Quadriceps tendon autograft for primary anterior cruciate ligament reconstruction in comparison to hamstring tendon autografts

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Purpose
One of the pillars of successful anterior cruciate ligament (ACL) reconstruction is the choice of the ideal graft substitute. The central one-third of the quadriceps tendon is apparently a good autograft option, representing a modular reconstructive option with minimal donor site morbidity. The aim of this research is to compare the functional outcome of primary ACL reconstruction using quadriceps tendon autografts in comparison to the hamstring tendon autograft.
Patients and methods
This prospective, randomized clinical study included 60 patients with torn ACL randomly divided into group I (the control group), whereby ACL reconstruction was performed using the hamstring tendon autograft or group II (the study group), whereby ACL reconstruction was done using the central part of quadriceps tendon pure soft tissue autograft. The study was performed in our hospital between January 2016 and March 2018. The mean follow-up period was 2.2±0.4 years. Assessment was done clinically using the IKDC 2000 subjective and objective scoring system. Objective laxity measurements were performed using the KT-1000 at the end of follow-up.
Results
Clinical assessment of the patients in the 6th month postoperatively and at the end of follow-up averaged 2.2±0.4 years according to the IKDC 2000 Subjective and Objective Scoring System and revealed significantly better results for group II in early postoperative after 6 months, with comparable results at the end of follow-up. Objective laxity measurements at the end of follow-up revealed that the side-to-side difference is a little bit better in the quad group with no statistically significant results.
Conclusion
The central part of the quadriceps tendon is a viable autograft option for primary ACL reconstruction with good mid-term functional results, and minimal donor site morbidity as compared with the standard most commonly used hamstring tendon autograft; however, a longer term and multicenter studies are still needed to validate its routine use.

Keywords:
anterior cruciate ligament, autograft, hamstrings, quadriceps, reconstruction

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Introduction

The anterior cruciate ligament (ACL) is an important structure to prevent anterolateral rotatory instability of the knee. Early reconstruction of symptomatic torn ACL, especially in young and active subjects, will improve their quality of life and sustain a smooth and symptom-free daily activities [1].

The choice of the ideal graft to substitute for the torn ACL has been challenging to orthopedic surgeons over decades. The ideal graft should mimic the native ACL biomechanics with good biological properties that allow early ligamentaization and thus safe rehabilitation. The most commonly used graft substitute nowadays for ACL reconstruction is the hamstring tendons autograft [2,3].

The quadriceps tendon autograft has many potential theoretical advantages, including an easy harvest technique that does not require a learning curve and so can potentially be used by beginners. In addition, it can be obtained with or without bone block. Moreover, it provides fewer donor site morbidity with the extensor mechanism being less impaired as compared with the patellar ligament graft and the procedure spares the hamstring muscles. Lastly, the prepared central part of the quadriceps tendon provides excellent biomechanical

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properties, which exceed that of patellar ligament and hamstring tendons [4–6].

We hypothesize that the quadriceps tendon provides a viable alternative to the hamstring tendon as an autograft substitute during ACL reconstruction. So in this study, we compare the functional outcome of ACL reconstruction with quadriceps tendon and with hamstring tendons autograft [1].

Patients

This prospective, randomized clinical study included 64 patients with torn ACL that were randomly allocated into two groups using identical envelopes into either group I (the control group), whereby surgery was done using the hamstring tendon autograft or group II (the study group), whereby ACL reconstruction was used using the central part of quadriceps tendon pure soft tissue autograft. The study was performed in our hospital between January 2016 and March 2018. The mean follow-up period was 2.2 ± 0.4 years, each group consisted of 30 patients.

The process of randomization was done by a member of our team other than the surgeon who did the surgery. All of the patients were instructed and consented for the surgery. The study was approved by the local Research Ethics Committee. All surgical procedures were done by the same orthopedic consultant surgeon specialized in sport injuries and arthroscopy. The follow-up in the outpatient clinic was done by the same member of our team who was not blinded to the procedure.

The inclusion criteria were isolated ACL injury of more than 2 months duration in a skeletally mature patient. Patients with complex knee injuries or associated meniscal and/or chondral injuries were excluded from the study. Also, patients with past knee surgery were excluded.

Both groups have comparable basic demographic data with no statistically significant differences Table 1.

