Comparing Knee Laxity After Anatomic Anterior Cruciate Ligament Reconstruction Using Quadriceps Tendon Versus Semitendinosus Tendon Graft

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Investigation performed at Martin Luther Hospital, Berlin, Germany

Background: The choice of graft in anterior cruciate ligament (ACL) reconstruction is still under discussion. The hamstrings are currently the most used grafts for primary ACL reconstruction in Europe. However, increased interest has arisen in the quadriceps tendon (QT) as an alternative autologous graft option for primary ACL reconstruction.

Purpose: To evaluate knee stability and the subjective outcome after ACL reconstruction using either autologous QT graft in implant-free femoral press-fit fixation technique or semitendinosus tendon (ST) graft.

Study Design: Cohort study; Level of evidence, 2.

Methods: We evaluated 50 patients who underwent ACL reconstruction, including 25 patients who received autologous ipsilateral QT graft (QT group) and 25 patients who received the ipsilateral ST graft (ST group). The follow-up for this prospective comparative study was at least 2 years after surgery, comprising KT-1000 arthrometer testing, pivot-shift test, Knee injury and Osteoarthritis Outcome Score (KOOS), Lysholm score, and rerupture rate.

Results: The mean patient age was 31.72 years (9 women, 16 men) in the QT group and 32.08 years (13 women, 12 men) in the ST group. The mean ± standard deviation postoperative side-to-side difference assessed using KT-1000 arthrometer was 1.56 ± 1.56 mm for the QT group and 1.64 ± 1.41 mm for the ST group, with no significant difference. No significant difference was found on any of the KOOS subscale scores ($P = .694$) or the Lysholm score ($P = .682$). No rerupture or positive pivot-shift test occurred during follow-up. No difference was found in donor-site morbidity between the study groups.

Conclusion: Clinical outcomes were not significantly different between QT and ST grafts in the current study. Thus, the QT may serve as a good alternative graft for primary ACL reconstruction.

Keywords: ACL reconstruction; hamstrings; quadriceps tendon; press-fit technique

The choice of graft in anterior cruciate ligament (ACL) reconstruction is still under discussion. The hamstrings are currently the most used grafts for primary ACL reconstruction in Europe,[27] showing good results regarding revision rates, stability, and patient-reported outcomes (PROs) determined using the Knee injury and Osteoarthritis Outcome Score (KOOS).[15] In contrast to bone–patellar tendon–bone autografts, which have long been considered the gold standard,[11] hamstring tendon (HT) grafts entail reduced incidence of anterior knee pain, kneeling pain, and loss of extension with no difference in stability.[9] Still, a review from 2011, including 19 trials, concluded that using patellar tendon (PT) grafts led to more stable knees but resulted in more frequent anterior knee problems.[19] This finding was confirmed by Persson et al,[21] showing higher revision rates for HT grafts compared with PT grafts in primary ACL reconstruction.

Recently, interest has arisen in the quadriceps tendon (QT) as an alternative autologous graft option for primary

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ACL reconstruction.[5,31] This graft shows morphologic and biomechanical characteristics that produce a suitable graft for ACL reconstruction.[30,33,35]

In a cadaveric study, ACL reconstruction using a QT autograft resulted in similar knee stability compared with using a quadrupled semitendinosus-gracilis tendon autograft.[30] Moreover, recent systematic reviews have demonstrated no differences in stability, functional outcome, overall patient satisfaction, range of motion, and complication rate for QT autografts in comparison with bone–patellar tendon–bone grafts. Furthermore, QT graft resulted in less donor-site morbidity and less anteroposterior (AP) knee laxity compared with HT graft.[4,32] Regarding anterior knee stability, Belk et al[4] found that 2 studies reported QT grafts resulted in less AP knee laxity compared with HT grafts. However, a registry study from Denmark, examining 531 QT grafts, 14,213 HT grafts, and 1835 PT grafts in ACL reconstruction between 2005 and 2017, demonstrated significantly increased anterior laxity for QT grafts compared with HT grafts and a higher rate of positive postoperative pivot-shift tests as well as a higher revision rate for QT (4.7%) in comparison with PT (1.5%) and HT (2.3%) grafts.[17] Given these contrary findings, more studies that examine QT autograft for primary ACL reconstruction are needed.

