evaluated using MRI, 4 (12.9%) had Sugaya type I repair integrity (Fig. 2); 16 (51.6%), type II; 7 (22.6%), type III; 2 (6.5%), type IV; and 2 (6.5%), type V (Table II). The prevalence of retears (Sugaya type IV or V) was 12.9% (4 of 31 shoulders). The supraspinatus tendons in 4 shoulders (12.9%) showed rupture although the SSC tendons were graded as healed.

Preoperative MRI scans were available for 26 shoulders and revealed SSC fatty infiltration at stage 0-2, with stage 0 in 17 shoulders (65.4%), stage 1 in 5 (19.2%), and stage 2 in 4 (15.4%). Postoperative fatty infiltration of the SSC was at stage 0-2 in 23 shoulders (74.2%) and stage 3-4 in 8 (25.8%). The SSC tendons could be graded as healed although the fatty infiltration of the SSC was graded as stage 3-4 (Fig. 3). Preoperative atrophy of the SSC was found at stage 0 in 19 shoulders (86.4%), stage 1 in 2 (9.1%), and stage 2 in 1 (4.5%). Postoperative atrophy of the SSC was at stage 0 in 10 shoulders (45.5%), stage 1 in 6 (27.3%), stage 2 in 5 (22.7%), and stage 3 in 1 (4.5%).

Preoperative radiographs were available for 15 patients, showing stage 0 in 6 (40%), stage 1 in 8 (53.3%), and stage 2 in 1 (6.7%), according to the Samilson-Prieto classification.[35] Ten-year radiographs were available for 20 patients. They revealed glenohumeral arthritis, according to the Samilson-Prieto classification, at stage 0 in 5 shoulders (25%), stage 1 in 9 (45%), and stage 2 in 6 (30%). They also revealed a mean subacromial space of 8.9 ± 2 mm, according to the method described by Walch et al.[41]

No correlation was found between the postoperative Constant score and SSC tendon healing ($P = .28$), SSC muscle fatty infiltration ($P = .76$), and atrophy ($P = .83$). SSC muscle fatty infiltration showed no correlation with SSC tendon healing ($P = .26$). Multivariable regression analysis revealed no significant associations between the independent factors, including patient sex, age, smoking habits, injections, dominant shoulder, profession, and tear onset (chronic vs. traumatic), and the Constant score, SSV, and tendon healing (Sugaya classification) (Table III).

Table II
Postoperative assessment

Outcome	Preoperative	Postoperative	*P* value
Complications			
Total		2 (6)	
Infection		1 (3)	
Frozen shoulder		1 (3)	
CS subscore, points			
Pain	6.4 ± 2.3 (2-12)	12.5 ± 3.2 (5-15)	<.001
Activity	10.5 ± 3.3 (4-16)	16.8 ± 4.3 (5-20)	<.001
Mobility	28.1 ± 8.8 (10-40)	34.1 ± 5.5 (20-40)	<.001
Strength	9.9 ± 7.5 (0-25)	12 ± 6.6 (2-24)	.05
Total CS, points	55.1 ± 18.1 (24-92)	75.4 ± 17 (42-97)	<.001
SSV		80.9 ± 20.3 (10-100)	
Sugaya classification			
I		4 (12.9)	
II		16 (51.6)	
III		7 (22.6)	
IV		2 (6.5)	
V		2 (6.5)	

CS, Constant score; *SSV*, Subjective Shoulder Value.
Data are presented as mean ± standard deviation (range) or number (percentage).

Discussion

The results of this study revealed that isolated SSC repair achieves satisfactory long-term functional and structural outcomes, which are comparable to previous short- and mid-term results. Thus, our hypothesis was confirmed.

Several studies have reported clinical short- to mid-term results after open repair of isolated SSC tears.[4,8,10,11,15,16,23,36] Their mean postoperative Constant scores were between 79.5 and 89.3, with a mean follow-up period from 24 to 46 months. Since Burkhart and Tehrany[6] published an arthroscopic repair technique for SSC tears in 2002, a few studies on arthroscopic SSC repair have been reported.[2,3,5,19,20,24,31,36] Their mean postoperative Constant scores were between 74 and 89, with a mean follow-up period from 12 to 49.4 months, which is comparable to the results of open procedures. However, in contrast to the aforementioned short- and mid-term results, Seppel et al[36] reported a mean Constant score of 74.2, which is lower than that of previous studies, with a mean follow-up period > 8 years. Similarly, our 10-year follow-up showed a relatively lower mean Constant score of 75.4. This finding suggests that clinical function may slightly decrease in the long term.

