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Increased risk for early revision with quadriceps graft compared with patellar tendon graft in primary ACL reconstructions

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Abstract

Purpose: Bone patella-tendon bone (BPTB) and hamstring tendon (HT) autografts are the most used grafts in primary anterior cruciate ligament (ACL) reconstructions (ACLR) in Norway. Quadriceps tendon (QT) autograft has gained more popularity during the past years. The purpose of this study is to compare revision rates and patient-reported outcomes of primary QT with BPTB and HT autograft ACL reconstructions in Norway at 2-year follow-up. It was hypothesized that there would be no difference in 2-year revision rates between all three autografts.

Methods: Data included primary ACLR without concomitant ligament surgeries, registered in the Norwegian Knee Ligament Register from 2004 through 2021. Revision rates at 2 years were calculated using Kaplan–Meier analysis. Hazard ratios (HR) for revision were estimated using multivariable Cox regression analysis with revision within 2 years as endpoint. Mean change in patient-reported outcome was recorded pre-operatively and at 2 years through the Knee Injury and Osteoarthritis Outcome Score (KOOS) subcategories 'Sport' and 'Quality of Life' was measured for patients that were not revised and analysed with multiple linear regression.

Results: A total of 24,790 primary ACLRs were identified, 10,924 with BPTB, 13,263 with HT and 603 with a QT graft. Patients in the QT group were younger (23.5 years), more of them were women (58.2%) and over 50% had surgery <3 months after injury. The QT group had the highest prevalence of meniscal injuries (61.9%). Revision estimates at 2-years were 3.6%, 2.5% and 1.2% for QT, HT and BPTB, respectively ($p < 0.001$). In a Cox regression analysis with QT as reference, BPTB had a lower risk of revision (HR 0.4, 95% CI 0.2–0.7, $p < 0.001$). No significant difference was observed in the revision risk between QT and HT (HR 1.1, 95% CI 0.7–1.8, n.s.). The two most common reported reasons for revision were: traumatic

Abbreviations: ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; BPTB, bone patella-tendon bone; CI, confidence intervals; HR, hazard ratios; HT, hamstring tendon; ICRS, International Cartilage Repair Society Classification System; KOOS, Knee Injury and Osteoarthritis Outcome Score; n.s., not significant; NKLR, The Norwegian Knee Ligament Register; QT, quadriceps tendon; QTB, bone quadriceps-tendon.

graft rupture and nontraumatic graft failure. There were no differences between the groups in change of KOOS in subcategories 'Sport' and 'Quality of Life' at 2-years follow-up.

Conclusion: The 2-year risk of revision after ACLR with QT was higher than BPTB and similar to HT. No difference was found between the groups in patient-reported outcomes. This study provides valuable insights for both surgeons and patients when making decisions about the choice of autografts in primary ACL reconstructions.

Level of Evidence: Level II.

KEYWORDS

ACL reconstruction, clinical outcomes, hamstring tendon, patellar tendonn, quadriceps tendon, revision rate

INTRODUCTION

There are several factors that influence the patient-specific graft choice in primary anterior cruciate ligament reconstruction (ACLR) [15]. In Norway, hamstring tendons (HT) and bone patella-tendon bone (BPTB) autograft are the most commonly used grafts in ACLR [46]. BPTB autograft is reported to excel in restoring rotational laxity, promoting quicker graft-tunnel incorporation and facilitating a quicker return to high-level activity and are associated with lower revision rates [19, 32, 43, 45, 49]. Despite possible disadvantages such as anterior knee pain, risk of patella fracture [3, 26, 56, 59] and possibly an increased risk for osteoarthritis [64], some surgeons still consider the BPTB as the gold standard for ACLR [8].

The HT autografts may offer reduced donor site morbidity and improved initial extension strength of the knee compared with BPTB [37]. However, they come with potential disadvantages such as widening of the graft tunnels [29, 61], slower graft-tunnel healing [52], knee flexor strength reduction [12, 23], risk for increased knee laxity [11] and higher revision risk [19, 43, 65].