Currently, the QT graft is mostly used in revision ACL reconstruction,[8,10,25] resulting in similar anterior laxity, rotatory stability, and PROs in comparison with the contralateral semitendinosus-gracilis tendon graft.[10] One benefit of the QT graft is the possibility of a femoral press-fit fixation.[1,7] Biomechanical and clinical studies have shown that the press-fit fixation is a reliable method for femoral graft fixation.[12] The advantage of this fixation technique is the circumferential bone-to-bone contact, which allows better healing of the graft and eliminates the need for a costly implant.[12,13]

The purpose of the current study was to compare anterior laxity, rotatory stability, and PROs after primary anatomic ACL reconstruction using either autologous QT graft, fixed using a femoral press-fit technique, or semitendinosus tendon (ST) graft. We hypothesized that primary ACL reconstruction using a QT graft would result in similar knee laxity and PROs compared with using an ST graft.

METHODS

This study was approved by an ethical review board, and the study protocol was registered with the Deutsches Register Klinischer Studien (German Clinical Trials Register). All patients provided written informed consent. Patient recruitment and baseline data collection were performed at Martin Luther Hospital Berlin.

Patients

A total of 50 patients who underwent primary ACL reconstruction between August 2014 and August 2016 in our hospital, receiving either QT graft (QT group) or autologous ST graft (ST group), were consecutively included according to the inclusion and exclusion criteria (Table 1). Patients aged <18 years were excluded from the study to allow better comparability because in our clinic, we use ST grafts fixed via interference screws only for persons with closed physes. Furthermore, a survey that includes children needs to meet very high requirements set by the ethics commission in Germany, and the study would not have been feasible.

TABLE 1
Inclusion and Exclusion Criteria for Study Patients

Inclusion Criteria	Exclusion Criteria
Primary anterior cruciate ligament rupture	Severe varus or valgus malalignment (>2 cm space between epicondyles for varus, malleoli for valgus)[14]
Anterior cruciate ligament reconstruction using either ipsilateral autologous semitendinosus or quadriceps tendon graft	Additional ligamentous instability (rupture of the medial collateral ligament, lateral collateral ligament, or posterior cruciate ligament)
Operation (based on arthroscopy) performed at Martin Luther Hospital Berlin	Transosseous meniscal repair
Age ≥18 years	Arthroscopy combined with high tibial osteotomy and/or slope correction
	Chondral lesion grade >2 according to the Outerbridge classification

The indications for ACL reconstruction were the same for both treatment groups. These included a radiologically confirmed ACL rupture on preoperative magnetic resonance imaging scans with subjective (giving-way) and passive instability (positive pivot shift; KT-1000 arthrometer side-to-side difference of >4 mm). The decision for either graft was made by the patient after receiving basic information about the tendons and differences in incisions and operative technique.

Surgical Technique

The surgical technique for anatomic ACL reconstruction, with regard to tunnel drilling and tibial fixation, was similar for both groups.[7,23] Femoral fixation was different between the 2 treatment groups (press-fit for QT vs cortical button for ST). All surgeries were performed by the senior author (W.P.). Concomitant injuries of the meniscus were treated when necessary using partial resection or repair based on the location and morphologic characteristics of the injury.