MRI has been an imaging technique mainly studied and accepted for identifying tendon tears.[1,13,25,26] However, only a few studies have reported radiologic results, particularly the retear rate after arthroscopic SSC tendon repair. Because of claustrophobia or other reasons, the numbers of patients undergoing postoperative MRI were small, mostly <20.[19,20,36] Only 1 article reported the postoperative MRI results; the study included 32 patients with an average period of 16.2 months after surgery.[31] Thus, long-term sizable MRI results are valuable. In our series, 31 shoulders (88.6%) were evaluated using MRI. The prevalence of retears (Sugaya type IV or V) was 12.9%, which is comparable to that in a previous open and arthroscopic study reporting retear rates of 0%-16.6%. Our MRI results suggest that SSC repair can provide satisfactory structural results as long as 10 years later.

Fatty infiltration is an important index reflecting the quality of the tendon, which can be evaluated using MRI.[12,18] Reviewing the literature, we note that the postoperative change in fatty infiltration of the SSC belly after repair of the SSC remains controversial.

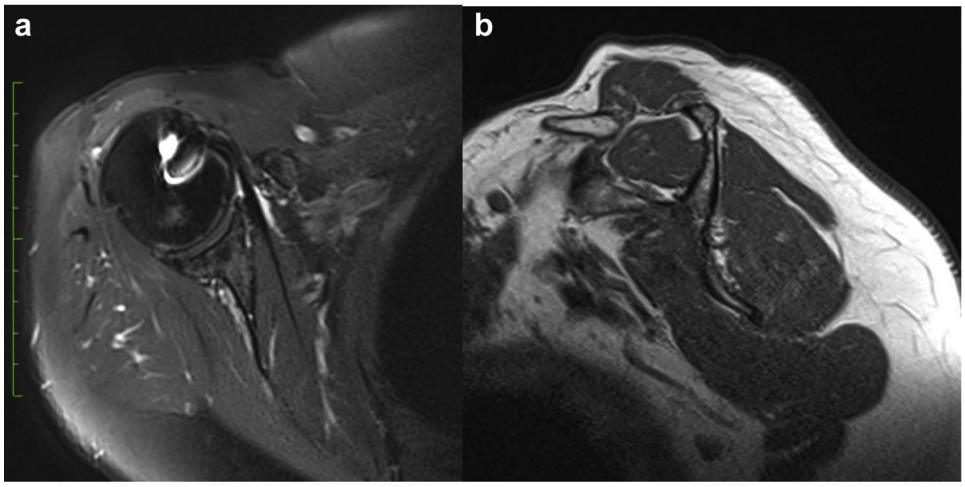

Figure 2 Postoperative magnetic resonance imaging of healed subscapularis tendon without fatty infiltration. (**a**) Subscapularis tendon with repair integrity graded as Sugaya type I. (**b**) Fatty infiltration of subscapularis graded at stage 1.

