Is Quadriceps Tendon Autograft a Better Choice Than Hamstring Autograft for Anterior Cruciate Ligament Reconstruction?

A Comparative Study With a Mean Follow-up of 3.6 Years

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Background: The quadriceps tendon (QT) autograft is known as an effective graft for anterior cruciate ligament (ACL) reconstruction and shows a similar functional outcome to the bone-patellar tendon-bone (BPTB) in randomized controlled trials, with a lesser incidence of complications. Up until now, only 2 studies have compared QT to hamstring tendon (HT) autograft.

Hypothesis: The functional outcomes of the QT technique are at least as good as those of the HT technique, with the same morbidity.

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

Methods: Ninety-five patients underwent isolated ACL reconstruction between January 1 and December 31, 2012. Fifty underwent ACL reconstruction with the QT and 45 with the HT. The same surgical technique, fixation method, and postoperative protocol were used in both groups. The following parameters were evaluated: surgical revisions, functional outcome (Lysholm, Knee injury and Osteoarthritis Outcome Score [KOOS], Tegner, subjective International Knee Documentation Committee), joint stability (KT-1000, Lachman, pivot shift), anterior knee pain (Shelbourne-Trumper score), and isokinetic strength. Descriptive statistics are presented for these variables using the Student *t* test.

Results: Eighty-six patients (45 QT, 41 HT) were reviewed with a mean follow-up of 3.6 ± 0.4 years; minimum follow-up was 3 years. There were 4 reoperations in the QT group (including 1 ACL revision) and 3 in the HT group (including 2 ACL revisions) ($P > .05$). The Lysholm (89 ± 6.9 vs 83.1 ± 5.3), KOOS Symptoms (90 ± 11.2 vs 81 ± 10.3), and KOOS Sport (82 ± 11.3 vs 67 ± 12.4) scores were significantly better in the QT group than in the HT group. In terms of stability, the mean side-to-side difference was 1.1 ± 0.9 mm for the QT group and 3.1 ± 1.3 mm for the HT group based on KT-1000 measurements ($P < .005$). The negative Lachman component was higher in the QT group than in the HT group (90% vs 46%, $P < .005$). There was a trend for the negative pivot-shift component to be higher in the QT group than in the HT group (90% vs 64%, $P = .052$). The Shelbourne-Trumper score was the same in both groups. There was no difference between groups in terms of isokinetic strength.

Conclusion: The use of a QT graft in ACL reconstruction leads to equal or better functional outcomes than does the use of an HT graft, without affecting morbidity.

Keywords: anterior cruciate ligament; quadriceps tendon; sports medicine

Several types of grafts have been used to restore knee stability after an anterior cruciate ligament (ACL) tear.[12] Good clinical results have been reported using autografts from the extensor mechanism and the hamstring tendon (HT).[§]

Several studies have compared the bone–patellar tendon–bone (BPTB) technique to the quadriceps tendon (QT) technique.[11,13,20-22,24,25,35] No differences between the grafts in residual laxity and patient-reported outcomes

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§References 2, 4, 8, 9, 15, 16, 18, 32, 47, 50.

(PROs) have been reported.[11,20] The QT technique appears to lead to better outcomes in terms of extensor mechanism strength (less deficit at 6 months postoperative),[36] likely due to the significantly lower incidence of anterior knee pain after QT.[22,24]

To our knowledge, only 2 published studies have compared QT and HT autografts.[22,44] In Sofu et al,[44] 23 ACL reconstruction procedures were performed using the QT and 21 using the HT. The patients were reviewed after 3 years, and no significant differences were found in the PROs (Tegner and Lysholm scores). However, residual laxity (using the KT-2000 arthrometer) was less in the HT than in the QT patients. More than 3-mm side-to-side difference in laxity was found in 52.1% of QT patients and 9.6% of HT patients. These results differ from published results on residual laxity after ACL reconstruction using QT or HT.‖ Lee et al[22] recently published a comparison between single-bundle ACL reconstruction using the QT and double-bundle ACL reconstruction using the HT. But since that study compared 2 different reconstruction techniques, it was impossible to determine which effects were due to the graft itself.

