Primary Versus Revision ACL Reconstruction Using Quadriceps Autograft

A Matched-Control Cohort Study

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Background: The incidence of anterior cruciate ligament (ACL) reconstruction is increasing, and quadriceps tendon (QT) autograft is gaining popularity for both primary and revision ACL reconstruction.

Purpose: To evaluate the differences in the patient-reported functional outcomes, concomitant injuries, and graft failure in primary versus revision ACL surgery using QT autograft.

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

Methods: A total of 376 patients with primary ACL reconstruction and 138 patients with revision ACL reconstruction were retrospectively retrieved from a prospectively collected ACL registry. A minimally invasive technique was used for QT autograft harvesting. The surgical procedure and rehabilitation protocol were identical in both groups. To maintain a homogeneous cohort for the study, the groups were matched by age, sex, and preinjury outcome scores (Lysholm knee score, Tegner activity level, and visual analog scale [VAS] for pain). Initial baseline assessments of outcome scores were compared with scores collected at the 2-year postoperative mark.

Results: The mean age of the primary group and revision group was 32.9 ± 10.2 years (range, 18-55 years) and 32.3 ± 9.9 years (range, 19-55 years) respectively. Significant preinjury to postoperative improvements were noted in Lysholm (88.2 ± 16.4 vs 83.5 ± 15.0; $P = .007$) and VAS pain (0.9 ± 1.3 vs 1.5 ± 1.6; $P = .001$) scores after primary ACL reconstruction compared with revision reconstruction. However, no significant difference was found in Tegner activity level (6.7 ± 1.8 vs 5.9 ± 1.8; $P > .430$). Primary ACL injury was associated with significantly higher concomitant medial collateral ligament injuries ($P = .019$), while the revision group was associated with significantly higher concomitant cartilage ($P = .001$) and meniscal ($P = .003$) injuries. A significantly higher graft failure rate was noted in the revision group compared with the primary ACL reconstruction group (13.0% vs 5.6%; $P = .005$).

Conclusion: Both primary and revision ACL reconstruction with QT autograft had acceptable functional outcomes. The primary group had better outcomes than the revision group, possibly due to the lower prevalence of meniscal and cartilage injuries in the primary group compared with the revision group. The revision group was associated with higher graft failure than the primary group. QT autograft is a viable graft choice for both primary and revision ACL reconstruction.

Keywords: ACL; anterior cruciate ligament; quadriceps graft; QT autograft; revision ACL

In the past few decades, the incidence of anterior cruciate ligament (ACL) injuries has been on the rise. The failure rate of ACL reconstruction has been reported between 5% and 25%, which results in an increased number of revision surgeries.[2,23] The cause of failure may be difficult

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to determine, and often, it may be multifactorial. The main reasons for the failure of the primary reconstruction seem to be reinjury, tunnel misplacement, and biological failure.[2,5] Revision ACL surgery is considered to be more challenging than primary reconstruction. Slightly inferior results are noted for revision surgery compared with the primary reconstruction, particularly in terms of patient-reported outcome measures, return to sports, knee stability, and the development of osteoarthritis (OA).[11] Graft choice for the ACL reconstruction influences the clinical outcomes, graft rupture, and complications.[12,21] Therefore, the appropriate choice of graft is an essential part of ACL reconstruction.

In primary reconstruction, graft selection typically depends on surgeons' preference, while in revision, it depends on multiple factors such as primary graft used, tunnel enlargement, and preferred surgical technique. Bone–patellar tendon–bone (BPTB) and hamstring tendon (HT) are the 2 most commonly used autografts for primary reconstruction with a predominance of HT.[20] A higher failure rate has been reported with HT compared with BPTB grafts.[20,22] Both HT and BPTB are associated with donor-site morbidity. BPTB harvesting may result in anterior knee pain, limited range of movement, and OA of the knee.[12] Moreover, due to the risk of damage to open physes, BPTB cannot be harvested in skeletally immature patients. HT autograft harvesting may cause sensory deficits due to the injury of infrapatellar branches of the saphenous nerve, compromise medial stability of the knee in a medial collateral ligament (MCL)–deficient patient, and cause weakness of internal rotation and knee flexion.[14,15] On the other hand, quadriceps tendon (QT) harvesting may cause patellar fracture if harvested with bone block and weakness of the extensor mechanism.[17]

