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A Matched-Pairs Study with a Mean Follow-Up Of 6.5 Years

Armin RUNER[1,5], Aline SUTER[2], Tommaso ROBERTI di SARSINA[2], Lena JUCHO[1], Peter GFÖLLER[2], Robert CSAPO[2,3], Christian HOSER[2], Christian FINK[2,4]

Authors given as first name and SURENAME

1 – Dept. of Orthopedics and Traumatology, Medical University of Innsbruck, Innsbruck, Austria

2 – Gelenkpunkt - Sports and Joint Surgery, Innsbruck, Austria

3 – Centre for Sport Science and University Sports, University of Vienna, Vienna, Austria

4 – Private University for Health Sciences, Medical Informatics and Technology (UMIT), ISAG, Research Unit for Orthopaedic Sports Medicine and Injury Prevention

5 - Department for Orthopaedic Sports Medicine, Klinikum rechts der Isar, Technical University of Munich, Ismaninger Str. 22, 81675, Munich, Germany

Institution: Study performed at Gelenkpunkt - Sports and Joint Surgery, Innsbruck, Austria

Corresponding author: Christian Fink, Gelenkpunkt - Sports and Joint Surgery, Innsbruck, Austria. E-Mail: c.fink@gelenkpunkt.com Phone: +43 512 397030

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Abstract

Objectives: To compare clinical and functional outcomes of patients after primary anterior cruciate ligament reconstruction (ACLR) using quadriceps tendon- (QT-A) and hamstring tendon (HT-A) autograft with a minimum follow-up (FU) of 5 years.

Methods: Between 2010 - 2014, all patients undergoing ACLR (QT: 119, HT: 511) were recorded in a prospectively administered database. All patients with primary, isolated QT-A ACLR and without any concomitant injuries or high grade of osteoarthritis were extracted from the database and matched to patients treated with HT-A. Re-rupture rates, anterior-posterior (ap) knee laxity, single-leg-hop test (SLHT) performance, distal thigh circumference (DTC) and patient reported outcome measurements (PROMs) were recorded. Between-group comparisons were performed using chi-square-, independent-samples T- or Mann-Whitney-U tests.

Results: 45 QT-A patients were matched to 45 HT-A patients (n=90). The mean FU was 78.9±13.6 months. 18 patients (20.0% / QT: N=8, 17.8%; HT: n=10, 22.2%; p=.60) sustained a graft rupture and 17 subjects (18.9% / QT: n=9, 20.0%; HT: n=8, 17.8%; p= .79) suffered a contralateral ACL injury. In high active patients (Tegner-activity-level≥7) the rerupture rate increased to 37.5% (HT-A) and 22.2% (QT-A; p=.32). No statistical between-group differences were found in ap knee laxity side-to-side (SSD) measurements (QT-A: 1.9±1.2mm, HT-A: 2.1±1.5mm; p=.60), subjective IKDC- (QT: 93.8±6.8, HT: 91.2±7.8, p=.17), Lysholm- (QT: 91.9±7.2, HT: 91.5±9.7, p=.75) or any of the five subscales of the KOOS score (all p>.05). Furthermore, Tegner-activity-level (QT: 6(1.5), HT: 6(2), p=.62), VAS for pain (QT: 0.5±0.9, HT: 0.6±1.0, p=.64), Shelbourne-Trumper-Score (QT: 96.5±5.6, HT: 95.2±8.2, p=.50), Patient-and-Observer-Scar-Assessment-Scale (POSAS) (QT: 9.4±3.2, HT: 10.7± 4.9, p=.24), SSD-DTC (QT: 0.5±0.5, HT: 0.5±0.6, p=.97), return to sports rates (QT-A: 82.1%, HT-A: 86.7%) and SLHT (QT: 95.9±3.8%, HT-A: 93.7±7.0%) did not differ between groups. Donor site morbidity (HT-A n=14, 46.7%; QT-A n=3, 11.5%; p=.008) was significantly lower in the QT-A group. Five patients (11.1%) of the HT-group and three patients (6.7%) in the QT-group required revision surgery (p= .29).

Conclusion: Patient-reported outcome measures, knee laxity, functional testing results and re-rupture rates are similar between patients treated with QT- and HT-autografts. However, patients with QT-autograft have smaller tibial skin incisions and lower postoperative donor site morbidity.

