Original Article

No Difference in Complication Rates or Patient-Reported Outcomes Between Bone—Patella Tendon—Bone and Quadriceps Tendon Autograft for Anterior Cruciate Ligament Reconstruction

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Purpose: To compare subjective outcomes and complications of anterior cruciate ligament reconstruction (ACLR) using either bone—patellar tendon—bone (BPTB) or quadriceps tendon (QT) autograft. **Methods:** A retrospective analysis of prospectively collected data identified consecutive cohorts of patients undergoing ACLR with either BPTB or QT autograft. Patients with less than 12-month follow-up and those undergoing concomitant osteotomies, cartilage restoration, and/or other ligament reconstruction procedures were excluded. Pre- and postsurgical patient-reported outcomes including International Knee Documentation Committee, Knee Injury and Osteoarthritis Outcome Score, Patient-Reported Outcomes Measurement Information System (PROMIS), Single Assessment Numeric Evaluation, Tegner, and Marx were compared between groups. Complications requiring reoperation were recorded. **Results:** One hundred nineteen patients met inclusion criteria, including 39 QT autografts and 80 BPTB autografts. Demographic information was comparable between groups. Mean follow-up was comparable between groups (QT 22.4 $\pm$ 10.6 months vs BPTB 28.5 $\pm$ 18.5 months, $P = .06$). At minimum 12-month follow-up (range 12.0-100.8 months), patients in both groups demonstrated statistically significant improvements in International Knee Documentation Committee (QT 60.0%, $P < .0001$; BPTB 57.7%, $P < .0001$), all Knee Injury and Osteoarthritis Outcome Score domains, PROMIS Mobility T-Score (QT 27.2%, $P = .0001$; BPTB 23.2%, $P < .0001$), PROMIS Global Physical Health (QT 14.4%, $P = .002$; BPTB 13.4%, $P = .001$), PROMIS Physical Function (QT 29.6%, $P < .0001$; BPTB 37.1%, $P < .0001$), PROMIS Pain Interference (QT −16.5%, $P < .0001$; BPTB −20.8%, $P < .0001$), Single Assessment Numeric Evaluation, (QT 76.9%, $P < .0001$; BPTB 73.3%, $P < .0001$), Tegner (QT 92.9%, $P = .0002$; BPTB 101.4%, $P < .0001$), and Marx (QT −26.6%, $P = .02$; BPTB −32.0%, $P = .0002$) with no statistically significant differences between the 2 groups. Overall postoperative reoperation rate did not differ between groups (QT 12.8% vs BPTB 23.8%, $P = .2$). Revision ACL reconstruction rate did not differ between groups (QT 5.1% vs BPTB 7.5%, $P = .6$). **Conclusions:** Patients undergoing autograft ACLR with either BPTB or QT demonstrated significant subjective improvements in patient-reported outcomes from preoperative values and no statistically significant differences in outcomes between the groups. Complication and revision ACLR rates were similar between the 2 groups. **Level of Evidence:** III, retrospective cohort study.

Anterior cruciate ligament (ACL) injuries are one of the most common injuries of the knee for active individuals. Previous studies have estimated the annual incidence of ACL injuries to be 60.9 per 100,000.[1] Surgical techniques for anterior cruciate ligament reconstruction (ACLR) continue to evolve in

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an effort to improve safety and efficacy, decrease complications, and decrease graft-site morbidity. Graft failure is an uncommon but devastating outcome. ACL reinjury occurs in approximately 3.6% of cases in patients who have undergone ACLR.[2,3] Risk factors for reinjury have included younger patient age, graft type, and activity level.[3,4] Ideal graft selection, an integral consideration for success of ACLR, remains controversial.