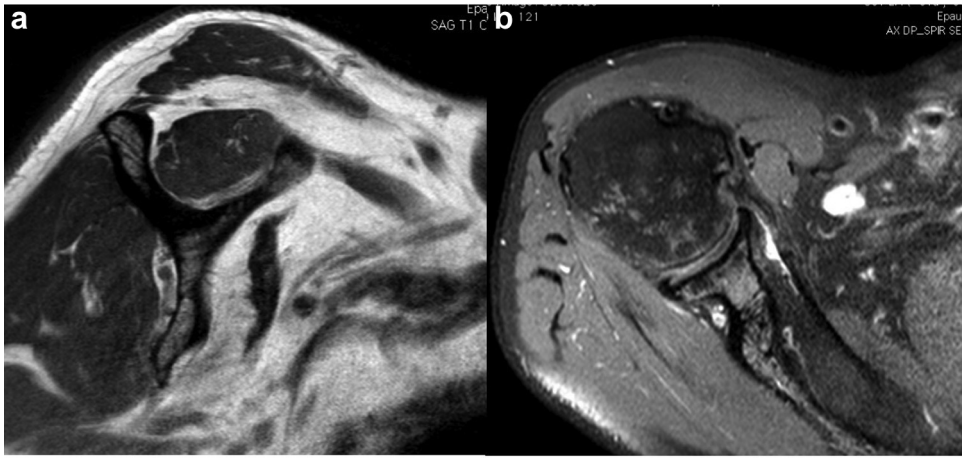

Figure 3 Postoperative magnetic resonance imaging of healed subscapularis tendon with severe fatty infiltration of subscapularis muscle. (**a**) Fatty infiltration of subscapularis graded as stage 4. (**b**) Subscapularis tendons graded as healed with Sugaya type II repair integrity.

Table III
Effect of preoperative factors on CS, SSV, and tendon healing

Factor	*P* value on multivariable regression analysis		
	CS	SSV	Sugaya classification
Age	.5	.6	.68
Sex	.06	.2	.4
Dominant shoulder	.85	.88	.26
Smoking habits	.11	.57	.99
Previous trauma	.26	.27	.33
Injections	.65	.09	.15
Profession	.9	.99	.36

CS, Constant score; *SSV*, Subjective Shoulder Value.

Grueninger et al[19] reported a significant decrease in fatty infiltration of the SSC at 1 year of follow-up after repair of traumatic isolated SSC tears. However, Bartl et al,[3] Lafosse et al,[24] Fuchs et al,[11] and Gerber et al[14] did not observe a progression of fatty infiltration after SSC repair at 27-38 months of follow-up. It is interesting to note that Nové-Josserand et al[28] reported progression of fatty infiltration in 55% of patients in the arthroscopic group and 62% in the open group despite successful surgery at a follow-up of 36 months. In 10 patients in the arthroscopic group (45%) and 6 patients in the open group (46%), localized severe fatty infiltration (stages 3 and 4) was found at the superior and deep part of the SSC muscle and was not observed preoperatively. Toussaint et al[39] reported that the fatty degeneration score (Bernageau criteria) of the SSC muscle belly worsened after exclusion of recurrent tears. They also observed stage 3 or 4 fatty degeneration in 11 cases postoperatively vs. none preoperatively with $\geq$6 months of follow-up. In a semiquantitative MRI assessment, Nikulka et al[26] found increased fatty degeneration of the upper SSC 35.4 months after open shoulder stabilization surgery, in which the SSC was detached 1 cm medially from the lesser tuberosity and reattached anatomically after anteroinferior glenoid and labrum treatment, compared with a normal control group of 12 healthy volunteers. Similarly, our results showed that severe fatty infiltration increased in 26% of the patients with grades 3-4 at 10 years after SSC repair, which was not observed preoperatively, although the retear rate was only 12.9%. Consistently with authors of previous studies, we concluded that the fatty degeneration of the SSC muscle belly seemed to progress over time even when tendon healing was achieved. The postoperative worse and newly emerging fatty infiltration may be related not to the lack of tendon healing but to the consequence of

high and uneven tension in the SSC tendon repair, improper rehabilitation, postoperative level of motion, and so on. Therefore, to achieve a comprehensive evaluation of repaired SSC quality, not only the retear rate but also the fatty infiltration of the SSC belly is essential to be evaluated on postoperative MRI.

The relationship between postoperative SSC fatty infiltration and clinical outcomes remains unknown. Nové-Josserand et al[28] found that the postoperative fatty infiltration of the SSC muscle had no significant influence on subjective and functional outcomes or the results of SSC tests, including the belly-press test and lift-off test, after arthroscopic repair of isolated SSC tears at 36 months of follow-up. Similarly, Toussaint et al[39] stated that postoperative fatty degeneration of the SSC muscle belly progressed over time but did not significantly affect clinical outcomes. However, recently, in a 10-year follow-up of arthroscopic repair for combined full-thickness tears of the SSC and supraspinatus tendons, Nové-Josserand et al[27] revealed that postoperative SSC fatty infiltration (Fuchs stage B or C) was always associated with poorer clinical and anatomic outcomes. The observation of substantial SSC fatty infiltration was associated with poorer healing of the supraspinatus and SSC. In most cases with fatty infiltration of the upper half of the SSC muscle in which the tendon was considered healed (38 of 43), the clinical outcomes (SSV and Constant score) were poorer than those of patients with no infiltration and similar to those of patients whose tendon did not heal and had widespread fatty infiltration.[27] However, we did not find any relationship between postoperative fatty infiltration and clinical outcomes. The clinical significance of fatty infiltration needs further research.