In recent years, the use of quadriceps tendon (QT) autograft has gained more popularity. A QT graft can be harvested with or without bone plug [39] (bone quadriceps-tendon; QTB), both demonstrating lower donor site morbidity compared with BPTB and HT [28, 41]. It has a predictable length and volume which might reduce the risk of failure [24, 42, 54, 55]. Furthermore, biomechanical, histological and magnetic resonance studies may favour QT graft compared with BPTB graft [9, 53, 57, 63]. However, previous published studies that evaluated BPTB, HT and QT (with or without bone plug) have reported similar outcomes with regard to function and suggested that ACLR with QT autograft is a reliable and safe choice [13, 18, 31, 47, 50, 54].

The Norwegian Knee Ligament Register (NKLR) was established in 2004, and all hospitals performing anterior cruciate ligament (ACL) surgery in Norway report to the register [21]. The results of QT ACL reconstructions in Norway have not been previously documented. This information could potentially assist both surgeons and patients in making well-informed decisions regarding graft selection. Based on the data from NKLR, we aimed to compare the revision rates and patient reported outcomes at 2 years after primary ACL reconstruction between QT, BPTB and HT autografts in Norway.

It was hypothesized that there would be no difference in the outcome at 2 years comparing patients who underwent ACLR with QT grafts with those who were operated with BPTB or HT grafts.

MATERIALS AND METHODS

All patients enroled in the NKLR have signed informed consent. The Norwegian Data Inspectorate have granted permission to the register regarding data collection, analysis and publication. For register-based studies, the Norwegian Regional Ethics Committee has determined that additional ethical approval is not required.

NKLR

NKLR is a nationwide register that collects data on cruciate ligament surgeries from all hospitals and private clinics in the country.

Supported by the Norwegian government, it has been mandatory to report data both from the private and public hospitals since 2017. The primary objective is to evaluate current practice and to improve treatment outcomes [16].

The gathered data includes detailed information related to the patient and the procedure, including date of surgery and injury, activity at the time of injury, concomitant injuries, graft utilized, graft fixation and intraoperative findings/procedures. Additionally,

TABLE 1 Baseline demographics.

	BPTB		Hamstring		QT
		Subgroup[a]		Subgroup[a]	
Number of primary ACL reconstructions	10,924	4111	13,263	5862	603
Femoral tunnel placement technique					
Anteromedial	7036	3148	5023	2034	586
Transtibial	988	82	866	398	1
Other[b]	39	15	72	68	6
Mean age (SD)	27.3 (9.9)	25.9 (9.4)	29.0 (10.5)	28.8 (10.4)	23.5 (9.2)
BMI classification (%)					
<25	46.5	52.9	35.9	36.7	71.8
>25	33.5	30.6	29.8	27.6	26.2
Missing	20.0	16.5	34.3	35.7	2.0
Mean time since injury (%)					
0–3 months	3148 (28.8)	1403 (34.1)	2696 (20.3)	2154 (36.7)	304 (50.4)
4–6 months	2176 (19.9)	865 (21.0)	2822 (21.3)	1617 (27.6)	110 (18.2)
>6 months	5133 (47.0)	1660 (40.4)	7025 (53.0)	3771 (64.3)	169 (28.0)
Missing	467 (4.3)	183 (4.5)	720 (5.4)	2091 (35.7)	20 (3.3)
Sex (% female)	43.8	44.6	43.8	43.8	58.2
Injury or procedure – meniscus (%)					
No reported injury/procedure	4569 (41.8)	1664 (40.5)	6332 (47.7)	2703 (46.1)	236 (39.1)
Injury or procedure medial meniscus	2742 (25.1)	895 (21.8)	3338 (25.2)	1463 (25.0)	144 (23.9)
Injury or procedure lateral meniscus	1968 (18.0)	772 (18.8)	2126 (16.0)	1004 (17.1)	135 (22.4)
Injury or procedure both menisci	1565 (14.3)	766 (18.6)	1340 (10.1)	632 (10.8)	88 (14.6)
Meniscal injury not specified	80 (0.7)	14 (0.3)	127 (1.0)	60 (1.0)	0 (0.0)
Injury of cartilage (%)					
No reported injury	8463 (77.5)	3414 (83.0)	10542 (79.5)	4713 (80.4)	531 (88.1)
ICRS 1-2	1826 (16.7)	462 (11.2)	1944 (14.7)	736 (12.6)	43 (7.1)
ICRS 3-4	606 (5.5)	225 (5.5)	736 (5.5)	393 (6.7)	29 (4.8)
Missing	29 (0.3)	10 (0.2)	41 (0.3)	20 (0.3)	0 (0.0)
Activity (%)					
Pivoting	6480 (59.3)	2665 (64.8)	7274 (54.8)	3152 (53.8)	352 (58.4)
Skiing	1513 (13.9)	528 (12.8)	1987 (15.0)	936 (16.0)	120 (19.9)
Other sports	892 (8.2)	329 (8.0)	1175 (8.9)	538 (9.2)	62 (10.3)
Other	2039 (18.7)	589 (14.3)	2827 (21.3)	1236 (21.1)	69 (11.4)
Mean KOOS at 2 years (SD)					
Symptoms	79.3 (16.9)	80.4 (16.4)	77.1 (18.3)	77.2 (18.4)	79.8 (17.0)
Pain	85.3 (15.6)	86.9 (14.3)	84.3 (16.9)	84.7 (17.1)	87.6 (13.0)
ADL	92.2 (12.9)	93.6 (11.4)	90.9 (14.9)	91.2 (14.9)	94.6 (10.1)
Sport	65.1 (25.6)	68.4 (24.5)	66.7 (27.4)	67.3 (27.6)	72.9 (22.5)
QOL	66.8 (25.6)	69.1 (22.1)	66.0 (24.1)	66.2 (24.4)	70.0 (22.6)