Each graft type possesses both positive and negative attributes. Bone–patellar tendon–bone (BPTB) autograft permits bone-to-bone fixation but carries an increased risk of postoperative anterior knee pain, difficulty kneeling, and patella fractures.[5-10] Hamstring tendon (HT) autograft has been shown in many studies to provide similar outcomes to BPTB autograft[6-8,10-14]; however, size can be unpredictable and with smaller grafts being associated with greater failure rates.[15] In recent years, an alternative has increased in popularity and use—the quadriceps tendon (QT) autograft. Central QT autograft ACLR has previously been advocated by numerous authors.[16-21] QT autografts have multiple potential benefits compared with BPTB and HT autografts, including preservation of hamstring anatomy and function, reduced incidence of anterior knee pain and numbness, decreased risk of patella fracture, and minimal bone bleeding.[18] A historical concern for QT autograft was donor-site morbidity, including anterior knee pain, quadriceps muscle weakness, and decreased range of motion.[22] Nonetheless, Mulford et al.[23] showed an anterior knee pain rate of only 3%, full range of motion in 97% of patients and good quadriceps strength recovery.[23] Moreover, when compared directly with BPTB and HT autograft, patients who received a QT autograft have been shown to have achieved knee extension sooner and required less pain medication after reconstruction.[24] As such, it seems intuitive that QT represents a viable and reliable graft option with minimal donor-site morbidity.[23]

Despite favorable outcomes and a potentially reduced morbidity profile, the QT autograft is the least studied and least used autograft for ACLR. Polling data have demonstrated its use represents between 1% and 11% of all ACLR performed.[25,26] Rather, BPTB autografts are the most used, often considered the gold standard for ACLR autograft, and are the benchmark to which other grafts are compared.[2,4,27,28] There remains a lack of studies comparing outcomes of BPTB autografts and QT autografts.

The purpose of this study is to compare subjective outcomes and complications of ACLR using either BPTB or QT autograft. Our hypothesis is that there will be no difference in subjective outcome or complications between groups.

Methods

Following institutional review board approval (IRB #2007099), a retrospective review of prospectively collected data identified consecutive cohorts of patients undergoing ACLR with either BPTB or QT autograft. Surgery was performed by a single fellowship-trained sports surgeon between 2011 and 2019. All patients were offered both graft choices as options. BPTB autografts were considered the "gold-standard" for contact athletes and used preferably in those athletes if no absolute or relative contraindications, including patella alta, patella baja or a history of Osgood–Schlatter disease. QT autografts were offered as an alternative graft choice after informed literature review and were preferred in young patients with high-athletic demand. All data, including demographics, primary and secondary diagnoses, and surgical details, were confirmed by the primary investigator. Patients undergoing concomitant osteotomies, cartilage restoration, and other ligament reconstruction procedures were excluded. All included patients had at least 12 months of postoperative follow-up. Patient reported outcomes were compiled using the software platform PatientIQ (Chicago, IL). Pre- and postsurgical patient-reported outcomes (PROs) including International Knee Documentation Committee (IKDC), Knee Injury and Osteoarthritis Outcome Score (KOOS—Pain, Symptoms, ADL, Sport, and Quality of Life), Patient-Reported Outcomes Measurement Information System (PROMIS), Single Assessment Numeric Evaluation (SANE), Tegner, and Marx were compared between groups. These PROs were used to quantify overall patient wellness, as well as knee function and pain levels. Complications requiring reoperation, including revision ACL reconstruction, arthrofibrosis, infection, pain, meniscus tears, cyclops lesions and patellar fractures, were recorded.

Surgical Technique

All procedures were performed with the patient under general anesthesia by a single fellowship-trained orthopaedic sports medicine surgeon. The ACL stump was meticulously debrided from the femoral and tibial footprints. The center of the tibial footprint was demarcated with anatomic landmarks, including the remnant anterior cruciate ligament stump, the anterior horn of the lateral meniscus, the medial and lateral tibial spines, and the intrameniscal ligament. The femoral center of the footprint, centered between the lateral intercondylar ridge and the posterior articular margin, was demarcated with a microfracture awl. Tunnels were drilled via independent technique using an anteromedial portal for the femoral tunnel and tip aiming tibial guide for the tibia. The femoral tunnel was visualized from both the anterolateral and anteromedial portal and determined to be in the accurate position.