Keywords: anterior cruciate ligament; quadriceps tendon; hamstring tendon; autograft; graft rupture; donor site morbidity

What are the new findings

- Patient-reported outcome measures, knee laxity and functional testing results are similar between patients treated with QT- and HT- autografts in mid- to long-term follow-up (60-105 month, mean 78.9±13.6 month)
- Re-rupture- and contralateral ACL rupture rates range between 17.8% and 37.5% depending on the graft choice and activity level, but are statistically not different between patients treated with QT-A or HT-A
- In patients with QT-autograft the skin incision at the proximal tibia is significantly smaller and the postoperative donor site morbidity significantly lower compared to patients with HT-A.

Introduction

Although being one of the most performed and successful interventions in orthopedic surgery, anterior cruciate ligament reconstruction (ACLR) still poses challenges to patient and surgeon. These include postoperative residual knee instability, graft re-ruptures, management of harvest site morbidity and progressive development of osteoarthritis [1].

In the face of various tissues available for reconstruction, the selection of the optimal graft remains controversial. In addition to the widely used bone-patellar-tendon-bone (BPTB-A) and hamstring tendon (HT-A) autografts, the quadriceps tendon (QT-A) has become increasingly popular because of its potential advantages over traditional grafts [1-4]: Compared to BPTB-A and HT-A, the QT-A has a higher load to failure, strain at failure and Young's modulus of elasticity [5-8]. In dependency of the patients' needs, the QT-A can be harvested with or without femoral bone block [2,3,5,8]. While patient-reported outcome measures (PROMs), postoperative functional outcomes, re-rupture rates and postoperative laxity measures appear similar between grafts [1,9-16], reconstruction with QT-A may be associated with lower donor site morbidity due to shorter skin incisions and therefore resulting in lower regional hypoesthesia, pain and irritation [1,9,16,17]. In addition, the use of QT-A preserves the HT complex, which acts as a synergist to the ACL in limiting anterior tibial translation and valgus moments [18-20].

While most of the above-mentioned findings are based on short term follow-up (FU), there is little evidence about mid- to long term outcomes after ACL reconstruction (ACLR) using QT-A autograft. The aim of the present study was to compare clinical, functional and PROMs in patients undergoing primary, isolated anterior cruciate ligament reconstruction (ACLR) using quadriceps tendon- (QT-A) and hamstring tendon (HT-A) autograft with a minimum duration of 5 years FU.