TABLE 1 (Continued)

	BPTB		Hamstring		QT
		Subgroup[a]		Subgroup[a]	
Mean change of KOOS at 2 years (SD)					
Symptoms	6.8 (18.5)	5.5 (20.7)	4.7 (20.8)	4.5 (20.7)	3.4 (20.6)
Pain	11.0 (18.5)	9.4 (17.0)	10.6 (18.3)	10.6 (17.9)	9.3 (16.9)
ADL	8.8 (16.9)	6.9 (15.3)	8.4 (17.2)	8.3 (16.7)	7.7 (15.7)
Sport	21.2 (30.5)	19.3 (29.5)	23.7 (29.8)	23.4 (30.2)	22.3 (30.4)
QOL	31.5 (25.6)	31.5 (25.1)	31.3 (25.6)	31.7 (25.8)	33.5 (25.4)
Number of hospitals	75	16	75	17	17

Abbreviations: BPTB, bone patella tendon bone graft; HT, hamstrings tendon graft; QT, quadriceps tendon graft.
[a]Only reconstructed anterior cruciate ligaments from hospitals reporting use of QT grafts.
[b]Other methods for femoral tunnel drilling (available data: BPTB-74%, HT-45%, QT-98%).

patient-reported outcomes are assessed using the Knee injury Osteoarthritis Outcome Score (KOOS) [39], both before the surgery and at follow-up points of 2, 5 and 10 years. In 2018, 86% of primary ACLR were reported to the register [46].

Study population

All patients registered in NKLR from June 2004 through 31 December 2021, were eligible for inclusion. Patients who were operated with primary isolated ACL reconstruction with either of the three types of autografts here included. Patients under age 15 were excluded. Patients with concomitant multiligament surgeries and who received allografts were also excluded.

The following variables were requested from the register: patient age, sex, date of injury, date of primary surgery and potential revision surgery, causes of revision surgery, activity at primary injury, Body mass index (BMI, m^2/kg), meniscal injuries and treatment (lateral or medial meniscus, treatment: partial resection/resection/suture/no treatment), other reported ligaments injuries and reconstructions (posterior cruciate ligament, medial and lateral collateral ligament, posterolateral corner), cartilage injuries (the International Cartilage Repair Society Classification System (ICRS) grade 1–4 [36]), other reported injuries (fractures/injuries to nerves and to major blood vessels), and reported KOOS preoperatively and at 2 years follow-up.

Confounding factors

Patients' age, sex, BMI, time from injury to surgery were included in the statistical analysis as possible confounding factors.

