Suture Anchor-Based Quadriceps Tendon Repair May Result in Improved Patient-Reported Outcomes but Similar Failure Rates Compared to the Transosseous Tunnel Technique

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Purpose: The purpose of this study was to compare failure rates and patient-reported outcomes between transosseus (TO) suture and suture anchor (SA) quadriceps tendon repairs. **Methods:** Following institutional review board approval, patients who underwent primary repair for quadriceps tendon rupture with TO or SA techniques between January 2009 and August 2018 were identified from an institutional database and retrospectively reviewed. Patients were contacted for satisfaction (1-10 scale), current function (0-100 scale), failure (retear), and revision surgeries; International Knee Documentation Committee (IKDC) score and Knee Injury and Osteoarthritis Outcomes Score (KOOS) were also collected to achieve a minimum of 2-year follow-up. **Results:** Sixty-four patients (34 SA, 30 TO) were available by phone or e-mail at a mean of 4.81 ± 2.60 years postoperatively. There were 10 failures, for an overall failure rate of 15.6%. Failure incidence did not significantly differ between treatment groups ($P = .83$). Twenty-seven patients (47% of nonfailed patients) had completed patient-reported outcomes. The SA group reported higher subjective function (SA: 90 [85-100] vs TO: 85 [60-93], 95% CI of difference: -19.9 to -2.1×10^{-5}, $P = .042$), final IKDC (79.6 [50.0-93.6] vs 62.1 [44.3-65.5], 95% CI of difference: -33.0 to -0.48, $P = .048$), KOOS Pain (97.2 [84.7-97.2] vs 73.6 [50.7-88.2], 95% CI of difference: -36.1 to -3.6×10^{-5}, $P = .037$), Quality of Life (81.3 [56.3-93.8] vs 50.0 [23.4-56.3], 95% CI of difference: -50.0 to -6.2, $P = .026$), and Sport (75.0 [52.5-90.0] vs 47.5 [31.3-67.5], 95% CI of the difference: -45.0 to -4.1×10^{-5}, $P = .048$). **Conclusions:** There is no significant difference in failure rate between transosseus and suture anchor repairs for quadriceps tendon ruptures ($P = .83$). Most failures occur secondary to a traumatic reinjury within the first year postoperatively. Despite the lack of difference in failure rates, at final follow-up, patients who undergo suture anchor repair may report significantly greater subjective function and final IKDC, KOOS Pain, Quality of Life, and Sport scores. **Level of Evidence:** III, retrospective cohort study.

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Quadriceps tendon ruptures have become increasingly common. A recent study of the Finnish National Hospital Discharge Register found a 400% increase in quadriceps tendon repairs from 1997 to 2014, possibly attributable to longer life expectancy and increased participation in high-demand activity and more active lifestyles in older populations.[1] Surgical repair of the quadriceps tendon is necessary in almost all cases due to the devastating functional loss caused by extensor mechanism insufficiency. Many patients with quadriceps tendon ruptures have medical comorbidities and are at risk for a poor healing response.[2,3] Maximizing the strength and efficacy of a primary quadriceps repair is paramount to limit reoperation in these patients.

Recent biomechanical studies have compared various suture anchor (SA) repair techniques with traditional transosseus (TO) repairs. In most of these studies, SA

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repairs have shown less elongation under cyclic loading and higher failure strength compared to TO repairs.[4-7] Clinically, encouraging results have been reported for SA repairs as well. A series of 25 cases had no failures and only 1 patient with an extensor lag at 7-year follow-up.[8] However, literature directly comparing patient-reported outcomes between TO and SA repairs is sparse. A pilot study of 8 TO repairs and 9 SA repairs found equivalent outcomes between the 2 techniques, but these findings have yet to be confirmed with a larger cohort.[9]

The purpose of this study was to compare failure rates and patient-reported outcomes between TO suture and SA quadriceps tendon repairs. We hypothesized that SA repair would result in lower failure rates, higher patient satisfaction, and improved patient-reported outcome scores compared with TO repair.

Methods

Following institutional review board approval, patients who underwent surgical repair for full-thickness quadriceps tendon rupture between January 2009 and August 2018 by one of the 4 sports-fellowship trained surgeons (A.B.Y., B.J.C., N.N.V., and B.F.) were identified from a prospectively maintained institutional database and retrospectively reviewed. Patients were included in the study if they underwent a primary repair with either SA or TO tunnel techniques, based on surgeon preference. Patients were excluded if they had a partial tear, history of arthroplasty, the index repair was a revision, or if allograft augmentation was performed.