Table 1. Patient Demographics and Characteristics

Graft	Age, y	Sex (% Female)	BMI	Height, cm	Ethnicity (% Non-White)	Laterality (% Left)
QT (N = 39)	18.7 ± 6.3	42.1%	25.9 ± 7.7	166.7 ± 12.0	17.9%	46.2%
BPTB (N = 80)	21.0 ± 5.9	42.5%	26.8 ± 5.6	173.7 ± 8.6	23.8%	48.1%
P value	.053	1.0	.5	.0003*	.5	.8

BMI, body mass index; BPTB, bone−patellar tendon−bone; QT, quadriceps tendon.
*Significance determined using *t* test and χ^2 test where appropriate; *P* value less than or equal to .05 denotes significance.

The QT was harvested by using an approximately 6-cm longitudinal incision overlying the quadriceps tendon insertion. Patellar bone was not harvested for the QT grafts. Femoral and tibial fixation for the QT grafts were accomplished using the TightRope GraftLink technique (Arthrex, Inc., Naples, FL). For BPTB autograft, the central third of the patellar tendon was harvested along with bone from the patella and tibia at the respective tendon insertion sites. The harvested tissue was prepared on the back table. Femoral fixation was accomplished using either the adjustable suspensory technique with TightRope or traditional metallic screw technique. Fifty-one patients who received BPTB autograft underwent metallic screw fixation, whereas 29 had adjustable suspensory femoral fixation. Tibial fixation was accomplished using interference screw technique. Screw fixation was executed with titanium SOFTSILK screws (Smith & Nephew, Andover, MA). Otherwise, the procedures were performed identically.

Postoperative Protocol

All patients underwent an identical postoperative protocol. Patients were discharged with detailed instructions for the postoperative plan, including aspirin deep vein thrombosis prophylaxis, foot pump exercises, narcotic pain medication, and a home-exercise program. Patients were fitted with a hinged knee brace, which was to be locked in extension and worn at all times for ambulation and for sleeping. Patients were instructed to be weight-bearing as tolerated with crutches to assist with walking. Home exercises were initiated 24 hours after surgery with the goal of complete extension and 90° of flexion at initial follow-up, which was scheduled for 7 to 10 days postoperatively. Meniscus repair rehabilitation was the same in both groups with patients either weight bearing as tolerated or toe-touch weight-bearing based on their tear pattern. Formal physical therapy was initiated after the initial follow-up appointment. Return to greater-level activities were individualized, based on standardized, minimum time and progressive functional rehabilitation criteria.

Statistical Analysis

For each patient-reported outcome score and subscore, differences within and between the QT autograft cohort and the BPTB autograft cohort were analyzed. Preoperative scores, >12-month postoperative scores, and comparisons between these scores were analyzed. Continuous distributed variables were analyzed using a Student *t* test. Dichotomous data were analyzed using the Pearson χ^2 test, and results were reported as a frequency and percentage. Microsoft Excel was used for statistical analysis (Microsoft, Inc., Redmond, WA). Post-hoc power analysis was generated in G*Power (Düsseldorf, Germany).[29]