In recent years, QT graft has become increasingly popular for both primary and revision ACL reconstruction due to lower donor-site morbidity than BPTB and HT and decreased failure rate than HT graft.[20,31] Reduced postoperative pain and lesser use of analgesics were also reported with QT autograft.[28] However, to our knowledge, no study is available in the literature that compares primary and revision ACL reconstruction using autologous QT graft in both groups. Thus, the purpose of this study was to evaluate the differences in the patient-reported functional outcomes, concomitant injuries, and graft failure in primary and revision ACL surgery using the autologous QT graft. The hypothesis was that better functional outcomes, lesser concurrent injuries, and lesser graft failure would be associated with primary ACL reconstruction compared with revision reconstruction.

METHODS

The protocol for this study was approved by the local ethics committee, and all included patients provided written informed consent. Prospectively collected data were obtained from an ACL registry. Patients were included in the study if they fulfilled the following inclusion criteria: primary or revision ACL reconstruction using QT autograft, age between 18 and 55 years, and a minimum of 2-year follow-up after ACL reconstruction. The exclusion criteria were utilization of graft tissue other than QT, inflammatory arthritis or any other forms of arthritis, <2 years of follow-up, and conditions that might interfere with the standard postoperative rehabilitation protocol. Patients with multiligamentous injuries defined as ACL tear in combination with posterior cruciate ligament or collateral ligament tear were included to report concomitant injuries, but these patients were excluded from the analysis of patient-reported functional outcomes. Similarly, patients with graft failure within 2 years were included to report graft failure and concomitant injuries, but these patients were also excluded from the analysis of patient-reported functional outcomes.

Between January 2010 and January 2020, a total of 467 patients underwent primary ACL reconstruction and 148 patients underwent revision ACL reconstruction using QT autograft at a single institution. To maintain a homogeneous cohort for the study, the groups were matched by age, sex, and preinjury outcome scores that included the Lysholm knee score, Tegner activity level, and visual analog scale (VAS) for pain. Matching was done according to inclusion criteria, and after matching, 376 patients in the primary group and 138 patients in the revision group met the inclusion criteria and were included in the study.

In most patients, preoperative magnetic resonance imaging scans were obtained within 1 week of injury or reinjury to confirm ACL rupture and to evaluate concomitant injuries. Plain radiographs (anteroposterior and lateral views) were obtained to exclude any bone injury and

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Ethical approval for this study was obtained from Medizinischen Universität Innsbruck (reference No. AN2015-0050 346/4.28).

TABLE 1
Comparison of Demographic Characteristics Between the Primary and Revision QT ACL Reconstruction Groups[a]

Characteristic	Total (N = 514)	Primary (n = 376)	Revision (n = 138)	*P*
Sex				.607[b]
Female	248 (48.2)	184 (48.9)	64 (46.4)	
Male	266 (51.8)	192 (51.1)	74 (53.6)	
Side involved				**.039**[b]
Left	251 (48.8)	194 (51.6)	57 (41.3)	
Right	263 (51.2)	182 (48.4)	81 (58.7)	
Age, y				.527[c]
Mean ± SD	32.8 ± 10.1	32.9 ± 10.2	32.3 ± 9.9	
Median (IQR)	30 (25-40)	30 (25-42)	29 (25-37)	
Range	18-55	18-55	19-55	

[a]Data are reported as n (%) unless otherwise indicated. Boldface *P* value indicates statistically significant difference between study groups ($P < .05$). ACL, anterior cruciate ligament; QT, quadriceps tendon.
[b]Chi-square test.
[c]Independent *t* test.

signs of osteoarthritis (Ahlbäck stage ≥2). Plain radiographs were also performed postoperatively to evaluate the placement of the femoral and tibial bone tunnel and assess the correct position of the femoral button.