The primary outcome for this study was failure, defined as retear that necessitated operative or nonoperative treatment. Patients were contacted by e-mail or telephone interview for satisfaction (1-10 scale), current function (0-100 scale), failure (retear), and revision surgeries; secondary outcomes included the collection of patient-reported outcomes, including International Knee Documentation Committee (IKDC) score and Knee Injury and Osteoarthritis Outcomes Score (KOOS) scores. These forms were completed by patients over a secure web-based platform without the aid or supervision of study personnel. Patients who were available for telephone interview and/or completed patient-reported outcomes at a minimum of 2 years were included in the final analysis. For included patients, chart review was performed for comorbid conditions, including hypertension (HTN), hyperlipidemia (HLD), diabetes mellitus (DM), and chronic kidney disease (CKD); smoking history; and workers' compensation status.

Surgical Technique

A midline incision is made over the quadriceps tendon and patella with full-thickness subdermal flaps to expose the extent of the quadriceps tendon tear and retinacular involvement. Friable tissue on the torn tendon is identified and removed. The patellar insertion of the tendon is debrided and gently decorticated.

For the TO technique, high-tensile strength suture is passed through the tendon in a 4-limb Krackow configuration. Three TO drill tunnels are then placed through the patella longitudinally. The sutures are passed through the TO tunnels and tied over a distal patellar bone bridge. Knots are placed deep to the patellar tendon, and care is taken not to bind the patellar tendon or alter patellar height. A careful retinacular closure is performed both medially and laterally with nonabsorbable braided suture.

For the SA technique, 4.5-mm Swivelock anchors, 4.5-mm Corkscrew anchors, or 5.5-mm Corkscrew anchors (Arthrex) are placed in the proximal pole of the patella, with the anchor number varying between 2 and 3 based on surgeon preference. In this cohort, 2 anchors were most frequently used (32/35, 91.4%), followed by 3 (1/35; 2 were unspecified number). One limb of the suture from each anchor is passed through the quadriceps tendon in a Krackow configuration that traverses 3 to 4 cm proximal to the free edge and then doubles back to its origin at the free edge of the tendon. The other limb of each suture is passed through the tendon with a single-pass simple stich; this suture limb is then used as a sliding post to reduce the tendon to the anchor. The sutures are tied at the proximal pole of the patella after reduction is confirmed with tendon-bone apposition. A careful retinacular closure is performed both medially and laterally with nonabsorbable braided suture.

In both techniques, the final repair site is assessed for stability as the knee flexes. Postoperatively, patients are allowed to weight bear as tolerated with a knee brace locked in full extension. A gradual return of range of motion is prescribed with a goal of 90° of flexion by 6 weeks. Closed-chain strengthening exercises begin at 8 weeks with no weightbearing past 90° of knee flexion until 12 weeks. Advancement to sport-specific drills and running occurs at 20 weeks. Postoperative rehabilitation did not vary based on the repair technique.

Statistical Analysis

All statistical analysis was performed on STATA v16.1 (StataCorp). Demographic characteristics (age, sex, body mass index [BMI], comorbidities, smoking status, and workers' compensation status) were compared by unpaired t test or χ^2 analyses where appropriate. Due to the presence of nonparametric data determined by the Shapiro-Wilk test, patient-reported outcomes and time to failure were compared between the 2 repair groups by Wilcoxon rank-sum tests. Kaplan-Meier survival analysis with log-rank testing was performed for comparison of treatment groups. An a priori power analysis was conducted for the end points of failure and

Table 1. Demographic Characteristics of Repair Groups

Characteristic	Transosseous Tunnels	Suture Anchors	*P* Value
N	33	35	
Age, mean ± SD, y	54.75 ± 12.85	53.98 ± 12.48	.80
Sex, M/F, n	31/2	32/3	.69
BMI, mean ± SD	32.87 ± 5.04	32.82 ± 7.31	.98
Smoking history, n			.79
Current or former/never	10/22	11/21	
Presence of a comorbid condition, %	48.5	45.7	.82
Laterality, left/right/bilateral, n	15/16/2	21/13/1	.45
Workers' compensation status, n	5/33	4/35	.65

