ISAKOS Award Paper

Quadriceps tendon autograft for primary anterior cruciate ligament reconstruction show comparable clinical, functional, and patient-reported outcome measures, but lower donor-site morbidity compared with hamstring tendon autograft: A matched-pairs study with a mean follow-up of 6.5 years

Armin Runer, MD a,e, Aline Suter, MD b, Tommaso Roberti di Sarsina, MD b, Lena Jucho, MD a, Peter Gföller, MD b, Robert Csapo, Phd b,c, Christian Hoser, MD b, Christian Fink, MD b,d,e

a Department of Orthopedics and Traumatology, Medical University of Innsbruck, Innsbruck, Austria
b Gelenkpunkt - Sports and Joint Surgery, Innsbruck, Austria
c Centre for Sport Science and University Sports, University of Vienna, Vienna, Austria
d Private University for Health Sciences, Medical Informatics and Technology (UMIT), ISAG, Research Unit for Orthopaedic Sports Medicine and Injury Prevention, Austria
e Department for Sports Orthopaedics, Klinikum rechts der Isar, Technical University of Munich, Ismaninger Str. 22, 81675, Munich, Germany

Keywords:
Anterior cruciate ligament
Quadriceps tendon
Hamstring tendon
Autograft
Graft rupture
Donor-site morbidity

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 and 2014, all patients undergoing ACLR 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 measures (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-A: n = 8, 17.8%; HT-A: n = 10, 22.2%; p = .60) sustained a graft rupture and 17 subjects (18.9%/QT-A: n = 9, 20.0%; HT-A: n = 8, 17.8%; p = .79) suffered a contralateral ACL injury. In high active patients (Tegner activity level ≥ 7) re-rupture rates increased to 37.5% (HT-A) and 22.2% (QT-A; p = .32), respectively. Patients with graft failure did not differ between both groups in terms of mean age at surgery (QT-A: 26.5 ± 11.6 years, HT-A: 23.3 ± 9.5 years, p = .63) or graft thickness (mean graft square area: QT-A: 43.6 ± 4.7 mm²; HT-A: 48.1 ± 7.9 mm², p = .27). No statistical between-group differences were found in ap knee laxity side-to-side (SSD) measurements (QT-A: 1.9 ± 1.2 mm, HT-A: 2.1 ± 1.5 mm; p = .60), subjective IKDC- (QT-A: 93.8 ± 6.8, HT-A: 91.2 ± 7.8, p = .17), Lysholm- (QT-A: 91.9 ± 7.2, HT-A: 91.5 ± 9.7, p = .75) or any of the five subscales of the KOOS score (all p > .05). Furthermore, Tegner activity level (QT-A: 6.1, HT-A: 6.2, p = .62), VAS for pain (QT-A: 0.5 ± 0.9, HT-A: 0.6 ± 1.0, p = .64), Shelbourne–Trumper score (QT-A: 96.5 ± 5.6, HT-A: 95.2 ± 8.2, p = .50), Patient and Observer Scar -Assessment scale (POSAS) (QT-A: 9.4 ± 3.2, HT-A: 10.7 ± 4.9, p = .24), SSD-DTC (QT-A: 0.5 ± 0.5, HT-A: 0.5 ± 0.6, p = .97), return to sports rates (QT-A: 82.1%, HT-A: 86.7%) and SLHT (QT-A: 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 statistically 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 a smaller tibial postoperative scar length and lower postoperative donor-site morbidity. There is a tendency towards higher graft rupture rates in highly active patients treated with HT autograft.

Level of evidence: II

☆ Corresponding author. Gelenkpunkt - Sports and Joint Surgery, Innsbruck, Austria. Tel.: +43 512 397030.
E-mail address: c.fink@gelenkpunkt.com (C. Fink).

https://doi.org/10.1016/j.jisako.2022.08.008
Received 26 March 2022; Received in revised form 26 July 2022; Accepted 29 August 2022
Available online 8 October 2022
2059-7754/© 2022 The Author(s). Published by Elsevier Inc. on behalf of International Society of Arthroscopy, Knee Surgery and Orthopedic Sports Medicine. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
What are the new findings?