All ACL reconstructions were carried out by 2 fellowship-trained experienced surgeons (C.F. and C.Hoser). Both types of QT autograft (with bone block and without bone block) were used. The use of QT autograft with or without bone block was not randomized; rather, it depended on the surgeon's preference. One senior surgeon (C.F.) preferred QT autograft without bone block while the other senior surgeon (C.H.) preferred QT autograft with bone block. The surgical procedure and rehabilitation protocol were identical in both groups. A minimally invasive technique was used for QT autograft harvesting as described by Fink et al,[8] and the same technique was used for ACL reconstruction.

In the present study, the majority of the patients underwent surgery within 1 week of ACL injury (mean duration was 13.1 days for primary and 18.8 days for revision surgeries). During this period, patients were unable to do any sports activities. Because functional outcomes recorded during the acute phase of injury may not be reliable due to swelling and pain, we recorded and used the patient-reported preinjury scores rather than the preoperative scores as the baseline measure. Patients were specifically asked to fill out the questionnaire considering their preinjury state during the first week after surgery for the baseline functional scores. Similarly, patients were evaluated at a 2-year follow-up with the Lysholm knee score, Tegner activity level, and VAS pain, any concomitant postoperative injuries and graft failure.

Statistical Analysis

Categorical data were presented as numbers and percentages, while quantitative data were presented as mean, standard deviation, median (interquartile range), and range. The comparison of the quantitative variables was analyzed using an independent *t* test (for 2 groups), and paired *t* test was used for comparison across follow-up. The comparison of the qualitative variables was analyzed using the chi-square test and the Fisher exact test. The data were entered into Microsoft Excel, and the analysis was performed by using Statistical Package for Social Sciences (Version 21.0; SPSS) software. $P < .05$ was considered statistically significant.

RESULTS

In the primary ACL reconstruction group, of 376 patients, 192 (51.1%) were male and 184 (48.9%) were female. The mean age of this group was 32.9 ± 10.2 years (range, 18-55 years). In the revision group, of 138 patients, 74 (53.6%) were male and 64 (46.4%) were female, and the mean age was 32.3 ± 9.9 years (range, 19-55 years). In the revision group, 94 (68.1%) patients had their initial reconstruction performed with HT autograft while 44 (31.9%) patients had BPTB autograft for their primary ACL reconstruction. No significant difference was found in age ($P = .527$) and sex ($P = .607$) between the primary and revision groups (Table 1).

Patient-Reported Functional Outcomes

There were no significant differences in preinjury patient-reported outcomes between the primary and the revision ACL reconstruction groups (Table 2 and Figure 1). At 2 years of follow-up, significant improvement was noted in Lysholm ($P = .007$) and VAS pain ($P = .001$) scores for primary ACL reconstruction compared with revision reconstruction. Patients in the primary reconstruction group returned to baseline outcome levels, whereas the revision group had mild reductions in Lysholm and increases in VAS pain scores. However, at 2 years of follow-up, no significant difference was noted in the Tegner activity level between the 2 groups ($P > .05$) (Table 2 and Figure 1).

TABLE 2
Comparison of Patient-Reported Functional Outcomes Between Primary and Revision QT ACL Reconstruction Groups[a]

Outcome Measure	Total (n = 448)	Primary (n = 330)	Revision (n = 118)	*P*
Lysholm knee score				
Preinjury				.956[b]
Mean ± SD	87.1 ± 17.5	87.1 ± 18.2	87.0 ± 15.6	
Median (IQR)	95 (76.8-100)	95 (75-100)	9 (78.3-100)	
Range	5-100	5-100	30-100	
At 24 months				**.007**[b]
Mean ± SD	87.0 ± 16.2	88.2 ± 16.4	83.5 ± 15.0	
Median (IQR)	90 (82-98)	94 (85-99)	85 (80-94.8)	
Range	0-100	0-100	0-100	
Intragroup *P*		.419[c]	.052[c]	
Tegner activity score				
Preinjury				.293[b]
Mean ± SD	6.3 ± 1.9	6.2 ± 2.0	6.4 ± 1.6	
Median (IQR)	6 (6-8)	6 (5.3-8)	6 (6-8)	
Range	0-10	0-10	2-10	
At 24 months				.430[b]
Mean ± SD	6.0 ± 1.8	6.7 ± 1.8	5.9 ± 1.8	
Median (IQR)	6 (5-7)	6 (5-7)	6 (5-7)	
Range	1-10	1-10	2-10	
Intragroup *P*		.086[c]	**<.001**[c]	
VAS pain score				
Preinjury				.303[b]
Mean ± SD	1.6 ± 1.9	1.1 ± 1.8	1.3 ± 1.9	
Median (IQR)	0 (0-2)	0 (0-1)	1 (0-2)	
Range	0-10	0-10	0-10	
At 24 months				**.001**[b]
Mean ± SD	1.0 ± 1.4	0.9 ± 1.3	1.5 ± 1.6	
Median (IQR)	1 (0-2)	0 (0-1)	1 (0-2)	
Range	0-7	0-7	0-7	
Intragroup *P*		.061[c]	.411[c]	