Given that an isolated lesion of the SSC is rare and that large sample sizes are difficult to obtain, our study has strengths including the long follow-up period, the relatively large number of participants with isolated SSC tears, and the availability of postoperative anatomic MRI scans in 31 patients. Our study confirmed our hypothesis that isolated SSC repair can provide satisfactory long-term functional and structural outcomes, comparable to previous results. Furthermore, we found that severe fatty infiltration increased in 26% of the patients with grades 3-4 at 10 years after SSC repair, although fatty infiltration was not related to clinical outcomes and the retear rate was only 12.9%.

This study has several limitations that must be considered. First, the study design suffered from the inherent weakness of being retrospective and multicenter in nature. Second, because of the long-term follow-up of 10 years, 21 patients (34.4%) were lost to follow-up, raising the possibility of selection bias. Third, the SSC clinical test was not performed at follow-up. Finally, our series included mixed cases with both open repair and arthroscopic repair.

Conclusions

At a mean follow-up of 10 years after repair of isolated SSC tears, clinical results were satisfactory and functional improvement was maintained in the long term. Severe fatty infiltration increased in 26% of the patients with grades 3-4 at 10 years after SSC repair, but fatty infiltration was not related to clinical outcomes and the retear rate. Besides clinical outcomes and tendon integrity, the fatty infiltration of the tendons after SSC repair should be a focus, and the relationship between fatty infiltration and clinical outcomes needs further research.