Statistical analysis

Statistical analysis was performed using SPSS Statistics software (SPSS Inc, IBM Corp, and and Stata Statistical Software: Release 17. StataCorp LLC). *p* Values < 0.05 were considered statistically significant.

Revision rates at 2 years were calculated using Kaplan–Meier analysis and crude 2 years revision rates with 95% confidence intervals (CI) were reported. To compare revision rates, Log rank test was used. Hazard ratios (HR) with 95% CI were calculated using multivariable Cox regression model with revision within the first 2 years as endpoint, adjusted for confounding factors. The proportional hazards assumption of the Cox regression model was tested based on the Schoenfeld residuals and found to be satisfied. Mean change in patient-reported outcome (KOOS, subcategories 'Sport' and 'Quality of Life', preoperatively and at 2 years) for patients that were not revised was analysed with multiple linear regression.

In comparison, the QT group was smaller than the BPTB and HT group. To reduce and explore possible indication and selection bias bound to this difference, a subgroup analysis consisting of only patients that had surgery in hospitals operating with QT grafts was performed.

RESULTS

A total of 24,790 primary ACL reconstructions were included in the study. Patient characteristics and intraoperative findings are presented in Table 1. In total, 603 patients were operated with QT, 10,924 with BPTB and 13,263 with HT autografts. In the QT group, 99.8% of the grafts were harvested with a bone block. There were group differences in several clinically important factors including patient age, time to surgery from injury, sex, BMI and meniscal injuries. Among all

TABLE 2 Survival of the grafts.

2 years survival of grafts (95% CI)	BPTB		HT		QT
		Subgroup[a]		Subgroup[a]	
	98.8 (98.6–99.0)	98.6 (98.3–99.0)	97.5 (97.2–97.7)	97.1 (96.6–97.5)	96.4 (94.7–98.0)

Abbreviations: BPTB, bone patella tendon bone graft; HT, hamstrings tendon graft; QT, quadriceps tendon graft.
[a]Only reconstructed ACL from hospitals reporting use of QT grafts.

three graft types, the most frequently reported reasons for revision surgery were traumatic graft rupture and nontraumatic graft failure. No statistical differences were found between the cause of revision and the type of graft used. The estimated revision rates at 2 years were 3.6% (CI 2.0–5.3) 2.5% (CI 2.3–2.8) and 1.2% (CI 1.0–1.4) for QT, HT and BPTB, respectively, ($p < 0.001$) (Table 2, Figure 1). In the Cox regression analysis, BPTB had a lower revision risk (HR 0.4, 95% CI 0.2–0.7, $p < 0.001$), while there was no difference in revision risk found for HT (HR 1.1, 95% CI 0.7–1.8, n.s.) with QT as reference (Table 3).

At 2-year follow-up, a complete KOOS was available in 41% of the patients. When comparing the changes in KOOS subcategories 'Sport' and 'Quality of Life' from the preoperative assessment to the 2-year follow-up, no significant differences were found between the groups (Table 4).

In the subgroup analysis exclusively focusing on the 17 hospitals reporting use of QT grafts, the revision rates at 2-year follow-up for all three grafts were similar to what was observed in the primary group analysis (Table 2), with HR for BPTB compared with QT (0.4 [95% CI 0.25–0.75, $p < 0.003$]) mirroring the results of the main group analysis (Table 5).

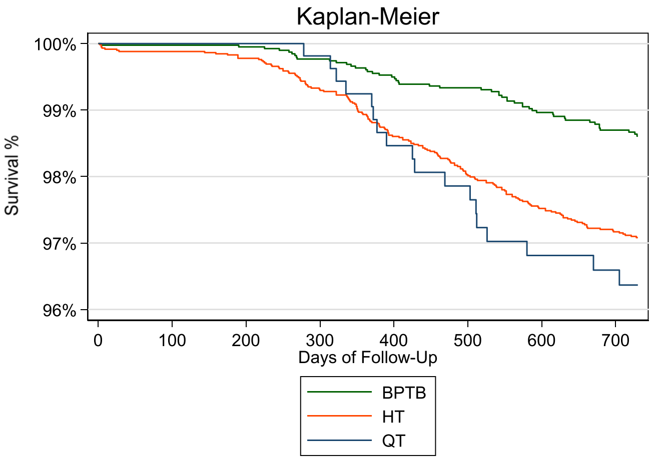

FIGURE 1 Kaplan–Meier survival estimates. Survival rate of the three autografts used in primary anterior cruciate reconstructions. BPTB, bone patella tendon bone; HT, hamstring tendon; QT, quadriceps tendon.