We hypothesized that the functional outcomes of the QT technique were at least as good as those of the HT technique, with the same morbidity. The goal of our study was to compare the outcomes (reoperation rate, stability, functional scores, anterior knee pain, and isokinetic strength) of these 2 techniques.

METHODS

Patients

This was a cohort study approved by our institutional review board.

Between January 1 and December 31, 2012, 95 patients underwent isolated ACL reconstruction at our facility by 2 senior surgeons who specialized in this procedure. Patients were included in this study if they met the following criteria: (1) older than 18 years of age, (2) primary single-bundle ACL reconstruction, (3) isolated ACL injury with no concomitant ligament injury, (4) unilateral ACL injury, (5) no previous surgery to the affected knee, (6) no chondral lesion worse than Outerbridge grade 2,[34] (7) intact or partially resected meniscus (meniscal suture repairs were excluded), (8) agreed to undergo a follow-up evaluation on February 1, 2016. Patients who did not meet these inclusion criteria were excluded.

Eight-six patients were enrolled on February 1, 2016; there were 9 patients lost to follow-up (5 QT and 4 HT). The average follow-up was 3.6 ± 0.4 years, and the minimum follow-up was 3 years. The 2 cohorts were comparable in terms of their characteristics (Table 1).

TABLE 1
Characteristics for Both Groups[a]

Type of Graft	QT (n = 45)	HT (n = 41)	*P*
Age	32.1 ± 8	30.9 ± 9	.82
BMI	22.4 ± 3.1	24.3 ± 2.9	.26
Sex ratio (male/female)	55/45	58/42	.37
Follow-up	3.4 ± 0.6	3.8 ± 0.9	.76
Tegner preoperative	7 ± 1.6	6.8 ± 1.8	.56
Time between injury and surgery, mo	10.2 ± 8	11.9 ± 9	.76

[a]Data are means ± SD. Comparison made using the Student *t* test. BMI; body mass index; HT, hamstring tendon; QT, quadriceps tendon.

Surgical Procedure

The patients underwent ACL reconstruction using the QT or HT, depending on which surgeon was treating them. In their daily practice, one surgeon always performed ACL reconstruction with a QT and the other always used HT. This was the only factor taken into account when selecting one graft over the other.

The type of anesthesia was determined based on patient preference. The patient was placed supine on the operating table with the operated knee in 90° of flexion. A tourniquet was applied in all cases (250 mm Hg). The knee was cleaned with betadine solution and covered with disposable draping.

For quadriceps graft harvesting, a midline skin incision was done from the proximal pole of the patella extending proximally to provide adequate exposure. A central strip of the QT was harvested measuring 8 to 10 mm in width and 70 to 90 mm in length (with bone block), along with a 20-mm bone block from the proximal patella. An oscillating saw was used to create the patella bone block. The cut surface of the tendon was then closed with interrupted sutures of No. 2 Vicryl. The bone block defect in the proximal patella was filled with bone debris generated during bone tunnel drilling. Two holes were drilled in the bone end of the graft to pass a No. 5 Ethibond suture. The tendon of the graft was whipstitched using 2-0 Vicryl. A detailed description of our QT method for ACL reconstruction has been published.[30]

For hamstring graft harvesting, a vertical skin incision was made over the anteromedial aspect of the proximal tibia over the pes anserinus. Both the gracilis and semitendinosus were harvested using an open tendon stripper. The distal attachments of the tendons were left intact. The tendons were then folded to form a 4-strand hamstring graft. Both ends were secured with whipstitch suture using No. 2 Vicryl.

The intra-articular surgical technique was identical: The single femoral tunnel was defined using the outside-in method closer to the anteromedial footprint. It was drilled with a cannulated reamer in a diameter corresponding to the width of the harvested graft. The tibial tunnel was created with a tibial jig set at 50° and then drilled with a cannulated reamer. Tibial remnants of the ACL stump were preserved as much as possible during tunnel preparation, which was drilled at the footprint of the native ACL. The mean diameter of the QT graft was 9 ± 0.62 mm, and the mean diameter of the HT graft was 7.8 ± 0.79 mm.