patient-reported outcomes on G*Power 3.1 (Version 3.1.9.7, Heinrich Heine University) and STATA v16.1. Based on a 3.8% reoperation rate of SA repair in the setting of patellar tendon rupture,[10] a minimum of 30 patients per group would be required to detect at least a 50% decrease in hazard ratio compared to the TO repair group with an $\alpha = 0.05$ and power of 80%. Since thresholds for minimal clinically important difference (MCID) after quadriceps repair have not been established, MCID values for IKDC after anterior cruciate ligament reconstruction (19 points) were utilized for power analysis. A minimum of 24 patients total would be required to detect a significant difference of 19 points between 2 groups (IKDC: 85.84 and 66.84), based on previously published postoperative outcomes of extensor mechanism repair.[11] All data are reported as mean ± standard deviation or median [interquartile range] with a 95% confidence interval (CI) of the difference for relevant comparisons. Missing data points were treated as null. Testing was 2-sided, and significance was set at $P < .05$.

Results

Demographics

A total of 101 patients met inclusion criteria for this study and were contacted for final follow-up. At time of contact, 31 patients chose not to participate or were lost to follow-up, and 2 patients were deceased. This left a final cohort of 68 patients (n = 33 with TO technique and n = 35 with SAs) with a telephone interview and/or completed patient-reported outcomes for analysis at a minimum 2-year follow-up. There were no significant differences between the included and excluded patients in age (54.4 ± 12.6 vs 58.0 ± 14.2 years, 95% CI of difference: −4.2 to 7.0, $P = .62$), sex (8.8% vs 7.4% female, $P = .80$), or BMI (32.8 ± 6.3 vs 30.2 ± 4.0 kg/m^2, 95% CI of difference: −3.9 to 2.0, $P = .53$).

In the final cohort, most patients were male (63/68, 92.6%), and the sex distribution was similar between treatment groups (93.9% vs 91.4% male, $P = .69$). Patients in the TO and SA groups were also similar in age (54.75 ± 12.85 vs 53.98 ± 12.48, 95% CI of difference: −5.4 to 6.9 years, $P = .80$, respectively), BMI (32.87 ± 5.04 vs 32.82 ± 7.31, 95% CI of difference: −3.3 to 3.4, $P = .98$, respectively), and smoking rates (68.8% vs 65.6% never smoker, $P = .79$). Presence of a comorbidity was common, with 47.1% of patients having at least 1 chronic medical condition (DM, HTN, HLD, CKD), and this did not differ between groups (48.5% vs 45.7%, $P = .82$). One patient in the SA group had a concomitant medial patellofemoral ligament repair; there were no other concomitant procedures in either group (Table 1).

Failure

Sixty-four patients were available by phone or e-mail at a mean of 4.81 ± 2.60 years postoperatively (TO sutures: 30 and SA: 34). There were 10 failures, for an overall failure rate of 15.6%. Incidence of failure did not significantly differ between treatment groups (TO: 5/30, 16.67% vs SA: 5/34, 14.7%, $P = .83$). Similarly, there was no difference in survival curve estimates by log-rank analysis ($P = .80$, Fig 1). Formal calculation and comparison of Kaplan-Meier median survival time was precluded by the lack of data trajectory past a survival probability of 0.5. For descriptive purposes, the time to failure was 2.1 months [1.7-3.3] and 6.3 months [2.0-25.0] in the TO and SA groups, respectively (95% CI of the difference: −27.7 to 4.6, $P = .69$) (Table 2). Overall, survival probabilities were similar

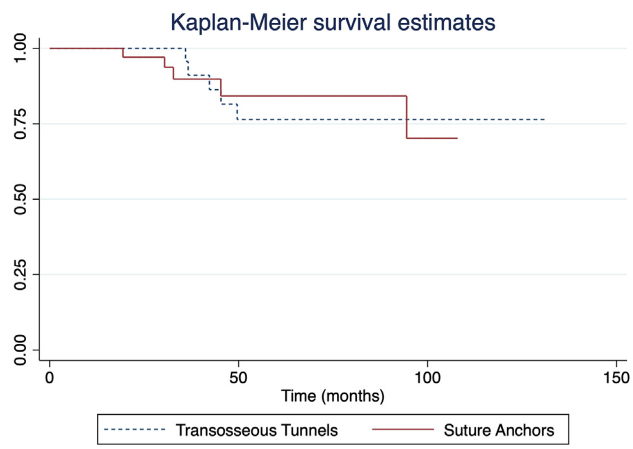

Fig 1. Kaplan-Meier survival curve demonstrating equivalent survival between repair groups on log-rank analysis ($P = .80$).