Quadriceps Tendon Harvesting and Femoral Fixation. A 4- to 5-cm longitudinal incision was made using a double knife (Karl Storz) to obtain the quadriceps tendon (Figure 1A). The length of the graft had to be at least 6.5 cm with a 1.5-cm bone block, which was harvested using an oscillating saw and shaped in a conical manner (Figure 1B). The diameter of the graft was 10 mm. This harvested bone block was essential for femoral press-fit fixation, whereas the other end of the tendon was secured using a baseball stitch and connected to an Endotack button (Karl Storz) (Figure 1C).[2,6]

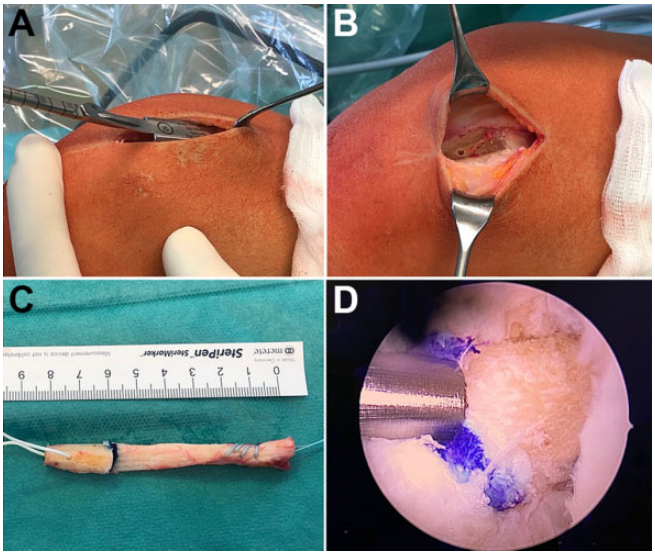

Figure 1. Quadriceps tendon harvesting. (A) A 4- to 5-cm incision is made using a double knife to obtain the quadriceps tendon. (B) A 1.5-cm bone block from the patella is harvested using an oscillating saw and shaped in a conical manner. (C) For femoral press-fit fixation, the total length of the graft including the bone block needs to be about 8 cm. (D) Arthroscopic view of the femoral press-fit fixation.

Semitendinosus Tendon Harvesting and Femoral Fixation. All grafts had an average cross-sectional diameter of 8 to 9 mm. Both the QT and ST grafts were presoaked in a 5 mg/mL vancomycin solution for 5 to 10 minutes.[20,34] An oblique incision approximately 3 to 5 cm medial to the tibial tuberosity was performed to harvest the ST under the sartorius fascia using a tendon stripper (Karl Storz).[27] The graft was quadrupled and looped over a Flipptack (Karl Storz) for femoral fixation; the other end was secured using a baseball stitch and connected to an Endotack button.[24]

Tunnel Preparation. For both treatment groups, the preparation of tunnels was the same. For the femoral side, the medial portal was used. Therefore, the knee was flexed to >110°. The surgeon used an anteromedial portal aimer (Karl Storz) to place a Kirschner wire (K-wire) into the center of the anatomic ACL insertion (landmarks for femoral tunnel placement are the intercondylar line and the cartilage border).[7,26] The position of the K-wire was double-checked via the anteromedial portal.[7,24] Then, in a stepwise manner, the femoral tunnel was drilled until the correct size (graft diameter, 1 mm) was achieved with a depth of 20 to 25 mm. For the last 1 mm of the tibial and femoral tunnels, a dilator (Karl Storz) was used. To assist the press-fit fixation of the QT bone block, a pestle was used (Figure 1D).

For the tibial side, the right tunnel aperture was identified, and a guidewire was placed in the middle of the ACL insertion. If the position was correct, boring was performed according to the diameter of the graft.

Tibial Fixation. Hybrid fixation was used on the tibial side for all patients. The ST or QT graft was first secured using a poly (D,L-lactic acid) interference screw (Mega Fix-P; Karl Storz) with a length of 2.3 cm and a diameter 1 mm smaller than the diameter of the tunnel. The grafts were secured distally and tied over the button using nonresorbable polyester sutures (No. 2 FiberWire; Arthrex). The correct position of femoral and tibial fixation was double-checked after the operation via radiography.

Concomitant Surgery. Suture repair (Fast-Fix; Smith & Nephew) and partial resection were undertaken for concomitant meniscal injuries, and debridement was conducted for cartilage damage with an International Cartilage Regeneration & Joint Preservation Society grade >2.