Disclaimer

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References

1. Adams CR, Brady PC, Koo SS, Narbona P, Arrigoni P, Karnes GJ, et al. A systematic approach for diagnosing subscapularis tendon tears with preoperative magnetic resonance imaging scans. Arthroscopy 2012;28:1592–600. https://doi.org/10.1016/j.arthro.2012.04.142.
2. Adams CR, Schoolfield JD, Burkhart SS. The results of arthroscopic subscapularis tendon repairs. Arthroscopy 2008;24:1381–9. https://doi.org/10.1016/j.arthro.2008.08.004.
3. Bartl C, Salzmann GM, Seppel G, Eichhorn S, Holzapfel K, Wörtler K, et al. Subscapularis function and structural integrity after arthroscopic repair of isolated subscapularis tears. Am J Sports Med 2011;39:1255–62. https://doi.org/10.1177/0363546510396317.
4. Bartl C, Scheibel M, Magosch P, Lichtenberg S, Habermeyer P. Open repair of isolated traumatic subscapularis tendon tears. Am J Sports Med 2011;39:490–6. https://doi.org/10.1177/0363546510388166.
5. Bennett WF. Arthroscopic repair of isolated subscapularis tears: a prospective cohort with 2- to 4-year follow-up. Arthroscopy 2003;19:131–43. https://doi.org/10.1053/jars.2003.50023.
6. Burkhart SS, Tehrany AM. Arthroscopic subscapularis tendon repair: technique and preliminary results. Arthroscopy 2002;18:454–63. https://doi.org/10.1053/jars.2002.30648.
7. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res 1987;214:160–4.
8. Deutsch A, Altchek DW, Veltri DM, Potter HG, Warren RF. Traumatic tears of the subscapularis tendon. Clinical diagnosis, magnetic resonance imaging findings, and operative treatment. Am J Sports Med 1997;25:13–22.
9. Edwards TB, Walch G, Nove-Josserand L, Boulahia A, Neyton L, O'Connor DP, et al. Arthroscopic debridement in the treatment of patients with isolated tears of the subscapularis. Arthroscopy 2006;22:941–6. https://doi.org/10.1016/j.arthro.2006.05.009.
10. Edwards TB, Walch G, Sirveaux F, Molé D, Nové-Josserand L, Boulahia A, et al. Repair of tears of the subscapularis. J Bone Joint Surg Am 2005;87:725–30. https://doi.org/10.2106/JBJS.D.02051.
11. Fuchs B, Gilbart MK, Hodler J, Gerber C. Clinical and structural results of open repair of an isolated one-tendon tear of the rotator cuff. J Bone Joint Surg Am 2006;88:309–16. https://doi.org/10.2106/JBJS.E.00117.
12. Fuchs B, Weishaupt D, Zanetti M, Hodler J, Gerber C. Fatty degeneration of the muscles of the rotator cuff: assessment by computed tomography versus magnetic resonance imaging. J Shoulder Elbow Surg 1999;8:599–605.
13. Garavaglia G, Ufenast H, Taverna E. The frequency of subscapularis tears in arthroscopic rotator cuff repairs: a retrospective study comparing magnetic resonance imaging and arthroscopic findings. Int J Shoulder Surg 2011;5:90–4. https://doi.org/10.4103/0973-6042.91000.
14. Gerber C, Fuchs B, Hodler J. The results of repair of massive tears of the rotator cuff. J Bone Joint Surg Am 2000;82:505–15.
15. Gerber C, Hersche O, Farron A. Isolated rupture of the subscapularis tendon. J Bone Joint Surg Am 1996;78:1015–23.
16. Gerber C, Krushell RJ. Isolated rupture of the tendon of the subscapularis muscle. Clinical features in 16 cases. J Bone Joint Surg Br 1991;73:389–94.
17. Gilbart MK, Gerber C. Comparison of the subjective shoulder value and the Constant score. J Shoulder Elbow Surg 2007;16:717–21. https://doi.org/10.1016/j.jse.2007.02.123.
18. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. Clin Orthop Relat Res 1994;304:78–83.
19. Grueninger P, Nikolic N, Schneider J, Lattmann T, Platz A, Chmiel C, et al. Arthroscopic repair of traumatic isolated subscapularis tendon lesions (Lafosse type III or IV): a prospective magnetic resonance imaging-controlled case series with 1 year of follow-up. Arthroscopy 2014;30:665–72. https://doi.org/10.1016/j.arthro.2014.02.030.
20. Heikenfeld R, Gigis I, Chytas A, Listringhaus R, Godolias G. Arthroscopic reconstruction of isolated subscapularis tears: clinical results and structural integrity after 24 months. Arthroscopy 2012;28:1805–11. https://doi.org/10.1016/j.arthro.2012.06.011.
21. Iagulli ND, Field LD, Hobgood ER, Ramsey JR, Savoie FH III. Comparison of partial versus complete arthroscopic repair of massive rotator cuff tears. Am J Sports Med 2012;40:1022–6. https://doi.org/10.1177/0363546512438763.
22. Keating JF, Waterworth P, Shaw-Dunn J, Crossan J. The relative strengths of the rotator cuff muscles. A cadaver study. J Bone Joint Surg Br 1993;75:137–40.
23. Kreuz PC, Remiger A, Erggelet C, Hinterwimmer S, Niemeyer P, Gachter A. Isolated and combined tears of the subscapularis tendon. Am J Sports Med 2005;33:1831–7. https://doi.org/10.1177/0363546505277118.
24. Lafosse L, Jost B, Reiland Y, Audebert S, Toussaint B, Gobezie R. Structural integrity and clinical outcomes after arthroscopic repair of isolated subscapularis tears. J Bone Joint Surg Am 2007;89:1184–93. https://doi.org/10.2106/JBJS.F.00007.
25. Lederer S, Auffarth A, Bogner R, Tauber M, Mayer M, Karpik S, et al. Magnetic resonance imaging-controlled results of the pectoralis major tendon transfer for irreparable anterosuperior rotator cuff tears performed with standard and