[a]Boldface *P* values indicate statistically significant difference between groups compared ($P < .05$). ACL, anterior cruciate ligament; QT, quadriceps tendon; VAS, visual analog scale.
[b]Independent *t* test.
[c]Paired *t* test.

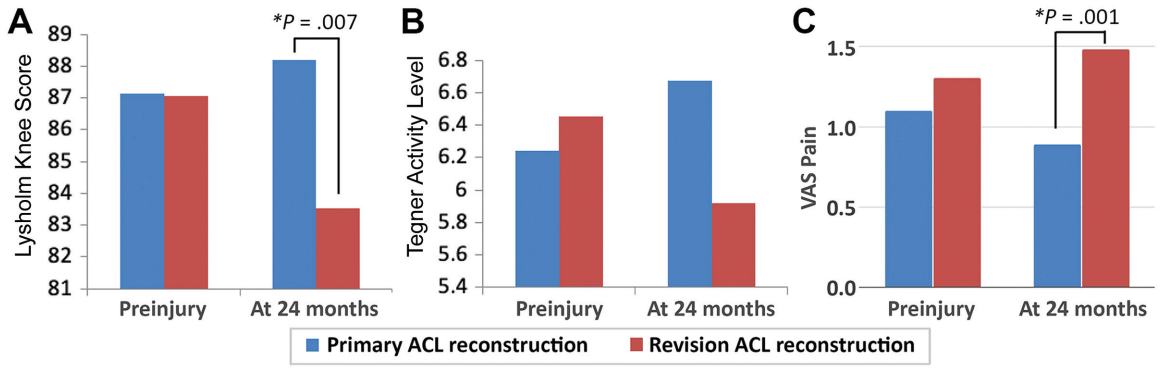

Figure 1. Preinjury and 2-year postoperative (A) Lysholm knee score, (B) Tegner activity level, and (C) visual analog scale (VAS) pain scores for the primary and revision anterior cruciate ligament (ACL) reconstruction groups. *Statistically significant difference between groups ($P < .05$).

TABLE 3
Comparison of Concomitant Injuries and Treatment Procedures Between Patients Undergoing Primary and Revision QT ACL Reconstruction[a]

Variable	Total (N = 514)	Primary (n = 376)	Revision (n = 138)	*P*
Concomitant injuries				
Meniscal tear	272 (52.9)	184 (48.9)	88 (63.8)	**.003**[b]
Medial meniscus	126 (24.5)	84 (22.3)	42 (30.4)	.059[b]
Lateral meniscus	146 (28.4)	100 (26.6)	46 (33.3)	.133[b]
Cartilage injury	58 (11.3)	30 (8.0)	28 (20.3)	**.001**[b]
MCL injury	27 (5.3)	25 (6.7)	2 (1.5)	**.019**[b]
Treatment procedures				
Resection of meniscus	109 (21.2)	62 (16.5)	47 (34.1)	**.001**[b]
Meniscal suture	163 (31.71)	122 (32.4)	41 (29.7)	.555[b]
Cartilage debridement	35 (6.8)	20 (5.3)	15 (10.9)	**.027**[b]
Microfracture	13 (4.47)	10 (2.7)	13 (9.4)	**.001**[b]
MCL reconstruction	2 (0.39)	1 (0.3)	1 (0.7)	.465[c]
MCL refixation by suture anchor	16 (3.11)	15 (4.0)	1 (0.7)	.082[c]

[a]Data are reported as n (%). Boldface *P* values indicate statistically significant difference between study groups ($P < .05$).
[b]Chi-square test.
[c]Fisher exact test.