Table 1 Comparison between group I hamstring (HT) and group II (QT) regarding basic preoperative clinical data

Variables	Group I 'Hamstrings' (HT)		Group II 'Quad'(QT)		*P* value
Age (years)					
Range	21–34		20–38		0.072
Mean±SD	26.20 ± 2.98		27.33 ± 2.94		
Sex					
Male	27	95.67	28	93.33	0.281
Female	3	4.33	2	6.67	
Duration of symptoms from injury to presentation in months					
Range	5–9	4–10			0.157
Mean±SD	6.80 ± 1.18	6.67 ± 1.58			
Mid-thigh circumference (cm)					
Range	55–78		48–77		0.087
Mean±SD	63.57 ± 6.82		61.17 ± 6.65		

Table 2 The difference between the two studied groups regarding preoperative clinical assessment parameters

Preoperative assessment	Group I Hamstrings		Group II 'Quad'		*P* value
Preop Subjective IKDC Score					
Range	30–45		30–55		0.066
Mean±SD	34.17 ± 4.37		36.33 ± 6.42		
Preop Objective IKDC grade					
B	2	6.67	3	10.00	
C	17	56.67	15	50.00	0.418
D	9	30.00	12	40.00	
Preop KT1000 side-to-side difference					
Range	7.5–12		7–13		0.436
Mean±SD	9.40 ± 1.45		9.47 ± 1.72		

Methods

All the patients were assessed using the IKDC 2000 subjective and objective testing. Objective laxity measurement using a KT-1000 arthrometer (MEDmetric, San Diego, CA, USA) with the knee at 30 ˚flexion using an anterior force of 133 N (30Ib) applied to the tibia was done. Preoperative MRI was done to all patients to confirm the diagnosis and exclude cases with associated meniscal and/or chondral injuries from the study. Table 2 shows the difference of the preoperative data between the two groups.

Other outcome assessment parameters include the mean time to return to activity of daily living as well as the sports activity. Finally, there is the need for revision surgery.

The surgical technique

Surgery was done under general anesthesia with the patient in the supine position, and the knee is semiflexed with a foot support and a side support keeping the knee in 90º flexion meanwhile allowing hyperflexion during femoral tunnel preparation. EUA was performed to confirm instability.

Hamstring graft harvest

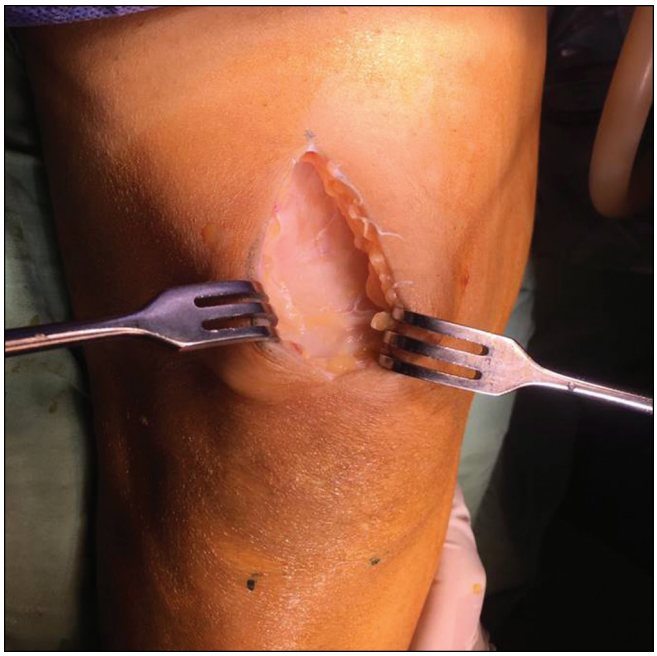
A vertical 2 cm incision is done over the anteromedial aspect of the tibia, 1 inch medially and 2 inches below the joint line. Subperiosteal dissection of the pes anserinus is done medially. Then the semitendinosis and the gracillis tendons were hooked and separated and then using a closed tendon stripper both tendons were harvested. Then they were doubled and whipstitched at each end using No. 5 Ethibond sutures (Ethicon, Somerville, NJ) using Krackow-type stitches. The diameter of the doubled hamstrings was measured as a preliminary step for femoral tunnel preparation.