modified fixation techniques. J Shoulder Elbow Surg 2011;20:1155–62. https://doi.org/10.1016/j.jse.2011.01.023.
26. Nikulka C, Goldmann A, Schroeder RJ. Magnetic resonance imaging analysis of the subscapularis muscle after arthroscopic and open shoulder stabilization. Clin Imaging 2010;34:269–76. https://doi.org/10.1016/j.clinimag.2009.06.030.
27. Nové-Josserand L, Collin P, Godenèche A, Walch G, Meyer N, Kempf JF. Ten-year clinical and anatomic followup after repair of anterosuperior rotator cuff tears: influence of the subscapularis. J Shoulder Elbow Surg 2017;26:1826–33. https://doi.org/10.1016/j.jse.2017.03.037.
28. Nové-Josserand L, Hardy MB, Leandro Nunes Ogassawara R, Carrillon Y, Godenèche A. Clinical and structural results of arthroscopic repair of isolated subscapularis tear. J Bone Joint Surg Am 2012;94:e125. https://doi.org/10.2106/JBJS.K.00008.
29. Piasecki DP, Nicholson GP. Tears of the subscapularis tendon in athletes diagnosis and repair techniques. Clin Sports Med 2008;27:731–45. https://doi.org/10.1016/j.csm.2008.06.005.
30. Resch H, Povacz P, Ritter E, Matschi W. Transfer of the pectoralis major muscle for the treatment of irreparable rupture of the subscapularis tendon. J Bone Joint Surg Am 2000;82:372–82.
31. Rhee YG, Lee YS, Park YB, Kim JY, Han KJ, Yoo JC. The outcomes and affecting factors after arthroscopic isolated subscapularis tendon repair. J Shoulder Elbow Surg 2017;26:2143–51. https://doi.org/10.1016/j.jse.2017.05.017.
32. Richards DP, Burkhart SS, Campbell SE. Relation between narrowed coracohumeral distance and subscapularis tears. Arthroscopy 2005;21:1223–8. https://doi.org/10.1016/j.arthro.2005.06.015.
33. Richards DP, Burkhart SS, Lo IK. Subscapularis tears: arthroscopic repair techniques. Orthop Clin North Am 2003;34:485–98. https://doi.org/10.1016/s0030-5898(03)00096-8.
34. Sakurai G, Ozaki J, Tomita Y, Kondo T, Tamai S. Incomplete tears of the subscapularis tendon associated with tears of the supraspinatus tendon: cadaveric and clinical studies. J Shoulder Elbow Surg 1998;7:510–5.
35. Samilson RL, Prieto V. Dislocation arthropathy of the shoulder. J Bone Joint Surg Am 1983;65:456–60.
36. Seppel G, Plath JE, Völk C, Seiberl W, Buchmann S, et al. Long-term results after arthroscopic repair of isolated subscapularis tears. Am J Sports Med 2017;45:759–66. https://doi.org/10.1177/0363546516676261.
37. Su WR, Budoff JE, Luo ZP. The effect of anterosuperior rotator cuff tears on glenohumeral translation. Arthroscopy 2009;25:282–9. https://doi.org/10.1016/j.arthro.2008.10.005.
38. Sugaya H, Maeda K, Matsuki K, Moriishi J. Repair integrity and functional outcome after arthroscopic double-row rotator cuff repair. A prospective outcome study. J Bone Joint Surg Am 2007;89:953–60. https://doi.org/10.2106/JBJS.F.00512.
39. Toussaint B, Audebert S, Barth J, Charousset C, Godeneche A, Joudet T, et al. Arthroscopic repair of subscapularis tears: preliminary data from a prospective multicentre study. Orthop Traumatol Surg Res 2012;98(Suppl):S193–200. https://doi.org/10.1016/j.otsr.2012.10.004.
40. Turkel SJ, Panio MW, Marshall JL, Girgis FG. Stabilizing mechanisms preventing anterior dislocation of the glenohumeral joint. J Bone Joint Surg Am 1981;63:1208–17.
41. Walch G, Edwards TB, Boulahia A, Nové-Josserand L, Neyton L, Szabo I. Arthroscopic tenotomy of the long head of the biceps in the treatment of rotator cuff tears: clinical and radiographic results of 307 cases. J Shoulder Elbow Surg 2005;14:238–46. https://doi.org/10.1016/j.jse.2004.07.008.
42. Warner JJ, Higgins L, Parsons I, Dowdy P. Diagnosis and treatment of anterosuperior rotator cuff tears. J Shoulder Elbow Surg 2001;10:37–46.