Methods

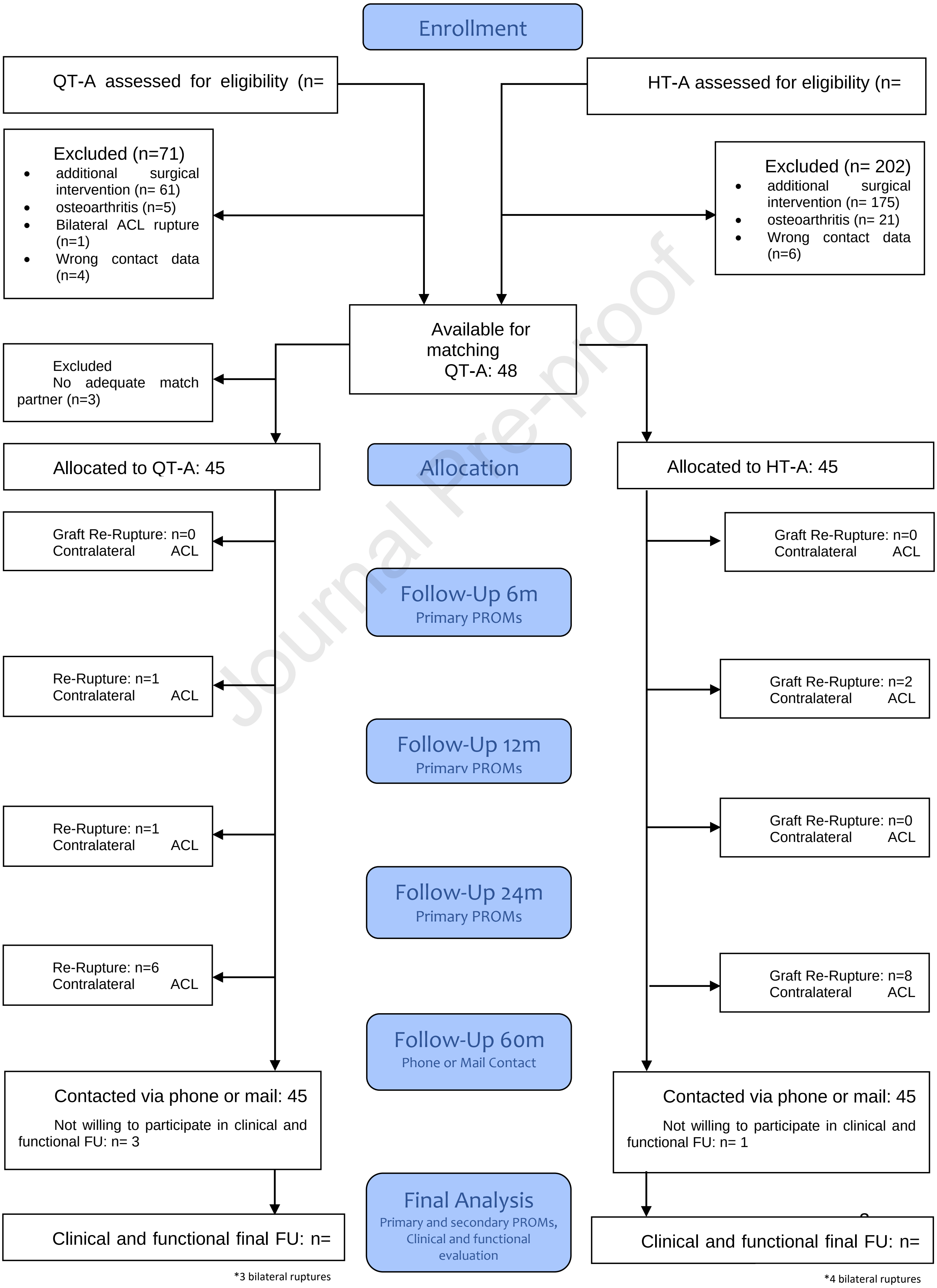
The study was approved by the ethical committee of the …. Informed consent was obtained from all participants prior to study inclusion. Between January 2010 and December 2014, all patients undergoing ACLR (QT: 119, HT: 511) in a single specialized orthopedic center were recorded in a prospectively administered Microsoft (MS) Access-based database.

At the end of the inclusion period and after careful examination of the applied inclusion and exclusion criteria, all patients with primary, isolated QT-A ACLR were matched by sex (100% accordance), time point of surgery (≤12 month), age (±3 years) and Tegner activity score (±1 score point) to patients treated with isolated HT-A. Inclusion criteria were as followed: a) primary, isolated ACL injury b) arthroscopical ACL reconstruction with quadriceps- (QT) or hamstring tendon (HT) autograft c) maintained meniscal hoop function with an intact or only partially resected meniscus (<30%) d) Kellgren – Lawrence osteoarthritis score equal or lower than two at time of surgery e) no intraoperative diagnosed chondral lesions higher than grade 3 according to the Outerbridge classification, f) patients older than 16 years and g) minimum five-year follow-up

All included patients were postoperatively followed up after 6, 12 and 24 months using Lysholm- and Tegner scores as well as a visual analog scale for pain. After a minimum of 60 months of FU all included patients were contacted by telephone to obtain a comprehensive medical history. All patients without a subsequent ipsi- or contralateral ACL injury were invited for personal clinical and functional follow up. A flow chart showing the patient selection procedure is shown in Figure 1.

Figure 1

Patient selection procedure



Surgery

All ACLRs were performed by three fellowship-trained and experienced orthopedic surgeons (C.F., C.H., P.G.). Apart from the graft harvesting technique, both the surgical procedure and the postoperative rehabilitation were identical for all patients. The selection of the graft was not randomized but chosen according to the patients' preferences after detailed explanation of the strengths and weaknesses of each graft.

Graft harvesting and reconstruction technique

ACL rupture was confirmed by performing routine diagnostic arthroscopy in all patients. Utmost care was taken to preserve the tibial and femoral ACL footprint. QT-A was obtained using a minimally invasive harvesting technique previously described by Fink et al. [2]. Through a 2-3 cm long transverse skin incision placed over the proximal border of the patella, a 6-8 cm long, 10-12 mm wide and 5 mm thick soft-tissue or bone-tendon QT-strip was obtained. After graft preparation, a flip button device (e.g. EndoButton™ [Smith&Nephew, Andover, USA]) was attached to either the bone block or the periosteal strip using a No. 2 FiberWire™ suture (Arthrex Inc).