Results

Current Procedural Terminology code "29888" identified 339 patients who underwent ACLR of any graft type between September 2011 and April 2019 with the primary surgeon. Fifty-one patients were excluded for undergoing ACLR with a graft type other than BPTB or QT. Of the remaining 288 patients, 97 patients were identified as undergoing QT autograft ACLR. Twenty-four of these 97 patients were excluded for not being a primary ACLR. Thirty-four additional QT ACLR patients were lost to follow-up or underwent concomitant osteotomy, cartilage restoration or other ligament reconstruction and were excluded. One-hundred ninety one patients were identified as undergoing BPTB ACLR. Of these 191 patients, 46 were identified as allografts and excluded. An additional 27 patients were excluded for not being a primary ACLR or due to concomitant osteotomy, cartilage restoration, or other ligament reconstruction. Of the remaining patients who underwent BTPB ACLR, only 80 patients met the 12-month minimum follow-up requirement. A total of 119 patients met inclusion criteria, consisting of 39 QT and 80 BPTB autografts (Table 1). The mean age at time of surgery was 18.7 (± 6.3 years) in the QT group and 21.0 (± 5.9 years) in the BPTB group (*P* = .053). Patient's mean height was 166.7 cm (±12.0) in the QT group versus 173.7 cm (±8.6) in the BPTB group (*P* = .0003). Sixteen of 39 (41.0%) in the QT group and 34 of 80 (42.5%) in the BPTB group were female (*P* = 1.0). Mean body mass index was 25.9 in the QT group and 26.8 in the BPTB group (*P* = .5). Seven of 39 (17.9%) in the QT group and 19 of 80 (23.8%) in the BPTB group were non-White (*P* = .5). Sixteen of 39 (41.0%) in the QT group and 42 of 80 (52.5%) underwent concomitant meniscus repair (*P* = .2).

PROs were listed for the QT and BPTB cohort, respectively (Table 2). There were no statistically

Table 2. Preoperative and Postoperative Patient-Reported Outcomes

Score Type	Graft	Preoperative Mean	Preoperative SD	Preoperative N	*P* Value QT vs BPTB	>12 Months Postoperative Mean	>12 Months Postoperative SD	>12 Months Postoperative N	*P* Value QT vs BPTB	Difference	*P* Value Preoperative vs Postoperative
IKDC	QT	48.4	13.6	18	.5	77.4	24.6	19	.5	60.0%	<.0001*
	BPTB	51.7	17.6	31		81.6	17.7	44		57.7%	<.0001*
SANE	QT	46.9	21.6	23	.7	83.0	16.8	30	.5	76.9%	<.0001*
	BPTB	49.4	25.6	24		85.5	18.2	44		73.3%	<.0001*
Tegner	QT	2.7	1.1	23	.4	5.2	2.7	20	.2	92.9%	.0002*
	BPTB	3.0	1.5	37		6.1	2.3	52		101.4%	<.0001*
Marx	QT	13.0	4.2	22	.8	9.6	4.9	19	.7	−26.6%	.02*
	BPTB	13.4	4.3	38		9.1	5.7	52		−32.0%	.0002*

KOOS Sub-scale	Graft	Preoperative Mean	Preoperative SD	Preoperative N	*P* Value QT vs BPTB	>12 Months Postoperative Mean	>12 Months Postoperative SD	>12 Months Postoperative N	*P* Value QT vs BPTB	Difference	*P* Value Preoperative vs Postoperative
ADL	QT	75.5	17.4	23	.5	94.9	13.6	30	.9	25.6%	<.0001*
	BPTB	78.8	18.8	38		94.6	8.9	56		20.0%	<.0001*
Pain	QT	71.0	16.8	23	.2	89.7	16.3	30	.6	26.4%	.0002*
	BPTB	77.1	16.4	36		89.9	10.8	55		16.6%	<.0001*
Sport	QT	37.0	22.9	23	.5	82.2	23.6	30	.4	122.3%	<.0001*
	BPTB	41.4	27.8	37		77.3	22.5	56		86.8%	<.0001*
Symptoms	QT	66.0	19.9	23	.4	83.7	16.3	30	.7	26.9%	.0008*
	BPTB	70.0	18.9	38		85.1	15.1	56		21.5%	<.0001*
QOL	QT	30.5	18.1	23	.2	64.4	26.3	30	.3	111.5%	<.0001*
	BPTB	36.2	18.3	38		69.7	23.6	56		92.6%	<.0001*