DISCUSSION

The most significant finding of this study was more than double risk for revision surgery in the first 2 years with QT autograft compared with BPTB autograft in primary ACL reconstructions. Previous register-based studies have assessed revision rates and patient-reported outcomes for QT patients. In a study based on the Danish Knee Ligament Register, Lind et al. [32] initially reported higher revisions rates after 2 years for QT grafts compared with BPTB and HT grafts (4.7%, 1.5% and 2.3%, respectively). These findings align with our results. The authors also noted that the elevated revision rates for QT grafts were particularly noticeable in younger patients aged 16–20 years. In a follow-up study aiming to expand on their findings, they concluded that the higher revision rates for QT grafts were associated with hospitals performing fewer than 100 ACL reconstructions annually [33]. Although data on hospital volume in the present study is lacking, the subanalysis, which included only hospitals performing QT reconstructions, yielded very similar results to the main analysis. This suggests that surgical site volume likely did not affect primary findings of the present study, although some failures may be attributed to a learning curve of a new surgical technique.

Additionally, a similar study based on the New Zealand ACL registry, including 1921 patients with HT, 558 with BPTB and 107 with QT did not reveal statistical differences in revision rates and patient-reported outcomes among all three grafts after primary ACL reconstruction [66]. However, only 67 out of the 107 QT grafts were available at risk to estimate the 2-year revision rate of 1.2%.

The higher revision risk in QT patients cannot be explained based on available data set. The average QT patient in the present study was typically younger, more frequently female and had surgery sooner after injury compared with the patients in the other graft groups. Younger age is a well-established risk factor for revision ACLR [4, 10, 43]. Likewise, patients who undergo surgery shortly after their injury face an increased risk of later revision surgery [17]. These risk associations may stem from higher activity level and an early return to pivoting sports [5, 62]. Age was adjusted for in the main analysis; unfortunately, the study's database did not contain complete records of the patients' activity level.

TABLE 3 Cox regression analysis.

2 years follow up	Crude RR	Crude 95%CI	Crude *p* Value	Adjusted[a] RR	Adjusted[a] 95%CI	Adjusted[a] *p* Value
QT	1			1		
BPTB	0.33	(0.20–0.54)	<0.000	0.43	(0.26–0.72)	0.001
HT	0.71	(0.44–1.14)	n.s.	1.10	(0.68–1.80)	n.s.

Abbreviations: BPTB, bone patella tendon bone graft; CI, confidence interval; HT, hamstrings tendon graft; n.s., not significant; QT, quadriceps tendon graft; RR, relative risk.

[a]Adjusted for sex, age, BMI, time since injury.

TABLE 4 Multiple linear regression KOOS (Subscales Sport and Quality of Life).

KOOS	*n*	Crude Mean difference of Δ[a]	Crude 95% CI	Crude *p*	Adjusted[b] Mean difference of Δ[a]	Adjusted[b] 95% CI	Adjusted[b] *p*
Δ Sport*							
QT	49	ref			ref		
BPTB	2864	−2.3	(−7.0,2.5)	n.s.	−1.9	(−6.7,2.8)	n.s.
HT	5606	0.5	(−4.2,5.2)	n.s.	1.4	(−3.3,6.2)	n.s.
Δ QOL*							
QT	49	ref			ref		
BPTB	2894	−2.7	(−6.7,1.3)	n.s.	−1.7	(−5.8,2.3)	n.s.
HT	5641	−2.7	(−6.7,1.2)	n.s.	−1.4	(−5.4,2.7)	n.s.

Abbreviations: BPTB, bone patella tendon bone graft; HT, hamstrings tendon graft; n.s., not significant; QT, quadriceps tendon graft.

*Complete pre-op KOOS and subcategorized at 2-years follow-up.

[a]Difference based on change from baseline to 2 years KOOS subscales.

[b]Adjusted for sex, age, BMI and time since injury.