Quadriceps tendon harvest

The knee is kept in 80º flexion by putting a sandbag under the thigh; this keeps the quadriceps tendon under tension and facilitates harvest. A vertical midline incision is performed starting 4 cm above the mid upper pole of the patella Fig. 1. The subcutaneous and fascial layers are dissected till reaching the quadriceps tendon. A rectangular graft was harvested from the middle portion of the tendon starting by a transverse cut at the periosteum covering the upper pole of the patella. The width of the graft is tailored as needed. Then two parallel longitudinal incisions were done medially and laterally and continued upward to get a minimum of 8 cm of the central superficial part of the tendon. The distal part of the graft was stitched to keep the graft under tension and facilitate the harvest of the superficial portion of the central part of the tendon without opening the suprapatellar pouch Figs 2, 3. The upper end of the harvested graft is cut by sharp dissection when the desired length is obtained.

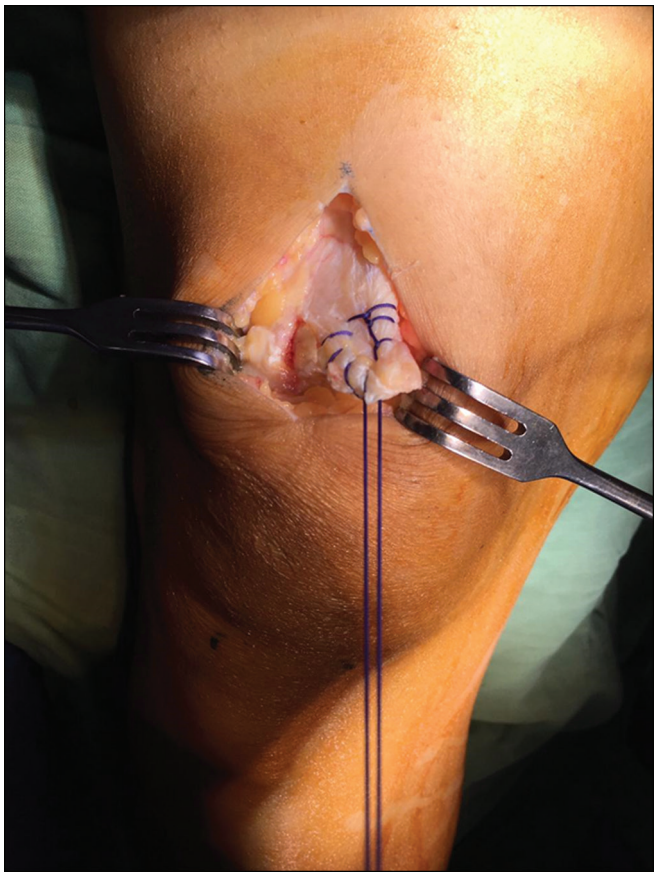
The suprapatellar pouch was accidentally violated in three cases, whereby repair of the synovium was done by N 2 Vicryl sutures to avoid fluid leakage during arthroscopy. The harvested quad tendon is whipstitched from both ends in the same way as the hamstring autograft using No. 5 Ethibond sutures (Ethicon, Somerville, NJ) using the Krackow-type stitches with an extension of about 30 mm and then its diameter is measured. Table 3 shows comparison of both groups regarding operative findings [7,8].

Figure 1



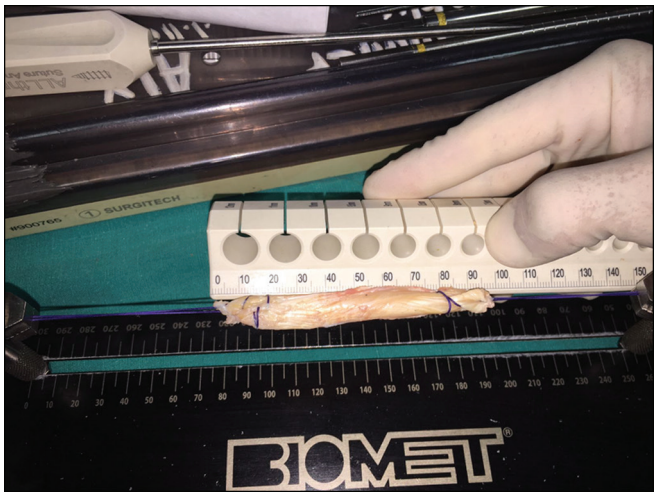
A 4 cm incision centered over the upper pole of the patella, dissection done till reaching the central part of the tendon characteristic.

Figure 2



The superficial central part of the tendon is freed up from the upper pole of the patella and Whip -stitched. The released part is kept under tension while dissection carried upwards till the desired length of the graft is reached.

Figure 3



Measuring the length of the graft after harvest before final preparation.