PROMIS Sub-scale	Graft	Pre-op Mean	Pre-op SD	Pre-op N	*P* Value QT vs BPTB	>12 Months Postoperative Mean	>12 Months Postoperative SD	>12 Months Postoperative N	*P* Value QT vs BPTB	Difference	*P* Value Preoperative vs Postoperative
Physical Health	QT	49.3	7.1	23	.8	56.4	8.5	32	1.0	14.4%	.002*
	BPTB	49.8	7.7	21		56.5	7.4	43		13.4%	.001*
Mental Health	QT	56.8	6.6	23	.6	55.9	7.5	30	.3	−1.5%	.7
	BPTB	57.7	5.6	21		57.9	9.6	43		0.3%	.8
Physical Function	QT	40.4	6.7	23	.7	52.4	10.0	30	.4	29.6%	<.0001*
	BPTB	39.5	7.3	21		54.1	8.7	41		37.1%	<.0001*
Pain Interference	QT	57.4	6.5	23	.4	48.0	8.2	30	.6	−16.5%	<.0001*
	BPTB	59.4	7.5	21		47.1	7.1	41		−20.8%	<.0001*
Mobility T-score	QT	41.5	7.2	16	.7	52.7	8.7	23	.9	27.2%	.0001*
	BPTB	42.6	6.7	16		52.4	7.6	33		23.2%	<.0001*

ADL, activities of daily living; BPTB, bone—patellar tendon—bone; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; PROMIS, Patient-Reported Outcomes Measurement Information System; QOL, quality of life; QT, quadriceps tendon; SANE, Single Assessment Numeric Evaluation; SD, standard deviation.

*Significance determined using the *t* test and χ^2 test where appropriate; *P* value less than or equal to .05 denotes significance.

significant differences in baseline PROs, including IKDC, KOOS subsets, PROMIS scores, SANE, Tegner, and Marx.

At minimum 12-month follow up (range 12.0-100.8 months; QT 22.4 ± 10.6 months vs BPTB 28.5 ± 18.5 months, *P* = .06) patients in both QT and BPTB groups demonstrated statistically significant improvements from preoperative values in IKDC, all KOOS domains, PROMIS scores to include Mobility T, Global Physical Health, Physical Function, and Pain Interference, SANE scores, Tegner scores, and Marx scores (Table 2). Postoperative PROMIS Global Mental Health scores did not differ from preoperative scores in either group (QT −1.5%, *P* = .7; BPTB 0.3%, *P* = .9). There were no differences in postoperative PROs between patients undergoing QT vs BPTB reconstruction (Table 2).

Complications were low and not statistically significant between groups (Table 3). The overall reoperation rate was 12.8% in the QT group compared with 23.8% in the BPTB group (*P* = .2). The QT autograft group had 2 subsequent revision ACL reconstructions (5.1%), and the BPTB group had 6 subsequent revision ACL reconstructions (7.5%) (*P* = .6). Mean time to revision ACL reconstruction was 12.0 months (range 4.3-19.6 months) in the QT group and 25.2 months (range 3.7-72.4 months) in the BPTB group (*P* = .5). Mean time to any reoperation was 15.2 months (range 2.3-40.9 months) in the QT group and 21.4 months (range 0.5-97.8 months) in the BPTB group (*P* = .7).

Discussion

In this comparative study, QT and BPTB autograft ACL reconstruction both demonstrated similar

Table 3. Complications Requiring Reoperation in BPTB Autografts and QT Autografts

Complications	BPTB Autograft (N = 80)	QT Autograft (N = 39)	*P* Value
Revision ACLR	6 (7.5%)	2 (5.1%)	.6
Arthrofibrosis	6 (7.5%)	1 (2.6%)	.3
Infection	1 (1.3%)	0	
Pain/removal of hardware	1 (1.3%)	0	
Meniscus tear	2 (2.5%)	1 (2.6%)	
Cyclops lesion of ACL graft	2 (2.5%)	1 (2.6%)	
Patella fracture	1 (1.3%)	0	
Total	19 (23.8%)	5 (12.8%)	.2

ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; BPTB, bone−patellar tendon−bone; QT, quadriceps tendon. Significance determined using the *t* test and χ^2 test where appropriate; *P* value less than or equal to .05 denotes significance.

postoperative improvement in patient report outcome measures with no statistically significant differences in reoperation rates. The results provide further support that QT autograft can produce reliable and similar results as compared with BPTB autograft reconstruction.