Alternatively, HT-A was harvested in a standard manner through a 3 cm anteromedial, oblique incision and armed using a No.2 FiberWire™ (Arthrex Inc.) suture in Krackow stitch technique. Again, the proximal fixation was achieved using a flip button device (e.g. EndoButton™ [Smith&Nephew, Andover, USA]).

Femoral and tibial tunnels were drilled through an anteromedial portal corresponding to the size of the graft. Bioabsorbable interference screws of either 23 mm or 28 mm length and of the same diameter as the bone tunnel were used for tibial fixation in both grafts. For additional fixation sutures were tied over a small fragment screw or an extracortical button Endotack® (Karl Storz, Tuttlingen, Germany).

Postoperative Rehabilitation

Both groups performed a standardized rehabilitation program, focusing on the early improvement of range of motion and pain control. Patients treated with bone-tendon QT-A were not subject to a more aggressive rehabilitation program than those with soft-tissue QT-A. All patients attended a two-day inpatient stay for mobilization training and pain therapy. Thereafter, outpatient physical therapy was performed for at least 12 weeks. During the first two postoperative weeks, only partial weight bearing was allowed, and knee flexion was limited to 90° using a knee brace. Thereafter, the restrictions of weight bearing and range of motion were lifted.

Outcome evaluation

Primary end points were the Lysholm- and Tegner activity score as well as the VAS (Visual analog scale) for pain. All three scores were assessed preoperatively as well as 6, 12, 24 months postoperatively and at final FU.

Secondary end points at final FU were additional PROMs including the subjective International Knee Documentation Committee (IKDC) and Knee Injury and Osteoarthritis Outcome Score (KOOS) score. Anterior knee pain including keeling pain was assessed using the Shelbourn and Trumper score. Cosmetical outcome was assessed using the POSAS (Patient and Observer Scar Assessment Scale) score [21].

A standardized clinical knee examination according to the objective IKDC form was carried out in all patients. Maximal anterior tibial translation (ATT) was obtained as objective measure of knee laxity using the KLT knee arthrometer (Karl Storz, Tuttlingen, Germany). The patient was positioned supine with the knee 30° flexed and using a leg holder to maintain a neutral knee position. Subsequently, one single rater

(A.R.) performed three consecutive measurements per leg. Results were averaged and the side-to-side difference was calculated.

The single-leg-hop-test (SLHT) was used to determine knee function and strength. Two tests per site were carried out and averaged to calculate the Limb Symmetry Index (LSI): score of the healthy limb/operated limb x100%. An LSI<100% indicates a deficit of the operated compared to the healthy knee and an LSI>90% is commonly used to testify readiness for sport [22]. The length of skin incisions and the distal thigh circumference, measured about 5cm above the proximal patella margin, were assessed with the leg fully extended. Donor site morbidity was assessed as the subjective rating of pain and/or sensory loss. The hypoesthetic area of the lower leg was tested as described by Kjaergaard et al.[23]. By applying light touch simultaneously to both legs, the area of hypesthesia was marked on the skin, copied first onto a transparency film and later onto quad paper. Subsequently the size of sensibility change was determined [23]. Full return-to-sport was achieved when reaching the preinjury Tegner activity level.

Statistics

Statistical analysis was performed using Microsoft Excel (Microsoft Version 16.52) and SPSS Statistics (IBM 28.0). Independent-samples t tests were applied to determine differences between the QT- and HT groups for interval-scaled data. For ordinal or non-normally distributed data, the Mann-Whitney U test was used. A Pearson Chi-square test was performed to compare dichotomous variables. The level of statistical significance was set to $p < .05$ (2-sided). Patient with an Tegner activity score of equal or higher than seven were categorized as “high active”, while those with a score below seven as “low active”.

The size of the sample included in this study was determined by *a priori* non-inferiority power analysis (G*Power, Version 3.1.9.), which was tailored to yield the minimum sample required to detect the minimal clinical important difference (MICD) in the Lysholm score (8.9 points [24]). Based on previously collected data on a similar patient population, a mean Lysholm score of 95 points and a standard deviation of 9 points were assumed for each group [3]. Using $\alpha = 0.05$ and $1-\beta = 0.95$ as input criteria, this test suggested that a minimum of 29 subjects per group had to be included.