- Patient-reported outcome measures, knee laxity and functional testing results are similar between patients treated with quadriceps tendon- and hamstring tendon autografts in mid- to long-term follow-up (60–105 month, mean 78.9 ± 13.6 month).
- Re-rupture- and contralateral anterior cruciate ligament 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 quadriceps tendon- and hamstring tendon autografts.
- In patients with quadriceps tendon autograft the postoperative scar length at the proximal tibia is statistically significantly shorter and the postoperative donor-site morbidity significantly lower compared to patients treated with hamstring tendon autograft.

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 ACLR reconstruction (ACLR) using QT-A autograft. The aim of the present study was to compare clinical- and functional results as well as 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. Primary outcome measure was the Lysholm-score. Secondary outcomes included PROMs, graft rupture- and contralateral ACL rupture rates as well as various functional and clinical outcomes. It has been hypothesize that there would be no statistically significant difference between both graft options in terms of clinical, functional or patient-reported outcomes.

Methods

The study was approved by the ethical committee of the Medical University of Innsbruck (AN2015-0050346/4.28). Informed consent was obtained from all participants prior to study inclusion. Between January 2010 and December 2014, all patients undergoing ACLR 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 Fig. 1.

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

ACLR was confirmed by performing routine diagnostic arthroscopy in all patients. Umost 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 Krakow 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, Tuttingen, 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. Return to full sports activity including competitive sports was allowed after 9–12 months at the earliest, depending on the sport.
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 Shelbourne and Trumper questionnaire. Cosmetical outcome was not assessed.

Fig. 1. Patient selection procedure.
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, Tuttingen, 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 ×100%. 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 postoperative scar length and distal thigh circumference, measured about 5 cm 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. Postoperative complications were subsequently recorded during scheduled or unscheduled visits.

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 a 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 (MID) 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 α = 0.05 and 1-β = 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. 52.9% (n = 18) of the patients treated with QT-A and 47.1% (n = 16) of those treated with HT-A reported a Tegner activity score of seven or higher. 93.3% (n = 43) and 88.9% (n = 40) of QT-A and HT-A patients, respectively performed at least one pivoting sport. Downhill skiing (n = 68, 75.6%), football (n = 39, 43.3%) and backcountry skiing (n = 18, 20%) were the most commonly performed sports. Patients’ characteristics and intraoperative details are summarized in Table 1. 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.

Patient-reported outcome measures

Statistically 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 2). 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 3.

Knee laxity

The mean side-to-side difference (SSD) in ap-translation was 1.9 ± 1.2 mm for the QT-A and 2.1 ± 1.5 mm 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 ITC (QT-A: 0.5 ± 0.5, HT-A: 0.5 ± 0.6, p = .97) was not statistically 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

Details on graft rupture rates are displayed in Table 4 and in the supplementary data. 18 subjects (20.0%/QT-A: n = 8, 17.8%; HT-A: n = 10, 22.2%; p = .60) sustained a graft rupture and 17 patients (18.9%/QT-A: n = 9, 20.0%; HT-A: n = 8, 17.8%; p = .79) suffered a contralateral ACL injury. Graft survival rate of QT-A and HT-A was comparable at 24 months (QT-A: 97.8%, HT-A: 95.6%), 48 months (QT-A: 88.9%, HT-A: 86.7%), 60 months (QT-A: 84.3%, HT-A: 84.4%) and final FU (QT-A: 82.2%, 77.8%). Graft type did not affect the timing of ACL re-rupture or rupture of the contralateral site.

In patients with graft failure, there were no statistically significant differences in mean age at surgery (QT-A: 26.5 ± 11.6 years, HT-A: 23.3