TABLE 5 Cox regression analysis of the subgroup of hospitals that use all three autografts.

2 years follow up	Crude RR	Crude 95% CI	Crude *p* Value	Adjusted[a] RR	Adjusted[a] 95% CI	Adjusted[a] *p* Value
QT	1			1		
BPTB	0.38	(0.22–0.65)	<0.001	0.42	(0.24–0.74)	0.003
HT	0.82	(0.50–1.33)	n.s.	1.10	(0.66–1.85)	n.s.

Abbreviations: BPTB, bone patella tendon bone graft; CI, confidence interval; HT, hamstrings tendon graft; n.s., not significant; QT, quadriceps tendon graft; RR, relative risk.

[a]Adjusted for sex, age, BMI, time since injury.

Although the literature describes female sex as a risk factor for ACL injury [38, 44], it appears not to affect the outcomes after reconstructive surgery [25, 51].

The QT group exhibited a higher incidence of meniscal injuries, and some of these may have required early repair and ACL reconstruction. This discrepancy might partially account for the differences in the recorded delay between injury and surgery among the groups. It has been hypothesized that unaddressed meniscal lesions could have adverse effects on knee stability and potentially increase the risk for ACL graft failure [6, 14, 30, 35, 60]. However, no clear association has been established between meniscal injuries and the risk of early ACL revision [2, 17].

Comparing QT grafts with BPTB graft, there are differences that may elucidate findings of this study. In addition to the benefit of reliable graft incorporation of the bone blocks in both ends of the BPTB graft, QT grafts have found to have a heterogeneity in the direction of the tendon fibres [7]. This could potentially weaken the in-vivo incorporation of the QT graft, although this has not been observed in time-zero biomechanical studies [22, 57].

In the present study, no differences were found in the change of KOOS, subcategories 'Sports' and 'Quality of Life' at the 2-year follow-up. This finding aligns with previous published studies that focused on patient-reported outcomes [18, 20, 34, 47, 58]. However, several studies highlighted that QT grafts were associated with lower donor site morbidity [1, 13, 27, 31, 47, 48], an aspect that the KOOS questionnaire unfortunately may not capture.

The major strength of the present study is the inclusion of large number of patients compared with smaller groups in clinical studies. The high coverage of the NKLR [46] and the availability of detailed pre-, per- and postoperative data with good validity [40] offer an opportunity to calculate adjusted risk estimates and revision rates. One limitation of this present study is that the QT group had a relatively smaller sample size and consisted of younger patients, potentially introducing a risk of selection bias. Hospitals with a higher usage of QT grafts may treat younger high-risk patients, and confounding factors not captured by the register may influence the results. Additionally, we lack information on whether patients underwent partial or full-thickness QT graft ACLR. Furthermore, differences in fixation techniques, tunnel placement (anteromedial or transtibial techniques), the involvement of multiple surgeons and the potential impact of a learning curve could all contribute to additional variability [33].

Revision ACLR was the primary endpoint in the study analysis. With addition of patient-reported outcome, one should be able to detect differences between the groups even when not all clinical failures undergo revision surgery. However, at the 2-year follow-up, complete KOOS subcategories 'Sport' and 'Quality of Life' data were available for only 41% of the patients. This relatively low response rate may not have captured all subjective failures, potentially affecting the study's results. Lastly, it's worth noting that the present study lacks data related to initial laxity, the specifics of the postoperative rehabilitation process and time of returning to sports.

CONCLUSION

In primary ACLR, QT grafts exhibited a risk of early revision that was over two times higher compared with those with patellar tendon grafts. No significant differences in patient-reported outcomes were observed among all three autografts.

AUTHOR CONTRIBUTIONS

Marek Zegzdryn analysed data and prepared manuscript. Gilbert Moatshe, Lars Engebretsen, Jon Olav Drogset, and Håvard Visnes provided critical feedback and helped shape research, analysis and manuscript. Stein Håkon Låstad Lygre performed statistical analysis. Andreas Persson conceived the study and oversaw overall direction and planning. All authors read and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest

ETHICS STATEMENT

No ethical consent is necessary in Norway for studies based on data from national board of health approved national healthcare registries. All of the patients participating in the study have signed an informed consent.

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