Table 2. Descriptive Analysis of Surgical Failures

No.	Age, y/Sex	Group	Time to Revision, mo	Mechanism of Reinjury or Failure
1	61/M	TO	1.74	Fall
2	41/M	TO	2.10	Motor vehicle accident
3	64/M	TO	0.98	Periodic instability, opening of healed incision
4	51/M	TO	6.89	Persistent pain, swelling, occasional instability
5	30/M	TO	3.34	Fall on flexed knee
6	63/M	SA	1.84	Fall
7	64/M	SA	2.30	Continued swelling, persistent deficit
8	42/M	SA	0.92	Motor vehicle accident
9	55/M	SA	10.0*	Recurrent falls, sensation of knee giving way on stairs
10	29/M	SA	2.49 years	Shuffling during basketball

SA, suture anchor; TO, transosseus.

*Time to diagnosis; patient underwent nonoperative management.

between groups at 2 years (TO: 83% [95% CI, 71%-98%] and SA: 88% [95% CI: 78%-99%].

There were no significant differences in demographic characteristics between the overall failure (any technique) and nonfailure groups in age (49.97 ± 13.83 vs 55.71 ± 12.28, 95% CI of difference: −4.5 to 16.0, $P = .24$), sex (100% vs 92.6% male, $P = .37$), BMI (34.08 ± 4.34 vs 32.27 ± 6.65, 95% CI of difference: −5.5 to 1.9, $P = .32$), presence of a comorbid condition (40% vs 48.1% with at least 1 condition, $P = .64$), smoking status (57.1% vs 67.9% never smoker status, $P = .57$), or workers' compensation status (0% vs 14.8%, $P = .19$).

Patient-Reported Outcomes

Patients with known failures were excluded from the analysis of subjective outcomes, leaving subjective satisfaction and function ratings for 54 patients. At the time of final follow-up (5.02 ± 2.68 years postoperatively), patients in each repair group had similar satisfaction ratings on a scale of 1 to 10 (SA: 10 [10-10] vs TO: 10 [7.5-10], 95% CI of difference: -1.5 to 2.9×10^{-5}, $P = .04$). The SA group reported a higher subjective function on a scale of 0 to 100 compared to the TO group (SA: 90 [85-100] vs TO: 85 [60-93], 95% CI of difference: -19.9 to -2.1×10^{-5}, $P = .042$).

Patients with known failures were removed from the analysis of patient-reported outcome measures (PROMs). PROMs were available for 27 (47%) patients (15 TO, 12 SA; n = 27 with IKDC, n = 25 with KOOS scores) at a mean of 5.29 ± 2.89 years postoperatively. Mean follow-up time did not significantly differ between the SA and TO groups (SA: 5.2 ± 2.8 vs TO: 5.3 ± 3.1 years, $P = .91$). The SA group had significantly greater final mean IKDC score than the TO tunnel group (79.6 [50.0-93.6] vs 62.1 [44.3-65.5], 95% CI of difference: −33.0 to −0.48, $P = .048$). Additionally, the SA group also demonstrated greater scores for KOOS Pain (97.2 [84.7-97.2] vs 73.6 [50.7-88.2], 95% CI of difference: -36.1 to -3.6×10^{-5}, $P = .037$), KOOS Quality of Life (81.3 [56.3-93.8] vs 50.0 [23.4-56.3], 95% CI of difference: −50.0 to −6.2, $P = .026$), and KOOS Sport (75.0 [52.5-90.0] vs 47.5 [31.3-67.5], 95% CI of the difference: -45.0 to -4.1×10^{-5}, $P = .048$). There were no significant differences in KOOS Daily Living (92.7 [75-97.8] vs 77.9 [59.2-91.5], 95% CI of difference: −30.9 to 1.5, $P = .12$) or KOOS Symptoms (78.6 [54.5-82.1] vs 83.9 [59.8-92.0], 95% CI of difference: −24.9 to 3.6, $P = .10$).

Patient-reported outcomes were available for 8 of 9 patients who underwent revision repair at a final follow-up of 2.6 ± 0.6 years from the index repair and are reported for descriptive purposes in Appendix Table 1.

Discussion

The primary finding of this study is that contrary to our hypothesis, there may be no significant difference in failure rate between quadriceps repair with SA and TO techniques. However, patients who underwent repair with SAs may demonstrate significantly greater subjective function on a 0 to 100 scale, IKDC scores, KOOS Pain, KOOS Sport, and KOOS Quality of Life scores at a minimum 2-year follow-up.