The intra-articular part of the surgery is almost identical in both groups. After standard routine checkup for all of the intra-articular structures, the ACL reconstruction was done through the transfemoral portal technique for all cases. An accessory anteromedial portal (AAM) is made under direct vision from the lateral portal [9].

Table 3 Comparison between the two studied groups regarding the intraoperative variables

Variables	Group I 'Hamstrings'	Group II 'Quad'	*P* value
Duration of surgery in minutes			
Range	60–100	45–70	0.0001*
Mean±SD	80.83±10.43	59.33±6.91	
Length of the doubled Hamstring versus the Quadriceps graft			
Range	11–15	7–12	0.0001*
Mean±SD	13.32±1.06	9.30±1.51	
Graft thickness in mms			
Range	7–9	8–10	0.012*
Mean±SD	7.77±0.63	8.20±0.81	

The anatomical femoral footprint was prepared, and the femoral tunnel was subsequently created within the anatomical femoral footprint.

After femoral tunnel preparation and leverage of the graft by means of a shuttle suture, fixation of the graft within the femoral tunnel is done by an interference screw of the same diameter as the graft. The interference screw (arthrex PEEK Interference Screws, made from PEEK-OPTIMA from Invibio) is introduced over a guidewire through the AAM while viewing from the AL portal. For tibial fixation, with the knee in 30° flexion, an adequate sized biodegradable interference screw was used to fix the graft in the tibial tunnel. An increment of 1–1.5 in the size of the screw relative to the tibial tunnel size was adopted to insure adequate fixation. Table 3 shows the differences in operative findings between the two groups Figures 4, 5.

The duration of surgery was significantly shorter in the quad group. The average length of the doubled hamstring graft was significantly more than the average length of the harvested central part of the quadriceps tendon. Finally, the average diameter of the soft tissue quad graft was significantly larger than the prepared double hamstring autograft. Table 3.

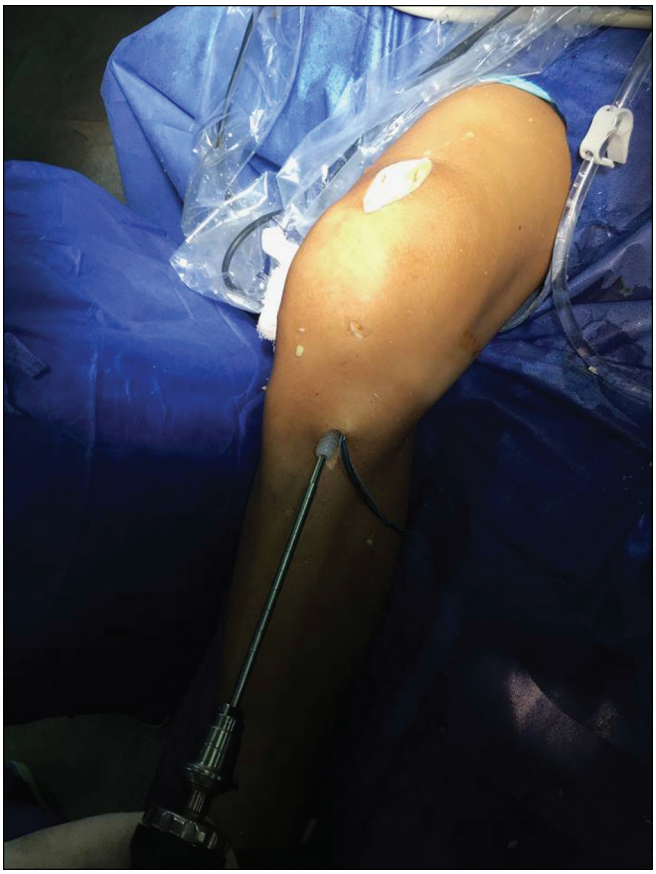
Statistical analysis

Statistical analysis of the collected data was done using the Statistical Package for the Social Sciences (SPSS/ version 24) software.