Rehabilitation. Both groups underwent the same rehabilitation protocol. Patients were permitted partial weightbearing for 2 weeks and a range of motion of 90°. Crutches were used for the period of partial weightbearing. A brace was used for 6 weeks. After 2 weeks, closed chain exercises were allowed. If meniscal repair was performed, the range of motion was restricted to 60° of flexion for the first 4 weeks, including partial weightbearing. After 8 weeks, recreational activities such as cycling or treadmill training were allowed; sport-specific training was allowed after 6 months at the earliest, based on consultation with the surgeon.

Follow-up Evaluation

The minimum follow-up was 2 years. The primary outcome measure was passive ligamentous AP laxity evaluated using the KT-1000 arthrometer (MEDmetric) at an applied force of 134 N. Secondary outcome measures were pivot-shift test according to the International Knee Documentation Committee 2000 examination form (equal, glide +, clunk ++, and gross +++) and postoperative clinical scores (KOOS subscales and Lysholm score). Both of these scoring systems have been validated for the German language.[18,28] Patient satisfaction in terms of donor-site pain was measured using a 5-point Likert scale: poor, average, good, very good, or excellent.

Statistical Analysis

According to a sample size calculation, 25 patients were needed in each group to obtain equality in the KT-1000 arthrometer measurements (primary outcome), providing a power of 80%. The enrollment of patients was stopped after the target number of participants was reached. The chi-square test was used to analyze sex distribution. The Kolmogorov-Smirnov and Shapiro-Wilk tests were used to test the parameters for normal distribution (age, AP laxity, KOOS, Lysholm score). The Mann-Whitney U test was used to analyze the results of postoperative laxity, Lysholm score, and KOOS subscales. A t test was used for the preoperative laxity measurement and KOOS to assess quality of life. The Fisher exact test was used to assess the results of the pivot-shift tests. The significance level was set at $P \leq .05$ for all tests (SPSS Version 25.0.0.0, IBM).

TABLE 2
Patient Characteristics

	Quadriceps Tendon Group (n = 25)	Semitendinosus Tendon Group (n = 25)
Age at surgery, y, mean ± SD	31.72 ± 15.24	32.08 ± 12.19
Sex, female:male, n	9:16	13:12
Concomitant meniscal injuries, No. of patients		
Medial meniscus	8	6
Lateral meniscus	5	3
Chondral lesions, n[a]	7	6
Grade 1	2	3
Grade 2	4	2
Grade 3	1	1
Grade 4	0	0

[a]Graded according to the International Cartilage Regeneration & Joint Preservation Society classification.

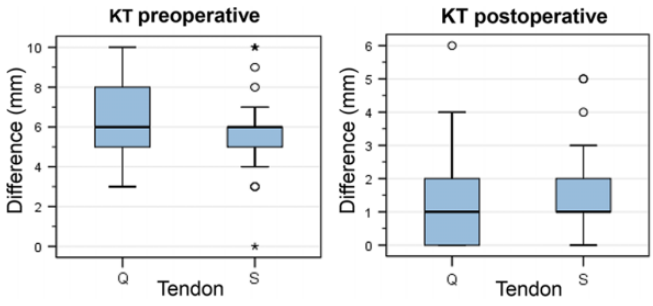

Figure 2. Results of KT-1000 arthrometer (MEDmetric) anteroposterior laxity measurements between the quadriceps (Q) and semitendinosus (S) tendon groups. No significant differences were seen between groups pre- or postoperatively. The horizontal line represents the mean, the box represents the upper and lower quartiles, and the vertical lines represent the minimum and maximum values. Circles and asterisks indicate outliers.

RESULTS

Patient Characteristics

The characteristics of all included patients are presented in Table 2. No significant difference was found between study groups regarding sex ($P = .254$) or age distribution ($P = .655$).

Concomitant injury of the knee joint (besides ACL rupture) was found in 13 patients in the QT group and 9 patients in the ST group (Table 2). Suture repair was required in 3 medial and 2 lateral menisci in the QT group and in 1 medial and 1 lateral meniscus in the ST group, and partial resection was undertaken for 5 medial and 3 lateral menisci in the QT group and 5 medial and 2 lateral menisci in the ST group. We found no difference in the magnitude of meniscal deficiency between the groups.