‖References 1, 3, 5, 20, 22, 24, 28, 29, 32, 33, 41.

TABLE 2
Comparison of Postoperative Functional Scores[a]

	All (n = 83)	QT (n = 44)	HT (n = 39)	*P*
Lysholm	86.4 ± 6	89 ± 6.9	83.1 ± 5.3	**<.05**
KOOS				
Pain	89 ± 6.9	90 ± 6.8	86 ± 7.2	.23
Symptoms	85 ± 10.7	90 ± 11.2	81 ± 10.3	**.017**
ADL	93 ± 5.2	95 ± 5.3	90 ± 4.9	.08
Sport	73 ± 14	82 ± 11.3	67 ± 12.4	**.003**
QOL	79 ± 12.3	78 ± 14.7	79 ± 10.3	.22
Tegner				
Last follow-up	5.7 ± 1.5	5.9 ± 1.4	5.6 ± 2	.42
Difference in preoperative	1 ± 1.4	1 ± 1.05	1.2 ± 1.8	.24
IKDC subjective	83 ± 15	84 ± 13	80 ± 17	.20

[a]Values are given as mean ± SD. Boldface indicates statistically significant difference. ADL, activities of daily living; HT, hamstring tendon; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; QOL, quality of life; QT, quadriceps tendon.

In both methods, the graft was then passed through the tibial tunnel, across the joint, and into the femoral tunnel. The femoral (tendinous) part of the graft was fixed first using an interference screw (MILAGRO; DePuy Synthes). After tensioning the graft several times, the tibial part (with the bone block) of the graft was then fixed using an interference screw (MILAGRO) with the knee in 30° of flexion, external rotation, and posterior drawer application.

Partial weightbearing (15-20 kg) was allowed for the first 4 weeks, followed by full weightbearing afterward. The sutures were removed on postoperative day 12. All patients underwent the same rehabilitation regimen. A booklet was given to all patients to ensure that they all followed the standardized rehabilitation regimen.

Outcome Measures

Functional outcomes consisted of the Lysholm,[26] Tegner,[48] Knee injury and Osteoarthritis Outcome Score (KOOS),[39] and International Knee Documentation Committee subjective[14] score at the last follow-up. Anterior knee pain was quantified using the Shelbourne-Trumper[42] score at the last follow-up; this questionnaire is designed to determine the incidence and severity of anterior knee pain as it relates to sporting or daily living activities, prolonged sitting, stair climbing, and kneeling.

Knee stability was measured at the last follow-up using the Lachman test, a pivot-shift test, and a manual maximum KT-1000 anterior drawer (MEDmetric). The Lachman results were graded as 0 (<3 mm), 1 (3-6 mm), 2 (6-10 mm), or 3 (>10 mm).[14] The pivot shift was graded as 0 (absent), 1 (subluxation), 2 (jump), or 3 (transient lock).[14] Anterior translation was measured using the KT-1000 arthrometer with the knee in 20° of flexion. All knee stability measurements were done by the same observer who was not blinded to the procedure.

The number and types of reoperations were recorded for each group.

Quadriceps (knee extension) and hamstring (knee flexion) isokinetic strength were assessed at 90 deg/s using the Con-Trex Multi Joint System (Con-Trex). After 1 minute of rest, 5 maximal extension-flexion efforts were performed at 90 deg/s. Subjects were encouraged to make a maximal effort. The uninjured knee was tested first, and then the same procedure was performed with the injured one. Quadriceps and hamstring isokinetic peak torques were compared with the uninjured leg, and the hamstring/quadriceps muscle balance was calculated. At our facility, this test is typically performed after about 6 months postoperatively to determine if patients are ready to return to sports.

We also measured patient satisfaction of postoperative result on a scale of 0 (not satisfied at all) to 10 (very satisfied).