Objective physical examination measures have been studied following use of autograft ACLR. Previous studies have shown no difference in stability or knee range of motion following ACLR when comparing QT, HT, and BPTB autografts.[30] Similarly, others have demonstrated no significant differences in knee laxity between HT and QT or BPTB and QT.[31,32] A recent systematic review demonstrated no differences in postoperative Lachman, KT-1000, pivot shift, or range of motion when comparing graft types.[33] Moreover, Mouarbes et al.,[34] in a meta-analysis of 27 clinical studies including 581 QT autografts, found no significant differences in Lachman test or pivot-shift test. Overall, these studies demonstrate no objective differences with range of motion or stability between graft types.[35]

Most studies have demonstrated that no major differences exist in PROs, including subjective IKDC scores, KOOS Sport/Symptom scores, and Lysholm scores when comparing QT, BPTB, and HT graft choices.[5,30-32,36-41] There is, however, heterogeneity in both graft fixation method and type of quadriceps graft harvested—quadriceps tendon with (QTB) or without (QT) bone block. Lund et al.[32] randomized 51 patients to BPTB or QTB and found no difference in subjective IKDC scores and KOOS scores but showed decreased kneeling and graft-site pain with QTB. Similarly, Kim et al.[30] compared 27 BPTB autografts with 21 QTB autografts with minimum 2-year follow up and found no difference between the 2 groups in IKDC scores. Moreover, Han et al.[37] compared 72 QTB autograft reconstructions with 72 BPTB autograft reconstructions with a minimum of 2-year follow up and found no difference between the groups in terms of stability, Lysholm scores, or IKDC scores. In contrast, Gorschewsky et al.[36] followed 124 QTB ACL reconstructions with minimum 2-year follow up and compared them with a group of 136 BPTB autograft reconstructions. Their results favored BPTB on IKDC patient reported satisfaction and functional scores. These results, however, all used a proximal patellar bone block, which may have an impact on donor-site morbidity, postoperative pain, fixation, and outcomes. Our study compared soft tissue only QT with BPTB and similarly demonstrated no significant differences in postoperative outcome measures between these groups across all KOOS measures, IKDC, Tegner, SANE, and PROMIS measures.

Soft-tissue—only QT has seen a recent increase in the literature, with increased interest as fixation methods have changed.[17,42] Early techniques used a hybrid of cortical suspensory fixation and interference screw-fixation methods.[18,19] While much of the literature has been focused on the biomechanical properties of the quadriceps graft, only a few recent studies have commented on PROs.[17,42-45] Schulz et al.[45] reported on a series of 55 QT ACLRs and demonstrated mean Lysholm scores of 89, with 89.1% reporting good or very good results. They used bioabsorbable transfix pins for femoral and tibial fixation. Todor et al.[44] compared 39 QT and 33 HT fixed with femoral cortical buttons and a tibial interference screw, identifying no differences in KT-1000 testing, Lysholm scores, modified Cincinnati, or the general SF-36. Our study, in contrast to those mentioned previously, reported outcome measures comparing BPTB with QT autografts. All patients improved from preoperative scores in both groups, and QT was not statistically different in outcome measures compared with BPTB autografts. The data presented in this study further support the use and study of soft-tissue—only QT as a viable and safe option for ACL reconstruction, performing comparable with BPTB in PRO measures at midterm follow-up. In addition, these data provide support for dual cortical suspensory fixation methods to secure our graft. Further long-term studies are needed to identify if these outcomes diminish over time.