Articular cartilage damage was present in 7 patients in the QT group and 6 patients in the ST group, and debridement was necessary for 5 patients in the QT group and 3 patients in the ST group. No difference was seen in the incidence of cartilage damage in the groups. Altogether, the medial compartment was involved in 8 patients; the lateral compartment, in 5 patients; and the patellofemoral joint, in 4 patients (Table 2).

Primary Outcome Measure

The mean ± standard deviation (SD) preoperative AP laxity was 6.48 ± 2.00 mm for the QT group and 5.84 ± 2.34 mm for the ST group. The value decreased postoperatively to 1.56 ± 1.56 mm for the QT group and 1.64 ± 1.41 mm for the ST group. No significant difference was found in AP laxity between the 2 groups pre- or postoperatively ($P = .380$ and .694, respectively) (Figure 2).

Secondary Outcome Measures

No patients had a positive pivot-shift test postoperatively. Regarding the KOOS subscales, no significant difference could be detected between the QT and ST groups. The mean KOOS scores were not significantly different between the QT and ST groups for Pain (91.56 vs 87.08, respectively), Symptoms (82.52 vs 82.32), Activities of Daily Living (96.24 vs 90.12), Sports (80.80 vs 79.60), or Quality of Life (70.56 vs 70.88) (Figure 3). In addition, no significant difference was seen in the postoperative Lysholm score for the 2 treatment groups: 88.60 ± 11.78 for the QT group and 86.28 ± 15.72 for the ST group ($P = .682$) (Figure 4).

As for donor-site morbidity, 22 patients (88%) in the QT group and 21 patients (84%) in the ST group reported "excellent" (5/5) or "very good" (4/5) results, including an irritation of skin sensitivity around the knee or anterior knee pain 2 years after surgery.

Complications

In the QT group, 2 patients experienced extension deficit postoperatively; of these, 1 patient was treated nonoperatively using physical training, and the other patient underwent repeated arthroscopy for cyclops lesion. In the ST group, 1 case of extension deficit was detected and treated operatively (cyclops lesion). No rerupture occurred during follow-up in either group, and no infections were documented.

DISCUSSION

The main finding of the present study is that primary anatomic ACL reconstruction using QT graft results in similar knee stability and PROs when compared with ST graft.

The optimum graft for anatomic ACL reconstruction is still under discussion. The graft should have proper biomechanical characteristics and restore the knee kinematics close to the native state. However, low donor-site morbidity, early graft incorporation, and good surgical handling are required.[29]