Results

Forty-five pairs, totaling 90 patients, were included in the study. Patients' characteristics and intraoperative details are summarized in Table 2. Follow-up time ranged from 60 to 105 months with a mean follow-up time of 78.9 ± 13.6 months. At final follow up, all patients were reached by telephone or mail, but three (3.3%) declined to participate in the personal clinical follow-up.

Table 1
Patient characteristics

	QT-A (n = 45)	HT-A (n = 45)	p*
Baseline characteristics			
Sex [female/male]	16/29	16/29	1.0
Age [y]	28.9 ± 11.6	27.2 ± 12.5	.99
Height [cm]	172.7 ± 10.0	175.2 ± 6.7	.24
Body Mass [kg]	71.9 ± 13.8	73.6 ± 11.0	.18
BMI (kg/m^2)	23.9 ± 2.6	23.9 ± 3.0	.39
Preop. Tegner Activity Score[§]	6 (1)	6 (2)	.15
Intraoperative details			
Mean graft square area [cm^2]	41.2±3.9	47.8±9.0	<.001
Partial Meniscectomy[#]			
medial	3 (7.0%)	4 (8.9%)	.76
lateral	7 (16.0%)	4 (8.9%)	.49
Chondromalacia (Grade 1/2/3/4)			
femoral	0 / 1 / 3 / 0	0 / 5 / 0 / 0	.70
tibial	0 / 3 / 1 / 0	0 / 2 / 0 / 0	.41
retropatellar	0 / 2 / 3 / 0	0 / 1 / 0 / 0	.09
Collateral Ligament Laxity (Grade 1/2/3)			
medial	0 / 2 / 0	0 / 0 / 0	.15
lateral	0 / 0 / 0	0 / 0 / 0	1.0

Values reported as mean±standard deviation; §, reported as median (Interquartil Range); p<0.05
QT, quadriceps tendon autograft; HT, hamstring tendon autograft; y, year; FU, Follow-up; BMI, Body Mass Index
#, patient with a meniscus resection >30% were not included in the study

Patient-reported outcome measures

No significant differences were observed between both groups at 6, 12, 24 and 60 months postoperatively for the Lysholm- Tegner activity scale and VAS score for pain (Table 3). At final FU 82.1% of the QT-A and 83.9% of the HT-A patients reported “good” or “excellent” Lysholm score results. Secondary PROMs at final FU are listed in Table 4.

Table 2
Primary Patient Reported Outcome Measurements

	QT-A	HT-A	p*
Lysholm			
Preoperative	91.6 ± 13.1	90.1 ± 19.6	.34
6 months	88.7 ± 9.4	86 ± 13.3	.45
12 months	90.0 ± 10.2	89.2 ± 11.2	.69
24 months	90.2 ± 18.4	89.5 ± 20.3	.65
60+ months	91.9 ± 7.2	91.5 ± 9.7	.75
Tegner Activity Score§			
Preoperative	6 (1)	6 (2)	.15
6 months	6 (2)	6 (2.3)	.33
12 months	6 (3.5)	6 (2)	.46
24 months	6 (3.5)	6 (1.3)	.54
60+ months	6 (1.5)	6 (2)	.62
VAS Score			
Preoperative	0.9 ± 1.1	0.7 ± 1.2	.78
6 months	1.3 ± 1.6	0.9 ± 0.8	.69
12 month	1.0 ± 1.1	0.8 ± 0.9	.93
24 month	0.6 ± 0.9	0.6 ± 1.0	.55
60+ month	0.5 ± 0.9	0.6 ± 1.0	.64

Values reported as mean±standard deviation; §, reported as median (Interquartil Range); $p < .05$
QT, quadriceps tendon autograft; HT, hamstring tendon autograft