Statistical Analysis

The statistical analysis was performed with Excel 2011 (Microsoft Corp) and XLSTAT 2011 (Addinsoft SARL) software packages. The normal distribution of the measured variables was verified using the Shapiro-Wilk test, and the homogeneity of variances was verified using Fisher's *f* test and Levene's test to ensure the conditions had been met for parametric testing. The significance threshold was set at $P < .05$. The descriptive analysis consisted of mean, median, and SD values. A comparative analysis was performed using the paired Student *t* test or chi-square test (nominal and ordinal scale data: ligament stability grades).

RESULTS

The Lysholm (89 ± 6.9 vs 83.1 ± 5.3; $P = .008$), KOOS Symptoms (90 ± 11.2 vs 81 ± 10.3; $P = .017$), and KOOS Sport (82 ± 11.3 vs 67 ± 12.4; $P = .003$) functional scores were significantly better in the QT group than in the HT group (Table 2 and Figure 1). There was no statistically significant difference in the other functional outcomes between the groups.

The Lachman and pivot-shift grades for the 2 groups are listed in Table 3. There was a significant difference between

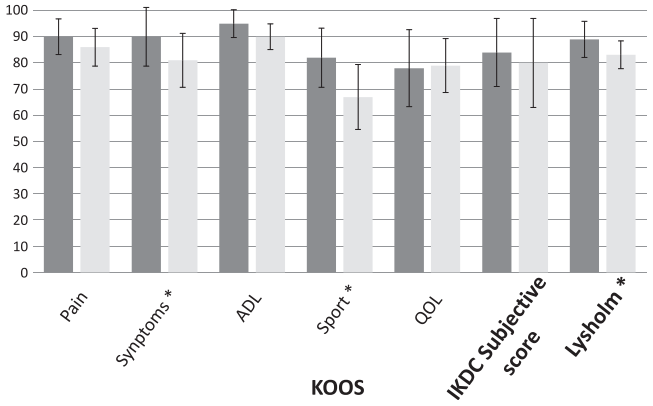

Figure 1. Mean and SD values for the patient-reported outcomes. *Statistically significant difference between groups. HT, light gray bars; QT, dark gray bars. ADL, activities of daily living; HT, hamstring tendon; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; QOL, quality of life; QT, quadriceps tendon.

the 2 cohorts in the distribution of the Lachman grades, with 93% of QT patients and 46% of HT patients having Lachman grade 0. There was a trend for the negative pivot-shift component to be higher in the QT group than in the HT group (93% vs 64%, $P = 0.052$). Anterior translation measured on the KT-1000 arthrometer found a side-to-side difference of 2.01 ± 1 mm in the entire study population (Table 4). The side-to-side difference in the QT group was 1.1 ± 0.9 mm and 3.1 ± 1.3 mm in the HT group ($P = .037$).

In the QT group, there was 1 rerupture after a new sport injury (contact sport) after 3.7-year follow-up, and there were 3 reoperations: 1 for a cyclops lesion (at 5.7 months), 1 to remove the femoral screw (at 13.1 months), and 1 for a grade 3 cartilaginous injury of the medial condyle (microfracture at 25.2 months).

In the HT group, there were 2 instances of graft rupture: 1 at 9.3 months related to undiagnosed posterolateral instability and 1 at 15.3 months after a new sports-related knee injury. One patient underwent reoperation at 15.3 months for arthroscopic arthrolysis.

The Shelbourne-Trumper score was 85.6 ± 4.1 in the overall population. It was 82.3 ± 4.3 in the QT group and 87.9 ± 3.4 in the HT group ($P = .17$). The isokinetic strength was similar between the 2 groups (Table 5). The mean satisfaction score was 8.3 ± 1.9 in the QT group and 7.3 ± 2 in the HT group ($P = .05$).

DISCUSSION

Our hypothesis was confirmed. Our study's main finding was that the functional outcomes (residual laxity, PRO) after 3.6-year follow-up were equal or better in the patients undergoing ACL reconstruction with the QT than with the HT. Morbidity was not statistically different between the 2 patient cohorts in terms of isokinetic strength and anterior knee pain.