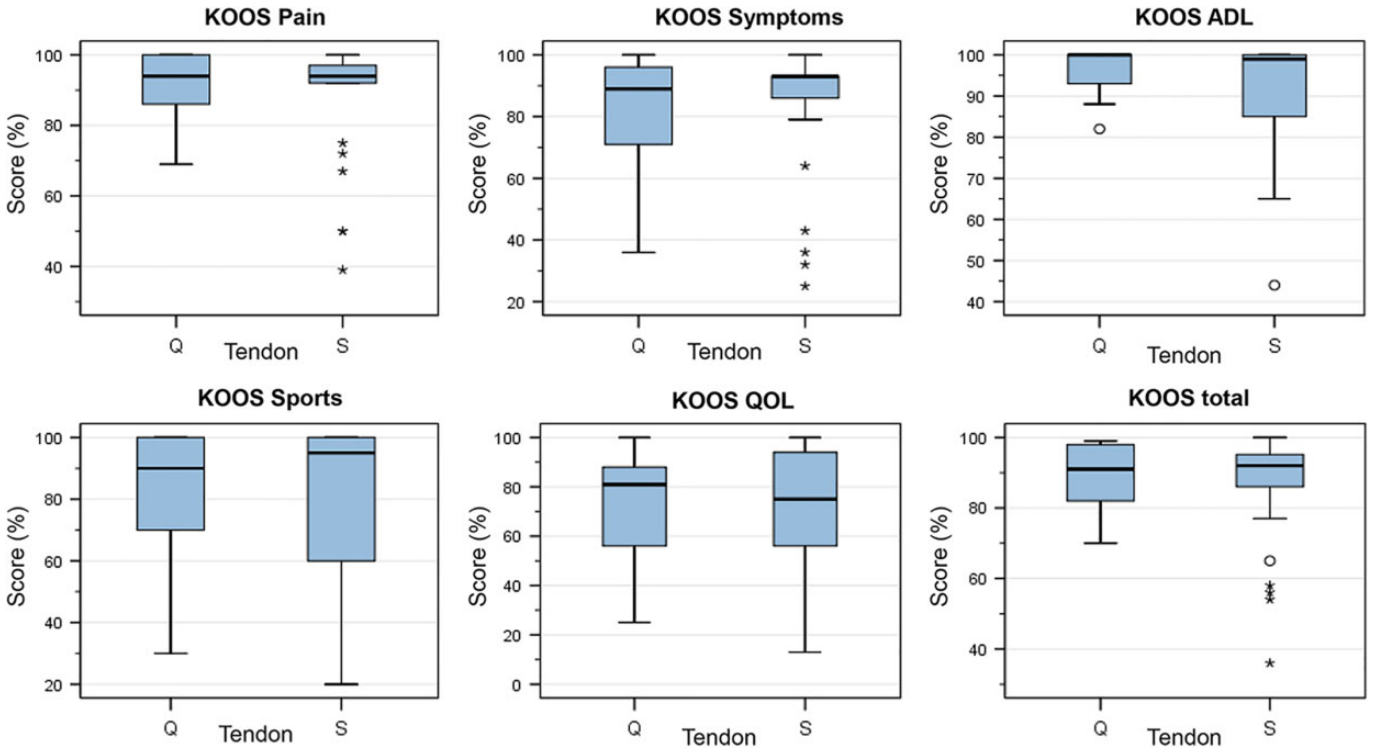

Figure 3. Results for Knee injury and Osteoarthritis Outcome Score (KOOS) subscales for the quadriceps (Q) and semitendinosus (S) tendon groups. No significant differences were seen between groups on any KOOS subscale. The horizontal line represents the mean, the box represents the upper and lower quartiles, and the vertical lines represent the minimum and maximum values. Circles and asterisks indicate outliers. ADL, Activities of Daily Living; QOL, Quality of Life.

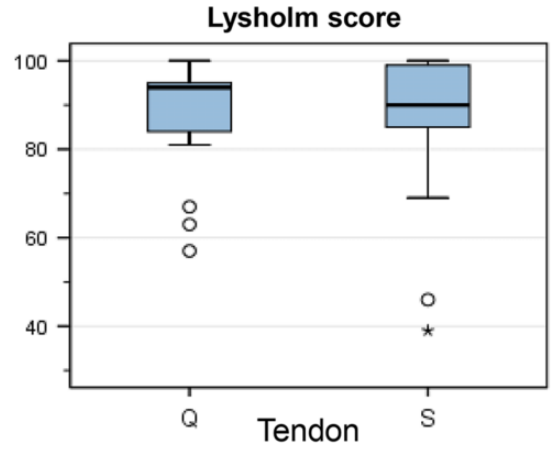

Figure 4. Lysholm scores for the quadriceps (Q) and semitendinosus (S) tendon groups. No significant differences were seen in scores between the groups. The horizontal line represents the mean, the box represents the upper and lower quartiles, and the vertical lines represent the minimum and maximum values. Circles and asterisk indicate outliers.

Consistent with the results of the present study, a biomechanical study has shown that ACL reconstruction using a QT graft restored AP laxity and rotatory stability to levels similar to those achieved using a semitendinosus-gracilis tendon graft.[30] An advantage of the QT graft for anatomic ACL reconstruction is the opportunity to harvest a full-thickness graft as well as a partial-thickness tendon graft with or without an additional bone block.[5] So far, several clinical studies have demonstrated good to excellent clinical outcome scores after anatomic ACL reconstruction using QT graft.