The statistical tests used is as follows:

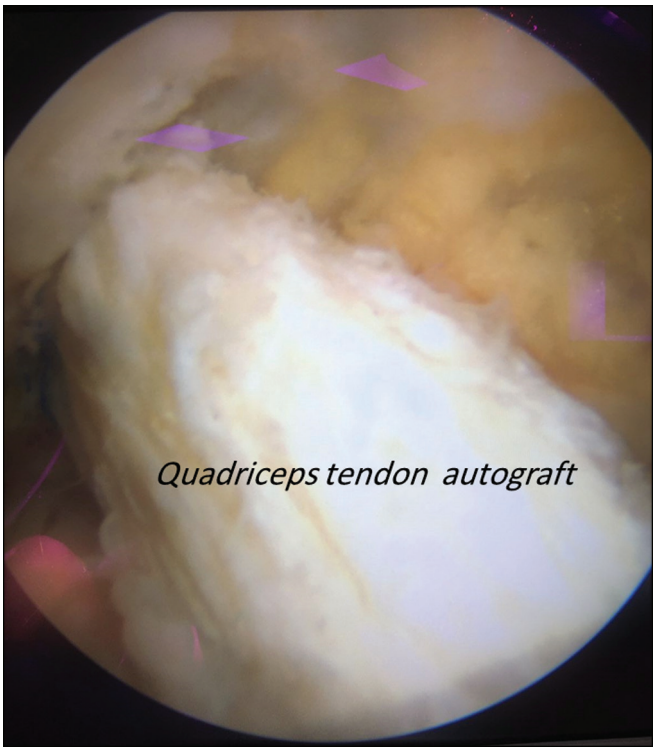
Arithmatic mean and standard deviation for normally distributed data were calculated. Comparison between two independent variables was done using an independent *t*-test, while the χ^2 test was used for comparison between categorized parameters. The level of significance was 0.05.

Figure 4



Fixation of the graft in the tibial tunnel by an interference screw through a separate antero-medial incision.

Figure 5



The arthroscopic view after reconstruction using the central one third of the quadriceps tendon autograft.

Results

Clinical assessment of the patients at the 6th month postoperatively as well as at the final follow-up, which averaged 2.2 ± 0.4 years according to the IKDC 2000 subjective and objective scoring system revealed significantly better results for the quad group in early postoperative after 6 months, with comparable results at the end of follow-up Table 4, Fig. 6.

Objective laxity measurements using the KT-1000 at the end of follow-up revealed that the side-to-side difference is a little bit better in the quad group with no statistically significant results Table 4.

Regarding other functional outcome parameters, patients in the quad group II had significantly better functional recovery as represented by statistically significant less time to return to activities of daily living (ADL) as well as less time needed to return to sport activities Table 5.

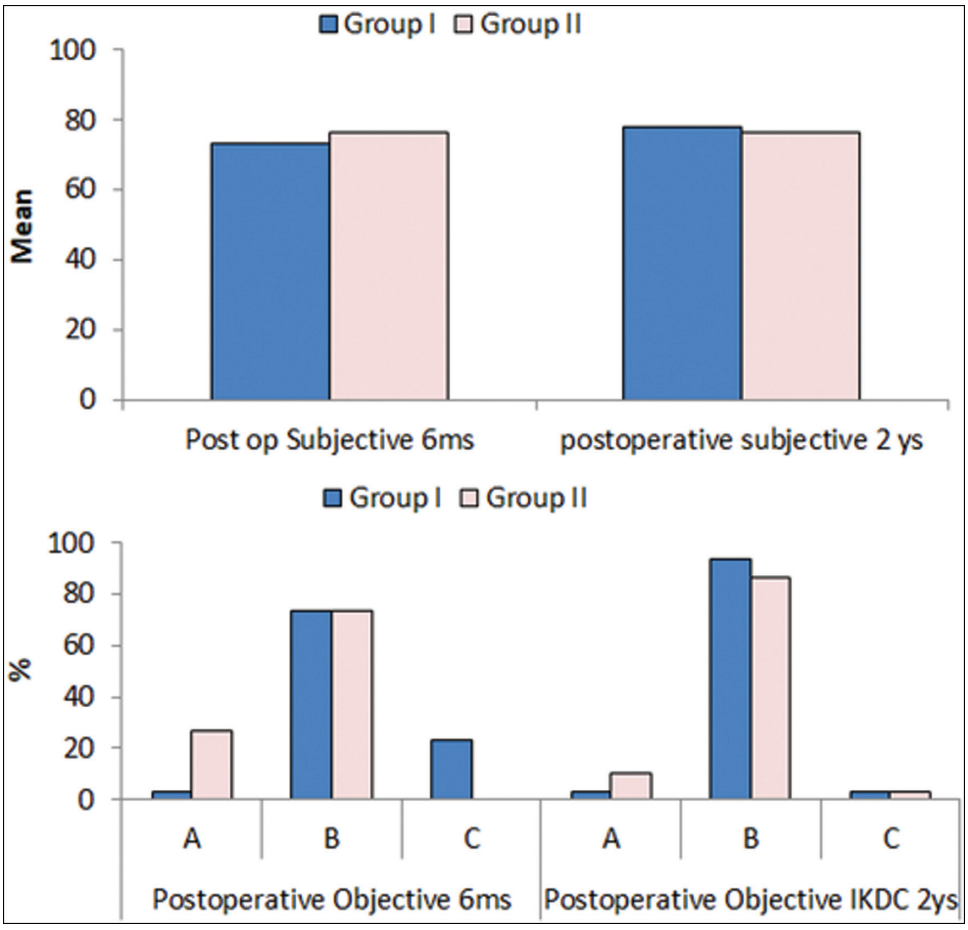
Table 4 Comparison between the two studied groups regarding the clinical outcome scoring parameters postoperatively