Graft failure is also an important consideration when selecting a graft for ACL reconstruction. The majority of published data demonstrate that there are no differences in failure rates among the 3 most commonly used autografts. Hurley et al.[33] demonstrated no differences in graft rerupture rates comparting QT and BPTB, with rates ranging from 0% to 2.8% for QT and 1.4% to 5.6% for BPTB. Similarly, comparing QTB and QT autografts, Crum et al.[43] found no significant differences in graft rupture between groups, with results ranging from 0% to 9%. Cavaignac et al.[31] compared QT autografts with HT autografts and found a failure rate of 2.22% and 4.44%, respectively. Younger age has consistently been associated with a greater rate of graft failure, with reports of 16.5% to 25% in patients younger than 25 years.[3,46,47] Interestingly, in our study, the overall complication rate of the BPTB group (23.8%) was almost double that of the QT group (12.8%). Although not statistically significant, the large relative difference suggests the possibility of a type 2 error. In addition, our study demonstrated a revision ACL reconstruction rate of 5.1% in the QT autograft group and of 7.5% in the BPTB group, demonstrating no differences between the groups. Our median time to failure within the QT group was 12.0 months, suggesting that early fixation failure was not a significant issue using dual cortical suspensory fixation. Moreover, our study population also represented a very young population, mean 18.7 years QT and 21.0 years BPTB, with failure rates consistent with those within the reported literature. These results further support that QT is a safe, reliable, and effective graft for ACL reconstruction.

QT autografts offer potential anatomical and biomechanical advantages over alternative graft types.[48] The mean cross-sectional area of the QT autograft has been shown to be significantly greater than that of the BPTB or HT autografts.[49,50] This increased cross-sectional area may reduce the well-known bungee and windshield effects, as well as the tunnel—graft mismatch, which is postulated to cause inflow of synovial fluid and cytokines with subsequent bone resorption and tunnel widening.[37,48,51] Moreover, knee strength should be considered when considering graft choice. A recent meta-analysis evaluating knee extensor strength found that QT knee extension strength was equivalent to BPTB with both weaker than HT. In addition, knee flexor strength was found to be greater in the QT autograft group than the HT autograft group.[52]

Our findings demonstrate good patient-reported functional and clinical outcomes and low complication rates at midterm follow-up following primary ACLR using QT autografts and BPTB autografts. Both groups showed significant improvements in almost all patient reported outcomes domains that we examined. Overall, the literature demonstrates that QT autografts show comparable clinical outcomes, functional outcomes and rupture rates compared with BPTB and HT autografts.[34] As a result, QT autografts appear to be a reliable alternative to traditional grafts, such as the BPTB autograft. Surgeons should familiarize themselves with the advantages of each graft type to personalize the most effective treatment for each patient in consideration of the patient's age, activity level, occupation, and postoperative functional goals.

Limitations

We acknowledge many limitations to this study. First, graft choice was not randomized in these groups. The decision for graft type was made at the discretion of the surgeon after lengthy discussion with the patient. Second, as a single-surgeon study, there is a risk of performance bias. In addition, the data primarily consist of subjective questionnaires completed by patients rather than objective clinical measurements, which introduces possibility for error. Nonetheless, previous studies have demonstrated that patient reported outcomes are an important metric for understanding ACL reconstruction.[53,54] Moreover, we feel that these limitations are mitigated by the fact that currently there is limited patient reported outcome data comparing BPTB to QT. Finally, the study is limited by the number of patients in both groups, which significantly limits the power. An estimated required sample size was calculated using the previously described minimal clinically important difference for KOOS of 8 points and a standard deviation of 15.[55] In our study, with 80 patients in the BPTB group and 39 patients in the QT group, the group allocation ratio was approximately 2. Using an effect size of $d = 0.533$ at an allocation ratio of 2, an estimated total sample size of 128 knees, including 85 BPTB knees and 43 QT knees, would be required to detect this difference at 80% power.[29] Although our groups approached the required sample size, a larger study may elucidate differences between the 2 groups.

Conclusions

Patients undergoing autograft ACLR with either BPTB or QT demonstrated significant subjective improvements in PROs from preoperative values and no statistically significant differences in outcomes between the groups. Complication and revision ACLR rates were similar between the 2 groups.

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