TABLE 3
Comparison of Postoperative Variables Related to Stability[a]

	All	QT (n = 44)	HT (n = 39)	*P*
Lachman				**<.005**
0	59 (71)	41 (93.1)	18 (46.2)	
1	21 (25.3)	4 (6.9)	17 (43.6)	
2	4 (4.7)	0	4 (10.2)	
Pivot shift				.052
0	66 (79.5)	41 (93.1)	25 (64.1)	
1	14 (16.8)	4 (6.9)	10 (25.6)	
2	4 (4.7)	0	4 (10.2)	

[a]Values are given as n (%). Boldface indicates statistically significant difference. HT, hamstring tendon; QT, quadriceps tendon.

TABLE 4
Comparison of Postoperative Side-to-Side Differences in Stability[a]

	All	QT (n = 44)	HT (n = 39)	*P*
Mean, mm	2.01 ± 1.0	1.1 ± 0.9	3.1 ± 1.3	**.037**
No. of patients with > 3-mm difference	26	5	21	**<.05**

[a]Values are given as mean ± SD. Boldface indicates statistically significant difference. HT, hamstring tendon; QT, quadriceps tendon.

Lee et al[22] reported results of a cohort study comparing double-bundle HT and bone-QT with 2-year follow-up. They included both isolated ACL and ACL associated with meniscal lesions (47% in the hamstring group and 62.5% in the quadriceps group). Our results are not very different from those of Lee et al. The only difference between the 2 studies concerns the laxity measured with KT-1000 arthrometer (QT: 1.1 ± 0.9 mm for the current study vs 2.1 ± 1.9 mm for Lee et al; HT: 3.1 ± 1.3 mm for the current study vs 1.9 ± 1.8 mm for Lee et al), and the pre- and postoperative Tegner scores are higher in our population. For the other factors, our results are similar (PRO-isokinetic test) to those of Lee et al, although we cannot compare the reoperation and rerupture rate since they did not report it in their study. To assess graft performance, our study design was better suited than previous studies: (1) Our patients were recruited consecutively over a 1-year period; (2) the same surgical technique was used in both groups, with the same method of fixation; (3) only patients with an isolated ACL injury were included in our study. It has been shown that concomitant meniscal injury greatly influences ACL reconstruction outcomes.[49]

Our results differed radically from those published by Sofu et al.[44] Contrary to our study, Sofu et al used different fixation methods for the 2 groups (screw for QT, transfemoral fixation for HT). The mean functional outcome scores were not given in the Sofu et al article, making a direct comparison with our results impossible. The PRO scores reported here are consistent with previously published results for both graft types.[3,27,38] The clinical laxity results (Lachman, pivot shift) reported here are also consistent with previously published results for ACL reconstruction

TABLE 5
Comparison of Postoperative Isokinetic Testing Results[a]

	All (n = 77)	QT (n = 40)	HT (n = 37)	*P*
Time after surgery, mo	6.3 ± 1.4	6.4 ± 1	6.3 ± 1.4	.37
Side-to-side difference, %				
Extension	24.5 ± 11.7	26.3 ± 11.3	23.1 ± 12.6	.61
Flexion	12.6 ± 15.3	8.2 ± 17.3	17.4 ± 20.3	.09
HT-QT ratio	69.2 ± 7.0	68.7 ± 6.8	69.7 ± 7.2	.6

[a]Values are given as mean ± SD. HT, hamstring tendon; QT, quadriceps tendon.