Table 1

Patient characteristics.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>QT-A (n = 45)</th>
<th>HT-A (n = 45)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (female/male)</td>
<td>16/29</td>
<td>16/29</td>
<td>1.0</td>
</tr>
<tr>
<td>Age [y]</td>
<td>28.9 ± 11.6</td>
<td>27.2 ± 12.5</td>
<td>.99</td>
</tr>
<tr>
<td>Height [cm]</td>
<td>172.7 ± 10.0</td>
<td>175.2 ± 6.7</td>
<td>.24</td>
</tr>
<tr>
<td>Body mass [kg]</td>
<td>71.9 ± 13.8</td>
<td>73.6 ± 11.0</td>
<td>.18</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>23.9 ± 2.6</td>
<td>23.9 ± 3.0</td>
<td>.39</td>
</tr>
<tr>
<td>Sports characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proop. Tegner activity score</td>
<td>6 (1)</td>
<td>6 (2)</td>
<td>.15</td>
</tr>
<tr>
<td>High active patients (Tegner ≥ 7)</td>
<td>18 (52.9%)</td>
<td>16 (47.1%)</td>
<td>.21</td>
</tr>
<tr>
<td>Pivoting sports</td>
<td>42 (93.3)</td>
<td>40 (88.9)</td>
<td>.46</td>
</tr>
<tr>
<td>Intraoperative details</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean graft square area [mm²]</td>
<td>41.2 ± 3.9</td>
<td>50.0 ± 11.4</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Partial meniscectomy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial</td>
<td>3 (7.0%)</td>
<td>4 (8.9%)</td>
<td>.76</td>
</tr>
<tr>
<td>Lateral</td>
<td>7 (16.0%)</td>
<td>4 (8.9%)</td>
<td>.49</td>
</tr>
<tr>
<td>Chondromalacia (Grade 1/2/3/4)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Femoral</td>
<td>0/1/3/0</td>
<td>0/5/0</td>
<td>.70</td>
</tr>
<tr>
<td>Tibial</td>
<td>0/3/0/0</td>
<td>0/2/0</td>
<td>.41</td>
</tr>
<tr>
<td>Retropatellar</td>
<td>0/2/0/0</td>
<td>0/1/0</td>
<td>.09</td>
</tr>
<tr>
<td>Collateral ligament laxity (Grade 1/2/3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial</td>
<td>0/2/0</td>
<td>0/0/0</td>
<td>.15</td>
</tr>
<tr>
<td>Lateral</td>
<td>0/0/0</td>
<td>0/0/0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Values reported as mean ± standard deviation; p < .05.
QT-A, quadriceps tendon autograft; HT-A, hamstring tendon autograft; y, year; FU, Follow-up; BMI, Body Mass Index.

a Patients with a meniscus resection >30% were not included in the study.

b reported as median (interquartile range)
differences were observed for age (QT-A: 25.9/C6 13.8 years, p<.05). Other than graft re-rupture or contralateral ACL rupture (p=.63) or graft thickness (mean graft square area: QT-A: 43.6 ± 4.7 mm², HT-A: 48.1 ± 7.9 mm², p=.27). Similar, in patients with contralateral ACL rupture no statistically significant between group differences were observed for age (QT-A: 25.9 ± 13.3 years, HT-A: 27.1 ± 13.8 years, p=.88) or graft thickness (mean graft square area: QT-A: 40.1 ± 2.2 mm²; HT-A: 48.9 ± 8.0 mm², p=.67).

Donor-site morbidity and complications

Statistically 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-A: n = 3, 11.5%; p=.008). The mean hypoesthetic area was 118.4 cm² in the HT-group and 11.5 cm² in the QT-group (p<.001). No or little anterior knee pain was reported with QT-A (mean = 91.6% and 96.7%; p<.001). The mean hypoesthetic area was 118.4 cm² in the HT-group and 11.5 cm² in the QT-group (p<.001). No or little anterior knee pain was reported with QT-A (mean = 91.6% and 96.7%; p<.001).

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 statistically 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, Cavagnac et al. reported statistically 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]. Mosurbes 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, statistically 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 statistical difference between QT-A and HT-A in terms of PROMs.
Table 4: Ratios of graft- and contralateral ACL rupture rates.