Table 3
Secondary Patient Reported Outcome Measurements$

	QT-A (n = 28)	**HT-A** (n = 30)	**p***
IKDC	93.9 ± 6.8	91.2 ± 7.8	.17
Koos Symptoms	94.6 ± 6.5	90.2 ± 10.7	.06
Koos Pain	97.4 ± 5.4	96.2 ± 5.2	.40
KOOS ADL	99.4 ± 1.6	98.7 ± 2.4	.19
KOOS Sports	95.0 ± 8.0	92.7 ± 10	.33
KOOS QOL	89.8 ± 14.4	85.7 ± 15.1	.29
Shelbourn-Trumper Score	96.5 ± 5.6	95.2 ± 8.2	.50
POSAS	9.4 ± 3.2	10.7 ± 4.9	.24

$, Measurement values reported at final follow-up; Values reported as mean±standard deviation; p< .05
ADL, Activity of Daily Living; QOL, Quality of Life; POSAS, Patient and Observer Scar Assessment; QT, quadriceps tendon autograft; HT, hamstring tendon autograft Scale

Knee laxity

The mean side-to-side difference (SSD) in ap-translation was 1.9 ± 1.2mm for the QT-A and 2.1 ± 1.5mm for the HT-A (p= .60). The objective IKDC grade between the QT- and HT-group revealed a grade “A” in 76.9% and 57.1% (p=.12) and a grade “B” in 23.1% and 39.3% patients (p= .20), respectively. A negative Pivot-shift test was found in 92.3% of the QT-A and 85.7% of the HT-A group, respectively (p= .44).

Functional testing and Return-to-sports

The limb-symmetry-index for SLHT (QT-A: 95.9 ± 3.8%, HT-A: 93.7 ± 7.0) did not differ between groups. Five patients (17.8%) of the HT-A group and one (3.3%) patient of the QT-A group did not reach the recommended LSI>90% threshold for a safe return to sports (p= .18). The measured SSD for DTC (QT: 0.5 ± 0.5, HT: 0.5 ± 0.6, p= .97) was not significantly different between groups.

82.1% (n=23) of the patients in the QT-A and 86.7% (n=26) of those in the HT-A group returned to their preoperative exercise level according to the Tegner activity level (p= .64).

ACL re-rupture-, contralateral ACL injury and follow-up operations

18 subjects (20.0% / QT: n=8, 17.8%; HT: n=10, 22.2%; p= .60) sustained a graft rupture and 17 patients (18.9% / QT: n=9, 20.0%; HT: n=8, 17.8%; p= .79) suffered a contralateral ACL injury. Three ruptures (16.7%) occurred within the first postoperative year, two (11.1%) in the second postoperative year, three (16.7%), four (22.2%), three (16.7%), one (5.6%) and two (11.1%) re-ruptures in the third to seventh postoperative year, respectively. Graft type did not affect the timing of ACL re-rupture or rupture of the contralateral site.

In the analysis of highly active patients with an Tegner activity score equal or higher than seven, six out of 16 patients in the HT-A group (37.5%) and 4 out of 18 patients in the QT-A group (22.2%) sustained a graft rupture (p= .32). In contrast, four re-rupture per group (QT-A: 14.8%, HT-A: 13.8%) occurred in the low activity group (p= .80) (Table 5). All but one patient underwent revision ACL surgery.

Table 4
Ratios of rerupture- and contralateral ACL rupture rates

	Total Sample§	QT§	HT§	p*
Revision surgeries				
All patients (n = 90)	18 (20)	8 (17.8)	10 (22.2)	.60
Low activity (n = 56)	8 (14.2)	4 (14.8)	4 (13.8)	.80
High activity (n = 34)	10 (29.4)	4 (22.2)	6 (37.5)	.32
Contralateral surgeries				
All patients (n = 90)	17 (18.9)	9 (20)	8 (17.8)	.79
Low activity (n = 56)	12 (21.4)	6 (22.2)	6 (20.7)	.83
High activity (n = 34)	5 (14.7)	3 (16.7)	2 (12.5)	.73

§, reported in total number and percentage (%); p< .05
QT, quadriceps tendon autograft; HT, hamstring tendon autograft; ACL, anterior cruciate ligament

Donor site morbidity and complications

Significantly more patients in the HT-group (n=14, 46.7%) reported persisting sensory deficits, numbness or irritation at the donor site of the proximal lower leg (QT: n=3, 11.5%; p= .008). The mean hypoesthetic area was 114.3 ± 118.4 cm^2 in the HT-group and 40.4 ±13.4 cm^2 in the QT-group (p= .30). A significantly longer tibial scar length was measured in the HT-group (HT-A: 3.1 ± 0.6cm, QT-A: 1.8 ± 0.6cm; p< .001). No or little anterior knee pain was stated by 89.3% and 83.3% of the patients with QT-A or HT-A, respectively. Throughout the study period, no rupture of the quadriceps tendon occurred.