Variables	Group I 'Hamstrings'		Group II 'Quad'		*P* value
Postop subjective IKDC score 6 months					
Range	70–80		70–90		0.013*
Mean±SD	73.00 ± 4.28		76.50 ± 7.21		
Postoperative subjective IKDC score at the end of follow-up					
Range	70–85		70–80		0.107
Mean±SD	77.67 ± 4.30		76.11 ± 3.62		
Postoperative objective 6 ms					
A	1	3.33	8	26.67	
B	22	73.33	22	73.33	0.0001*
C	7	23.33	0	0.00	
Postoperative Objective IKDC 2 years					
A	1	3.33	3	10.00	
B	28	93.33	26	86.67	0.210
C	1	3.33	1	3.33	
KT 1000 postop at the end of follow-up					
Range	3–6		2–6		0.084
Mean±SD	4.01 ± 0.98		3.22 ± 0.99		

Complications

None of the patients in either group developed spontaneous failure of the graft requiring revision. Only one patient in the hamstring group had a twisting injury during sport activity 18 months after surgery. MRI revealed complete rupture of the graft.

Figure 6



Comparison between the two studied groups regarding postoperative outcome using the Subjective IKDC 2000 Scoring System A and Objective IKDC 2000 Grade B at both the 6th postoperative month and at the end of follow-up.

Table 5 Comparison between the two studied groups regarding functional outcome measures

Variables	Group I 'Hamstrings	Group II 'Quad'	*P* value
Return to activities of daily living (ADL) in weeks			
Range	3–6	2–4	0.0001*
Mean±SD	4.87±0.78	2.87±0.57	
Return sport activity in months			
Range	5–7	4–6	0.032*
Mean±SD	6.21±0.51	5.10±0.48	

Before this traumatic event the patient was doing well. Revision ACL reconstruction was done for him using the ipsilateral quadriceps tendon autograft followed by rehabilitation. Follow-up of this patient revealed recovery of knee stability. One patient within the quadriceps tendon group developed backing out of the tibial screw starting from the 15th month postsurgery. No instability was reported, and an MRI was conducted revealing an intact graft. Surgical removal of the screw was done in the 20th month postoperatively. Examination under anesthesia revealed a stable knee with a negative pivot shift test; the patient refused to have a second look arthroscopy.

One patient in the quadriceps group developed superficial wound infection that was responsive to oral antibiotics. One patient in the hamstring group also developed extensive ecchymosis of the leg and thigh that responded to conservative treatment over 3 weeks. One patient in the hamstring group developed DVT of the deep veins of the calf in 4th week postoperatively, which was treated medically, however, with some delay in his rehabilitation protocol. The patient was able to catch up without significant compromise to his functional outcome.

Four patients in the hamstring group developed persistent paresthesia over the anteromedial aspect of the leg that resolved partially over 6 months, leaving a small patch.

Discussion

This study revealed that the use of the central part of the quadriceps tendon as a source of autograft during primary ACL reconstruction provides a safe, reproducible, and modular reconstructive option and produce functional outcome that is comparable to the standard method using the hamstring tendon autograft.