Concomitant Injuries

Patients undergoing revision ACL reconstruction had a significantly higher prevalence of meniscal tear ($P = .003$) and chondral defects ($P = .001$) than those in the primary ACL reconstruction group. However, no significant difference was noted in medial or lateral meniscal injury between the primary and revision groups ($P > .05$). MCL injuries were significantly higher in the primary reconstruction group ($P = .019$) (Table 3 and Figure 2).

Graft failure

The overall graft failure rate for the primary and revision groups was 5.6% and 13.0%, respectively (Table 4). The graft failure rate was significantly higher in the revision ACL reconstruction group than in the primary group ($P = .005$) (Table 4 and Figure 3).

DISCUSSION

The most important findings of this study were that significant improvements were noted in Lysholm and VAS scores in primary ACL reconstruction compared with revision ACL reconstruction. No significant difference was noted in Tegner activity level between the 2 groups. Primary ACL injury was associated with more frequent concomitant MCL injuries, while the revision group was associated with significantly higher incidence of concomitant cartilage and meniscal injuries. A higher graft failure rate was also noted in the revision group.

Only a few studies are available that have compared primary and revision ACL reconstruction with respect to the patient-reported functional outcome or/and concomitant injuries or/and graft failure, but none of them uses QT autograft.[3,18,24,30,33] Moreover, previous studies[18,24,33] did not have a matched control group. Kim et al[18] found similar patient-reported outcomes in primary and revision groups with a higher percentage of instability in revision ACL-reconstructed knees. This study was not match-paired, and the authors used HT autograft for primary and tibialis anterior tendon allografts for revision. Similarly, Carolan et al[3] noted no significant difference in International Knee Documentation Committee and Cincinnati questionnaires between primary and revision ACL reconstruction groups, but significantly inferior results were reported for reactive strength and explosive strength in the revision ACL limb. This study used BPTB and HT autografts for primary ACL reconstruction and BPTB, HT, and QT autografts for revisions. They also had a very short follow-up (9 months). In a matched control analysis with HT autograft and a minimum 2-year follow-up, Weiler et al[30] reported significantly higher Lysholm score and subjective knee function in the primary compared with the revision reconstruction group. This present study has similarities with the previous study[30] in terms of study design and minimum 2-year follow-up. The present study also reported significantly improved Lysholm and VAS pain scores in the primary group, which is again similar to the previous study.

Numerous studies reported equal or better functional outcomes in primary QT autograft compared with HT and BPTB autografts.[4,19,25,27,28] In a recent large cohort study, Runer et al[27] found similar functional outcomes in the primary QT and HT groups. Similarly, in the previous prospective matched-pair analysis study, no significant differences were reported in functional outcomes between the primary HT and QT ACL reconstruction groups.[28] In their randomized control trial, Lind et al[19] also reported no difference between HT and QT graft groups regarding subjective patient outcomes, but they noted significantly lower donor-site morbidity in the QT group. In another randomized controlled trial, Cavaignac et al[4] found significantly