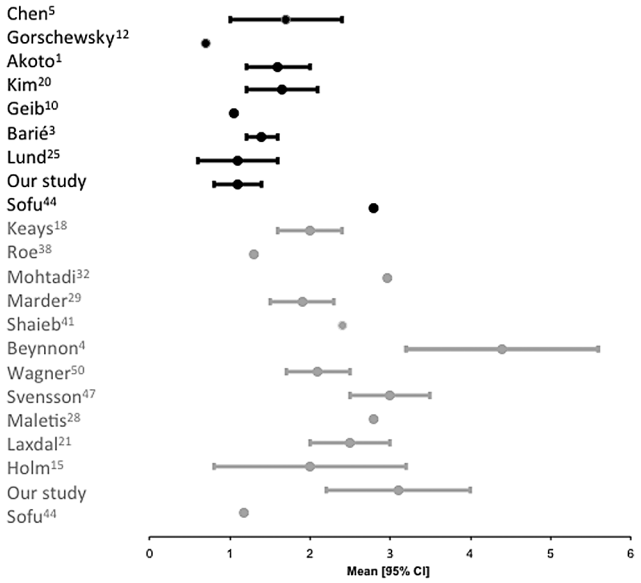

Figure 2. Published values for residual laxity measured with the KT-1000. Black bars correspond to QT grafts and gray bars to HT grafts. The dot corresponds to the mean value; 95% CIs are shown if given in the publication. HT, hamstring tendon; QT, quadriceps tendon.

using HT and QT grafts.[3,16,38] For example, after 5-year follow-up, Karikis et al[17] found that 50% of patients had a negative Lachman result in their single-bundle HT group, while we found 46%. As for the pivot shift, there was a strong trend toward better results in the QT group (P = .052). Including a larger number of patients may have made this finding statistically significant. Our findings for residual laxity were also consistent with published data (Figure 2). There is significant variation in side-to-side laxity within and between various published studies (Figure 2) when ACL reconstruction is performed with the HT method; there is less variability when the QT method is used.

Currently, the QT is the least used autograft for ACL reconstruction.[43] In 2010, a review of graft choices showed that 2.5% of all anatomic ACL reconstructions were performed with a QT autograft.[49] Recently, during an international meeting on anatomic ACL reconstruction, Middleton et al[31] surveyed 35 surgeons from more than 20 countries; these expert surgeons averaged more than 2100 ACL reconstructions over their careers. Use of the QT autograft represented 11% of all their ACL reconstruction cases. However, our study and several studies have shown excellent clinical results and low morbidity with the use of the QT autograft,[7,10] and a recent systematic review has confirmed that use of the QT for ACL reconstruction was safe, reproducible, and versatile.[43]

We recommend harvesting the graft from the thicker, medial portion of the QT,[35,37] but the lateral portion should be used if a longer graft is needed.[23,51] We never harvest a full-thickness graft for primary ACL reconstruction. This type of harvesting is indicated only for posterior cruciate ligament surgery or ACL revision.[6,19,34,44-46] We believe it is essential to preserve the deepest layer and to avoid opening the suprapatellar bursa; in the same vein, we carefully reclose the tendon defect. We believe that this reduces the risk of fluid leakage during the arthroscopy and prevents the development of adhesions between the QT and suprapatellar bursa. Contrary to most other authors,[1,3,10,40] we implant the bone portion of the graft in the tibial tunnel to prevent tunnel widening and the lower bone density of the tibial epiphysis.

Our study has certain limitations. First, 10% of patients were lost to follow-up after 3.6 years. This is likely due to the high population turnover in our city, which government sources estimate at 20% yearly. Second, the lack of preoperative data made it impossible to assess the difference the surgery made in the patients' progress. It also made it impossible to determine whether the groups were comparable on this aspect, which brings up the possibility of recruitment bias. However, the patients in the 2 groups came from the same region, had the same demographics, were operated on using the same technique (in particular, the same fixation method), and underwent the same rehabilitation protocol; only the type of graft used differed. This allowed us to compare 2 similar groups that differed only in terms of the type of graft used. Note that an assessment bias is possible because the observer was not blinded to the procedure. Moreover, a performance bias is also possible, as each procedure was done by a different surgeon.

This study reveals that use of a QT graft in ACL reconstruction leads to equal or better functional outcomes than does the use of an HT graft, without affecting morbidity. QT is a suitable autograft for ACL reconstruction.

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