A midterm follow-up study showed satisfactory results in ACL reconstruction using a QT autograft, with reduced donor-site morbidities.[16] The investigators evaluated 67 patients with a mean follow-up of 41 months. The Lysholm score significantly improved, from 71 preoperatively to 90 postoperatively; extension peak torque of the quadriceps muscle recovered to 89% of that of the contralateral knee at 2 years after surgery; and the patellar position in terms of congruence angle and Insall-Salvati ratio did not show any significant change. Barié et al[3] evaluated results of ACL reconstruction using a QT autograft and press-fit fixation in 112 patients with a mean follow-up of 12.4 months; good to excellent results were found in 81% of patients according to the Lysholm score and 86% of patients according to the International Knee Documentation Committee score. Furthermore, KT-1000 arthrometer testing showed that the AP translation was <3 mm in 83% of those patients. We also found excellent AP translation using the QT graft, which was not different from that using the standard ST graft.

Only a few studies have examined outcomes after ACL reconstruction using QT graft versus HT graft. In one of the first such studies, Runer et al[29] compared QT versus HT autografts for primary ACL reconstruction. A total of 80 patients were evaluated after 6, 12, and 24 months using subjective and functional PRO scores. No significant difference between the groups could be found. Lind et al[17] came to the same conclusion, comparing QT versus ST grafts in a randomized controlled trial. After 2 years of follow-up, with 99 patients included, QT graft did not result in inferior subjective outcomes compared with ST graft, knee stability was similar in both groups, and donor-site morbidity was lower in the QT group. Both studies used a cortical button or a titanium interference screw for femoral graft fixation.

The present study is the first to compare ACL reconstruction using QT autograft with implant-free press-fit femoral fixation versus conventional ST graft reconstruction. Our results showed that press-fit fixation is a safe femoral fixation method for autologous QT graft. The advantage of the press-fit technique is that no implants are required for fixation. This eliminates implant-specific side effects and costs,[3] although the bone plug might pull out of the femoral tunnel if the technique is not performed precisely. With regard to the general use of QT grafts for primary ACL reconstruction, the current study confirms the findings of previous studies. Comparing QT and ST grafts in a total of 50 patients, this study found no significant differences regarding clinical outcomes, assessed using subjective parameters (Lysholm, KOOS), or objective outcomes (AP laxity).

The choice of graft should be considered individually for each patient. A possible indication for the use of a QT autograft in primary ACL reconstruction could be concomitant acute or chronic medial knee instabilities. Using a QT graft in ACL reconstruction maintains the function of the ipsilateral hamstring muscles, which play an important role as relevant dynamic joint stabilizers for valgus moments. This is especially relevant for knees with medial collateral ligament deficiency.[11] Other patients who might benefit from QT grafts are competitive athletes in sports that entail valgus loading,[2] such as judo.

One possible limitation of this study is the small cohort and the lack of randomization. However, our power analysis showed that the planned group size was suitable for distinguishing group differences in our primary outcome parameter (AP laxity). Larger collectives are certainly necessary for some questions, such as revision rates. The choice of graft was made by every patient after careful discussion of the advantages and disadvantages. In terms of cosmetics, different types of scars depending on the withdrawal of the graft might have influenced the decision for either transplant, which might explain the higher rate of women in the ST group (Table 2). However, in contrast to randomized controlled studies, this study design is more similar to the normal clinical situation. A well-known disadvantage of randomized controlled trials is selection bias because some patients reject participation in the study, fearing they might receive a graft of poorer quality. For this reason, it is often not possible to generalize the results of these studies.[22] Another limitation is that no objective data regarding the patients' pre- and postoperative sports levels were obtained.

CONCLUSION

ACL reconstruction using the QT graft with an implant-free femoral press-fit fixation showed good clinical outcomes, similar to those of the ipsilateral ST graft in terms of knee laxity and PRO scores. Thus, the QT graft may be a good alternative for primary ACL reconstruction.

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