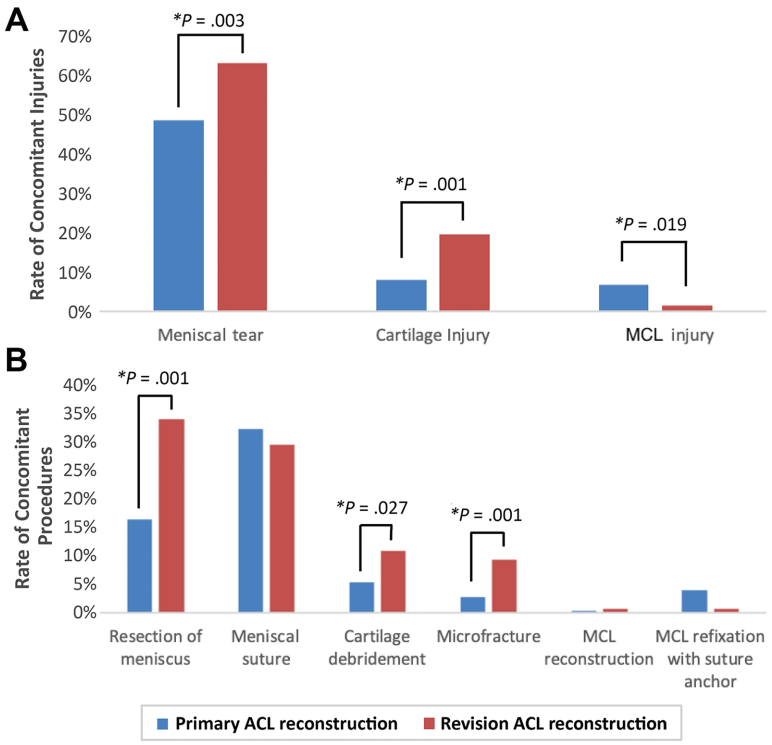

Figure 2. Rates of (A) concomitant injuries and (B) treatment procedures in the primary and revision anterior cruciate ligament (ACL) reconstruction groups. *Statistically significant difference between groups ($P < .05$). MCL, medial collateral ligament.

TABLE 4
Comparison of Graft Failure Between Primary versus Revision ACL Surgery Using Quadriceps Autograft[a]

Graft Failure	Total (N = 514)	Primary (n = 376)	Revision (n = 138)
No	475 (92.4)	355 (94.4)	120 (87.0)
Yes	39 (7.6)	21 (5.6)	18 (13.0)

[a]Data are reported as n (%). $P = .005$ (chi-square test).

higher Lysholm scores in the patients undergoing ACL reconstruction with the QT than with the HT autograft. A recent meta-analysis found better functional outcomes in the QT group than in the HT group and comparable functional outcomes with BPTB, but BPTB was associated with significantly higher donor-site morbidity.[25]

QT autograft has also gained popularity for revision ACL reconstruction.[31] Previous studies found similar functional outcomes with QT and HT autografts for revision reconstruction.[2,13] Another study[7] reported improved functional outcomes with QT compared with HT autograft in revision ACL reconstruction. Hunnicutt et al[16] demonstrated significant improvement in functional outcomes from the preoperative to postoperative period with QT autograft in revision ACL reconstruction. In the current study, QT autograft was used for both primary and revision ACL reconstruction, and patient-reported functional outcomes are comparable with previous studies.

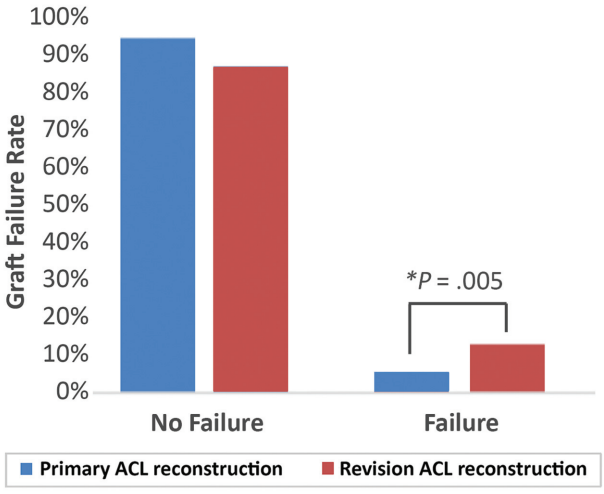

Figure 3. Rate of graft failure (%) in the primary and revision anterior cruciate ligament (ACL) reconstruction groups at 2-year follow-up. *Statistically significant difference between groups ($P < .05$).