<table>
<thead>
<tr>
<th>Complication</th>
<th>Total sample</th>
<th>QT-A</th>
<th>HT-A</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graft rupture rates</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All patients (n = 90)</td>
<td>18 (20)</td>
<td>8 (17.8)</td>
<td>10 (22.2)</td>
<td>.60</td>
</tr>
<tr>
<td>Low active patients (n = 56)</td>
<td>8 (14.2)</td>
<td>4 (11.5)</td>
<td>4 (13.8)</td>
<td>.80</td>
</tr>
<tr>
<td>High active patients (n = 34)</td>
<td>10 (29.4)</td>
<td>4 (22.2)</td>
<td>6 (37.5)</td>
<td>.32</td>
</tr>
<tr>
<td>Pivoting Sports (n = 82)</td>
<td>16 (19.5)</td>
<td>7 (16.7)</td>
<td>9 (22.5)</td>
<td>.58</td>
</tr>
<tr>
<td>Contralateral surgeries</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All patients (n = 90)</td>
<td>17 (18.9)</td>
<td>9 (20)</td>
<td>8 (17.8)</td>
<td>.79</td>
</tr>
<tr>
<td>Low active patients (n = 56)</td>
<td>12 (21.4)</td>
<td>6 (23.1)</td>
<td>6 (20.7)</td>
<td>.83</td>
</tr>
<tr>
<td>High active patients (n = 34)</td>
<td>5 (14.7)</td>
<td>3 (16.7)</td>
<td>2 (12.5)</td>
<td>.73</td>
</tr>
<tr>
<td>Pivoting Sports (n = 82)</td>
<td>15 (18.3)</td>
<td>9 (21.4)</td>
<td>6 (15.0)</td>
<td>.53</td>
</tr>
</tbody>
</table>

* Reported in total number and percentage (%); p < .05.

**High active = Tegner activity score ≥7, low active patients = Tegner activity score ≤6, QT-A, quadriceps tendon autograft; HT-A, hamstring tendon autograft; ACL, anterior cruciate ligament.

The present data extend the current state of knowledge on the short-term results by showing no statistically 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 statistical 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-significant 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, Mourbes et al. [9], Tan et al. [12] and Dai et al. [16] found no statistical 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 [12,23–36]. Lind et al. demonstrated a statistically 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 statistically significantly different SLHT- and DTC- LSI were observed between both groups. However, although not reaching the threshold of statistical 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 statistical 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 and 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. Whereas compared to BPTB-A, statistical non-significant differences with rupture rates ranging between 2.0% and 4.8% were found in the short term [9,44–46]. By contrast, statistically 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%) [40–42,47]. When comparing QT-A and HT-A, recent short-term studies reported no statistical significant differences in graft rupture in adults [1,10,11,13,14], whereas significantly lower reinjury rates were reported for QT-A in children [48]. A recent large registry study from our study group with 875 included QT-A and HT-A patients revealed that graft choice had a statistical significant predictive value for graft rupture with lower re-rupture rates in patients with QT-A (QT-A: 2.8%, HT-A: 4.9%) at 24 month postoperative [14]. Graft rupture rates in high active patients (Tegner activity score ≥7) increased to 5.0% and 11.1% for QT-A and HT-A group respectively [14].

In the present study, no statistically significant difference in graft rupture rate was observed in the mid- to long-term between patients treated with QT-A (17.8%) and HT-A (22.2%). However, it is of particular interest that in high-level athletes (Tegner ≥7) the re-rupture rate increased substantially in the HT-A cohort (37.5%) whereas it rose only slightly in the QT-A (22.2%) group (p = n.s.). These increased rates of graft rupture at mid- to long-term follow-up, particularly in active patients participating in pivoting sports, are higher than in registry studies, but are consistent with rates seen in several previous studies of athletes [49–55]. The present results support these previous findings, demonstrating that high-level pivoting sports and longer follow-up to be major risk factors for graft rupture. No statistically significant group difference in age at time of surgery and graft thickness was observed between patients with graft failure and contralateral ACL injury.

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 statistically significantly different between the two cohorts of the present study. However, patients with HT-A complained statistically 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 [1,7,44]. 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 statistically significantly longer postoperative scar
length 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 tested 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-A or HT-A. However, patients with QT-A have smaller tibial postoperative results and re-rupture rates are similar between patients treated with QT-A and HT-A. Results of primary ACL reconstruction using QT-A and HT-A.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare the following financial interests/personal relationships, which may be considered as potential competing interests: Christian Fink reports a relationship with Karl Storl SE and Co KG that includes consulting or advisory and speaking and lecture fees. Christian Fink reports a relationship with Medacata International SA that includes consulting or advisory, speaking and lecture fees, and travel reimbursements.

Acknowledgment

The authors thank Dr. Caroline Hepperger and all other team members for their constant help with data acquisition and data management.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jisako.2022.08.008.

References


A. Runer et al. ResearchGate