Suture anchor techniques for quadriceps tendon repair have been proposed as an alternative approach to traditional TO repair due to the increased risks of patellar fracture from violation of the patellar cortex with TO drilling and reduction in amount of dissection and patellar trauma with SA repairs.[12] Several biomechanical studies have been conducted with the goal of validating the role of SA repairs (Table 3). Initial studies demonstrated noninferiority for SA repairs without demonstrating a significant biomechanical advantage in gap formation or repair strength.[7,13] However, more recent studies have consistently shown improved mechanical characteristics for SA repairs.[4-6] In a cadaveric study of 12 specimens by Sherman et al.,[5] SA repair demonstrated significantly less gapping on cyclic loading with nonsignificant differences in ultimate failure load when compared to TO repair. Similarly, both Petri et al.[6] and Kindya et al.[4] found decreased elongation of SA repairs under cyclic loading with

Table 3. Review of Literature on Biomechanical Comparisons Between Repair Techniques

Study	Samples	Comparisons	Test Parameters	Key Findings
Lighthart et al.,[7] 2008	11 matched pairs of cadaveric lower extremities	Suture anchor repair (N = 11) Transosseus repair (N = 11)	1. Displacement after 10 cycles to 150 N 2. Gapping after 1000 cycles of flexion and extension	No difference in displacement or gapping between suture anchor and transosseus repairs.
Hart et al.,[13] 2012	5 matched cadaveric knees	Suture anchor double-row repair (N = 5) Transosseus repair (N = 5)	1. Cyclic loading from 50 to 250 N for 250 cycles 2. Load to failure	No difference in stiffness or gap formation. Lower load to failure for the suture anchor group with all failures occurring through broken anchor eyelets.
Petri et al.,[6] 2015	30 cadaveric knees	Titanium suture anchor repair (N = 10) Hydroxyapatite suture anchor repair (N = 10) Transosseus repair (N = 10)	1. Cyclic loading from 20 to 100 N for 250 cycles 2. Load to failure	Significantly less elongation under cyclic loading for suture anchor repairs compared to transosseus repairs. Higher failure loads for suture anchor repairs.
Sherman et al.,[5] 2016	12 cadaveric extensor mechanisms	Suture anchor repair (N = 6) Transosseus repair (N = 6)	1. Preload of 50 N followed by cyclic loading to 150 N, 200 N, and 250 N for 10 cycles each 2. Load to failure	Decreased gapping under cyclic loading for the suture anchor group. No difference in ultimate load to failure.
Kindya et al.,[4] 2017	20 matched pairs of cadaveric knees	Knotless suture tape anchor repair (N = 20) Transosseus repair (N = 10) Traditional suture anchor repair (N = 10)	1. 250 cycles to 100 N 2. Load to failure	Decreased displacement during cyclic loading, improved ultimate load, and increased stiffness for knotless suture tape compared to transosseus repairs and traditional suture anchor repairs.

higher failure loads for SA repairs in studies of 30 and 20 cadaveric knees, respectively.

Despite the abundance of biomechanical data, prior clinical outcome studies of quadriceps repair have been limited in their direct comparison of techniques as well as assessment of failure rates and risk factors. One case series of 13 knees after SA repair detected 2 reruptures for a final failure rate of 15.38%, which is comparable to the failure rate of SA repair presented in this study.[14] Another study of 25 patients after SA repair by Brossard et al.[8] reported high satisfaction rates (92% satisfied), comparable to the satisfaction rates reported in this study for SA repair (9.2/10).

A recent systematic review and meta-analysis of 8 studies comparing SA and TO repairs found that TO repairs had 5.5° better range of motion and an 8% lower complication rate, with no difference in Lysholm scores or rerupture rate.[15] Only 1 study included in that analysis was a direct comparison of SA and TO repairs. This study, a 2018 pilot study by Plesser et al.[9] reported equivalent results of both techniques in a sample of 17 patients, with respect to subjective scores, physical examination, and isokinetic strength testing. However, this study did not report any reruptures at a mean follow-up of 46 months for SA and 29 months for TO groups, so the authors were unable to compare failure rates between the 2 techniques. In comparison, the present study consisted of a larger sample size and was able to identify 10 failed quadriceps repairs with no significant difference in failure rate between SA and TO groups.