At the time of surgery, meniscal and cartilage status is an important factor because injury to these structures has been correlated with functional outcomes after surgery. In the current study, meniscal injuries were significantly higher in the revision group (63.8%) than primary group (48.9%). Barié et al[2] found a 59.5% incidence of meniscal

injuries during revision ACL reconstruction. In a study of patients from the Danish Knee Ligament Reconstruction Registry, a 56% incidence of meniscal injuries were reported in the revision group.[20] These findings are similar to the current study. In this study, articular cartilage injuries were significantly higher in the revision group (20.3%) than the primary group (8.0%). These findings are similar to previous studies[24,32] where significantly higher chondral defects were reported during revision ACL reconstruction. Although meniscal and chondral injuries were more common in the revision group, MCL injuries were more common in the primary group (6.7%) than in the revision group (1.5%). Similar results were noted in previous studies where the prevalence of MCL injuries was significantly higher in the primary group than in the revision group.[24,33]

Previous studies found good anatomic characteristics in QT grafts with respect to graft thickness, graft length, and graft volume, which is comparable with HT and BPTB autografts.[6,27,28] Moreover, superior biomechanical results were found compared with BPTB with respect to strain at failure, load to failure, and the Young modulus of elasticity.[29] In a previous meta-analysis, QT autograft had a comparable graft survival rate with BPTB, although better results were noted in the QT group.[25] In another meta-analysis, graft failure was significantly higher in the HT group than QT group for primary ACL reconstruction.[26] Similarly, Runer et al[27] found a significantly higher risk of graft failure in the HT group compared with the QT group for primary ACL reconstruction (4.9% vs 2.8%). In the revision ACL reconstruction group, a significantly higher failure rate was noted in the HT group compared with the QT group (17.4% vs 2.3%).[7] Therefore, the reported incidence of graft failure in previous literature with QT autograft was lower than HT and comparable with BPTB for primary and revision ACL reconstruction. Considering this fact, a higher graft failure rate should not be a concern with QT autograft for both primary and revision ACL reconstruction.

Lind et al,[20] studying patients from the Danish Knee Ligament Reconstruction Registry, reported a 4.2% failure rate for QT graft, which is similar to the current study where the failure rate was 5.6% for primary ACL reconstruction. In a recent revision ACL study with QT autograft, the failure rate was 13.8%, which is again similar to the current study where the failure rate was 13.0% in the revision group.[16] These findings indicate a higher graft failure rate in the revision ACL reconstruction group than in the primary group. Therefore, recent literature recommends additional lateral augmentation procedures in the form of lateral extra-articular tenodesis to reduce the risk of failure of revision ACL reconstruction.[1,9,10]

Limitations and Strengths

There are a few limitations of the study. First, this was a retrospective analysis of patient-reported subjective outcome measures; however, all data were collected prospectively, and graft failure and concomitant injuries were objective parameters. A prospective study considering objective scores along with subjective scores should be conducted, which will be of higher evidentiary value. Second, all patients with primary and revision ACL reconstruction, regardless of concomitant chondral and meniscal injuries, were included in the study. However, concomitant multiligamentous injuries were excluded from the functional outcome analysis. While isolated ACL ruptures in both groups might be considered a scientifically better approach, the data of the present study reflected a real-life scenario where concomitant knee injuries were frequent. Third, both the groups were matched control; therefore, the overall sample size was reduced and matching might have resulted in selection bias. This matching also excluded younger patients undergoing primary ACL reconstruction, who are known to have a higher failure rate.

Strengths of the study include the following: first, this was the first study that compared the patient-reported outcomes and graft failure in primary and revision groups by using QT autograft. Second, both the primary and the revision groups included a relatively large number of patients. Third, both groups were matched to eliminate confounding factors.

CONCLUSION

Primary and revision ACL reconstruction with QT autografts had acceptable functional outcomes. The primary group had better outcomes than the revision group, possibly due to the lower prevalence of meniscal and cartilage injuries in the primary group compared with the revision group. The revision group was associated with higher graft failure than the primary group. QT autograft is a viable graft choice for both primary and revision ACL reconstruction. The clinical relevance of the current study is that the incidence of revision ACL reconstruction is increasing, and surgeons should be aware of all the available graft options. QT autograft is gaining popularity for both primary and revision ACL reconstruction. The findings of this study will provide insight into the treatment plan and counseling of patients with primary and revision ACL reconstruction using QT autograft.

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