Five patients (11.1%) of the HT-group and three patients (6.7%) in the QT-group required revision surgery due to postoperative complications other than graft re-rupture or contralateral ACL rupture (p= .29). The mean time from primary- to revision surgery was 10.3 ± 5.9 month. All complications and the subsequent performed procedure are listed in table 6.

Table 5
List of complications and performed revision surgery

	Complication	Performed revision surgery
	HT	
1	Extension deficit due to cyclops lesion	Removal of cyclops lesion and tibial hardware
2	Extension deficit due to cyclops lesion	Removal of cyclops lesion and tibial hardware
3	Painful tibial hardware	Removal of tibial hardwear
4	Osteochondrosis dissecans	Refixation of osteochondrosis dissecants and removal of tibial hardwear
5	Extension deficit due to cyclops lesion	Removal of cyclops lesion and simultaneous removal of tibal hardwear
	QT	
1	Painful tibial hardware	Removal of tibial hardwear
2	Bone block dislocation	Reposition and refixation of tibial bone block using an interference screw
3	Extension deficit due to cyclops lesion	Removal of cyclops lesion

Discussion

The main outcome of the present study was that patients treated with QT-A reported similar PROMs compared to patients treated with HT-A at an average of 6.5 years after the initial ACL reconstruction. Knee laxity-, functional testing as well as the rate of subsequent graft- or contralateral ACL rupture did not differ between both groups. Donor-site morbidities and tibial scar length were significantly greater in patients treated with HT-A.

Patient reported outcome scores

Similar subjective postoperative outcomes after ACLR using QT- or HT-A have been reported at short term FU both by recent randomized- and non-randomized controlled studies [1,3,10,11,14,17,25]. Contrary, Cavaignac et al. reported significantly better subjective IKDC- and Lysholm scores after 3.4 years FU in patients treated with QT-A [13]. Three recent systematic reviews and meta-analyses focused on graft choice in ACL reconstruction [9,12,16]. Mouarbes et al.[9] compared QT-A to BPTB-A and HT-A. No statistical difference was reported for the Lysholm score between BPTB- or QT-A, however, significantly higher scores were found in patients operated with QT-A compared to those with HT-A. Contrary, Tan et al. [12] and Dai et al. [16] reported no difference between QT-A and HT-A in terms of PROMs.

The present data expand the current state of knowledge on the short-term results by showing no significant mid- to long-term differences in PROMs between patients treated with QT-A or HT-A.

Knee laxity

Anterior-to-posterior knee side-to-side differences measurements using arthrometers are important to objectively quantify postoperative knee laxity. Nonetheless, caution is advice when interpreting results from different devices and multiple examiners, as results may not be directly comparable [26]. Lind et al. [1] and Horstman et al. [27] reported in a randomized controlled trial no significant difference in side-to-side KT-1000 measurements two years postoperatively in patients treated with either partial thickness QT- or HT-A. Statistically non different short-term results were also reported in other non-randomized controlled trials [11,25,28-30], whereas some studies reported less ap-laxity in patients with QT-A [13,15,31]. Pooling all currently available data for a meta-analysis, Mouarbes et al. [9], Tan et al. [12] and Dai et al. [16] found no significant difference in postoperative knee laxity between QT-A and HT-A. Moreover, the number of positive pivot shift test did not differ statistically between grafts [9,12]. Like the results of the above-mentioned studies, the present data do not show any graft superiority regarding postoperative knee ap-laxity or positive pivot-shift test.

Functional testing and Return-to-sports

Calculating the Limb Symmetry Index (LSI) from SLHT-results is a valid, reliable and easy-to-use functional outcome measure for assessing a combination of lower leg muscle strength, neuromuscular control and confidence [1,22,32-36]. Lind et al. demonstrated a significantly higher LSI in patients treated with HT-A (LSI=97%) compared to QT-A (LSI=91%) one year postoperatively [1]. In the present study, no significantly different SLHT- and DTC- LSI were observed between both groups. However, although not reaching the threshold of significance, there appears to be a higher number of patients with HT-A (17.5%, QT-A: 5.6%) that do not reach the recommended 90% LSI threshold for safe return to sports even in the long run.