Similar to the pilot study by Plesser et al.[9] and the meta-analysis by Mehta et al.,[15] we found no difference between groups for the majority of patient-reported outcomes. However, there was a significantly higher subjective function, IKDC, and KOOS Pain, Sport, and Quality of life scores for SA repairs in our cohort. The MCID for the subjective function score is not well defined, so the clinical significance of this statistically significant difference between groups is not known. Our results suggest that SA repair may be equivalent to TO repair, which corroborates existing literature comparing the 2 techniques.[9,15] We propose that the potential underlying factors for poorer subjective function after TO repair may be related to the relatively greater dissection required to access the distal pole of the patella, including violation of the patellar tendon. Additionally, the fixation in the SA repair is adjacent to the tendon at the proximal pole, as opposed to the TO repair, which relies on the tensile strength of suture with knot fixation at the distal pole. Last, several biomechanics studies have demonstrated the superior biomechanical profile of SAs to TO repair with lower tendon−bone gap formation.[16] Greater gap formation may delay tendon healing or eventually constitute an operative failure, although this threshold has not been defined.[16] However, several potential confounding factors may complicate the interpretation of these differences, including patient activity levels, surgeon indication for technique choice, or a temporal effect in favored techniques (i.e., majority of SA procedures occurring in the later portion of the timeframe compared to TO tunnel techniques). While this study did not observe differences in surgical failure rates, the differences in patient-reported outcomes may reflect an underlying difference in biomechanical performance of the repairs.

Descriptive analysis of failures demonstrates that most failures (7/10) overall were due to traumatic reinjury (falls and motor vehicle accidents being the most common). Notably, most failures occurred within the first year after the index repair. Although the sample size for failure is insignificant to formally assess patterns, our study provides additional insight into the various mechanisms by which reinjury may occur after quad tendon repair.

Limitations

This study has several limitations. As a retrospective analysis, patient-reported outcomes were limited to cross-sectional postoperative analysis, and therefore, trends in outcomes over time could not be assessed and final follow-up time could not be standardized. Additionally, due to the retrospective nature, preoperative patient-reported outcomes were not consistently collected, and calculation of MCID achievement was not possible. Therefore, although MCID values were utilized to characterize a meaningful difference between groups, this measure could not be utilized in its intended form as a patient-level metric. Retrospectively collected physical exam data were heterogeneously reported in the medical record. Consequently, range of motion, extensor lag, and return of ambulatory status could not be included for comparisons between groups. Furthermore, the patient cohort was pooled from the case logs of 4 senior surgeons. While the technique and indications described in the Methods section were largely standardized, there is inherent variability in individual technique, sutures and anchors utilized, and experience that may add to heterogeneity. Furthermore, lack of standardized descriptions in operative reports precluded the verification of a standardized technique. Therefore, although the current methods listed were based on current consensus between the senior surgeons, it is unknown if this exact technique was utilized consistently in each case. Last, patient-reported outcomes were not available for all patients, and the overall follow-up rate of approximately 67% (68/101) and subsequently lower number with patient-reported outcomes (47%) is concerning for transfer bias. Similarly, despite the detection of statistical significance in some measures, the wide dispersion measures and confidence intervals may indicate heterogeneity in the cohort.

Conclusions

There is no significant difference in failure rate between TO and SA repairs for quadriceps tendon ruptures ($P = .83$). Most failures occur secondary to a traumatic reinjury within the first year postoperatively. Despite the lack of difference in failure rates, patients who undergo SA repair may report significantly greater subjective function and final IKDC, KOOS Pain, KOOS Quality of Life, and KOOS Sport scores.

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Appendix

Appendix Table 1. Patient-Reported Outcomes by Treatment Type and Status

Characteristic	Suture Anchor (n = 15)	Transosseous Tunnel (n = 12)	Revision Repair (n = 8)
IKDC	73.0 ± 23.4	56.8 ± 16.6	50.4 ± 15.2
KOOS Symptoms	78.2 ± 18.9	66.2 ± 22.8	71.9 ± 13.3
KOOS Pain	89.1 ± 14.0	71.2 ± 21.5	77.8 ± 9.6
KOOS ADL	86.0 ± 15.8	74.5 ± 18.5	78.4 ± 15.9
KOOS QoL	71.6 ± 30.8	44.6 ± 25.9	40.6 ± 29.6
KOOS Sport	69.6 ± 27.1	46.1 ± 27.1	44.3 ± 24.1

All values reported as mean ± standard deviation.

ADK, Activities of Daily Living; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcomes Score; QoL, quality of life.