Nevertheless, this does not carry over to the return-to-sports rate, where no difference between both groups was detected (QT-A: 82.1%, HT-A: 86.7).

ACL re-rupture-, contralateral ACL injury and follow-up operations

Graft rupture after ACL-R is not only a devastating personal experience but entails severe socioeconomic consequences. Together with functional performance during daily activities, graft survival has without doubt the biggest influence on patients' satisfaction [14]. Several factors, including graft choice, patients age und physical activity, seem to have a significant influence on graft re-rupture rates [14,37-43]. For primary ACL-R using QT-A, scant long-time data regarding graft survival exists. When compared to BPTB-A, non-significant differences with rupture rates ranging between 2.0%-4.8% were found in the short term [44-47]. By contrast, significantly higher re-rupture rates were reported in patients with HT-A (2.7%-4.5%) in three large Scandinavian registry studies and a meta-analysis when compared to BPTB-A (2.0%-3.0%) [40-42,48]. When comparing QT-A and HT-A, recent short-term studies reported no significant differences in graft rupture in adults [1,10,11,13,14], whereas significantly lower reinjury rates were reported for QT-A in children [49]. A recent large registry study from our study group with 875 included QT-A and HT-A patients revealed that graft choice had a significant predictive value for graft rupture with lower re-rupture rates in patients with QT-A (QT-A: 2.8%, HT-A: 4.9%) [14].

In the present study no significant difference was observed between patients treated with QT-A (17.8%) and HT-A (22.2%). Of particular interest, in high-level athletes (Tegner ≥7) the re-rupture rate dramatically increased in the HT-A cohort (37.5%) whereas it rose only slightly in the QT-A (22.2%) group (p= n.s.)

Donor site morbidity

Postoperative anterior knee pain, kneeling pain or sensibility losses at the anterolateral lower leg are undesired but common side effects of an ACLR. The rate of patients complaining about anterior kneeling pain was not different between the two cohorts of the present study. However, patients with HT-A complained significantly more about numbness and irritation at the lower leg. Harvesting the QT-A requires a smaller incision and appears to cause less sensory loss and discomfort compared to HT-A and BPTB [1,17,44]. Two recent systematic reviews and meta-analyses support these findings reporting similar [9] or even lower [16] rates of donor site morbidity in patients treated with QT-A compared to those with HT-A.

In agreement with the above-mentioned studies, the present results show favorable outcomes for the QT-A in terms of donor site morbidity. Due to a significantly longer skin incision at the proximal, antero-medial tibia, the infrapatellar- or even saphenous nerve appears to be at increased risk of injury during HT-A harvesting. This might result in higher rates of numbness and irritation at the lower leg.

Strength and Limitations

There are some limitations to this study. First, patients were not randomized to graft choice, but the graft was chosen under the consideration of patient's preference. Second, PROMs always carry a potential risk of misunderstanding of the questionnaires. Nonetheless, all questionnaires are frequently used and were previously testes for responsiveness, validity and reliability. Third, the power analysis was performed only to detect possible differences in subjective outcomes, whereas a calculation for graft rupture or contralateral ACL injury was not performed because of the small incidence of these events.

The most important strength of this work is the long follow-up time of more than 6.5 years. This is almost twice as long as the second longest study comparing QT-A to HT-A in primary ACLR. In addition, the matched-pair study design balanced important patient-specific factors known to influence postoperative outcomes (e.g., sex, age, athletic activity), improving the validity of the work by reducing bias. Finally, a large number of different subjective and objective postoperative factors were studied providing a good overview of the medium- and long-term results of primary ACL reconstruction using QT-A and HT-A.

Conclusion

Patient reported outcome measures, knee laxity, functional test results and re-rupture rates are similar between patients treated with QT- or HT autografts. However, patients with QT-autograft have smaller tibial skin incisions and lower postoperative donor site morbidity in the mid-term. The QT-autograft may be a better graft option for ACL reconstruction.

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Declaration of interests

☐ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☒ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Christian Fink reports a relationship with Karl Storz SE and Co KG that includes: consulting or advisory and speaking and lecture fees. Christian Fink reports a relationship with Medacta International SA that includes: consulting or advisory, speaking and lecture fees, and travel reimbursement.