By reviewing the literature, this is the first prospective, randomized, clinical study comparing the use of the hamstring tendon versus pure soft tissue quadriceps tendon autograft regarding the functional outcome after ACL reconstruction. The intra-articular arthroscopically assisted part of the surgery was almost identical, whereby the anatomical single bundle reconstruction using the transfemoral portal technique was used. Fixation of the graft within the femoral and tibial tunnels was done by interference screws. Surgeries were done by the same senior orthopedic sport injury consultant. The follow-up was done by the same surgeon in the OPD who was not blinded to the procedure. And to avoid confounding factors, cases were selected to have isolated ACL injuries while ACL combined with chondral and/or meniscal injuries were excluded from the study.

The search for an ideal graft substitute for ACL reconstruction has been a challenging issue among orthopedic surgeons. Hamstring tendon autograft, which is the commonly used graft substitute currently, provides a graft that is similar to the native cruciate as regards biomechanical properties. Moreover, the newly reconstructed graft possesses a large surface area for revascularization. However, the procedure may lead to weakness of the hamstring group of muscles resulting in a decrease in the power of deep flexion. Hamstring muscles are biomechanically considered one of the important protectors of the ACL, so sacrificing these muscles might compromise the stability of the anterior cruciate ligament. Besides, the graft needs a longer time to incorporate into the bony tunnel and the initial strength of fixation is less compared with that of the patellar ligament [1,7].

Using the hamstring tendons as an autograft might adversely affect the medial stabilizing structures of the knee, especially in cases of combined ACL and medial collateral ligament (MCL) injuries. Thus, using the quadriceps tendon autograft in these cases might be a wise option [10].

Staubli *et al*. and Fulkerson and colleagues recommended the use of quadriceps tendon autograft for ACL reconstruction [11–13]. The graft can be used as pure soft tissue graft or combined with a patellar bone block. It constitutes an alternative autograft option to spare the hamstring and at the same time does not affect the knee extension power as what happens with the bone patellar tendon autograft. The use of pure soft tissue in the central one-third of the quadriceps tendon is an easily reproducible procedure [13].

Sasaki N *et al*. [14], in a cadaveric biomechanical study, found that the QT autograft gave good results that can be predictive of knee function restoration if used for ACL reconstruction [14].

One of the parameters used to assess autograft options is the subsequent adverse effects on the donor site.

The harvest of the hamstring tendons might result in extensive ecchymosis of the medial aspect of the thigh and leg, and additionally might result in troublesome hypothesia over the anteromedial aspect of the leg due to injury of the saphenous nerve branches. However, the QT harvest incision is relatively safe, and the incision can be minimized using a special harvest knife or by proper traction or using an endoscopically assisted harvest technique [15–18].

One study conducted by Akoto R *et al*. in 2019, comparing the functional outcome after ACL reconstruction with the QT graft and press-fit fixation versus quadruple HT and interference screw fixation in a study after 1-year follow-up found comparable results that encourage the use of QT tendon as an autograft.

Cavaignac and colleagues in 2017 compared the outcome after primary ACLR using the quadriceps tendon bone autograft and hamstring tendon autograft. They found comparable and even better biomechanical as well as functional results for the QT regarding the objective laxity measurement using the KT-1000 arthrometer as well as by clinical assessment using the Lachman and pivot shift tests [15].

Belk and colleagues in 2018 in a systematic review found that the QT autograft yielded superior biomechanical and mid-term functional results as compared with other types of grafts with no difference in the failure rate. However, the side-to-side difference between the QT and HT groups was not statistically significant [19,20].

The benefits of quadriceps tendon autograft include preservation of medial supporting structures of the knee and a relatively safe harvest incision without subsequent hypothesia and/or numbness. In addition to an easy and reproducible harvest technique, the central quadriceps tendon as a pure soft tissue autograft without the use of a patellar bone plug minimizes the postoperative anterior knee pain. Being a modular graft, whereby the thickness as well as the length of the harvested tendon can be tailored according to the need, in revision cases a thick portion of the tendon can be harvested to accommodate the expanding tunnels [20–22].

Limitations of this study

The limitations of this study are the relatively small number of the study groups as well as the relatively short period of follow-up. The follow-up was done by the same surgeon; however, he was not blinded to the procedure.

Also, the method of randomization used in this study which is the closed envelope method was a simple one not using any specific computer software.

MRI and second-look arthroscopy were not done routinely for asymptomatic cases; only those having a second traumatic event were eligible for such procedures. Finally, the follow-up was done mainly clinically.

Strengths of the study

The surgical procedures for all patients were done by the same surgeons combined to avoid performance bias. The same technique was used in all cases, which is transportal anatomical single-bundle ACL reconstruction, and the same method of graft fixation within the femoral and tibial tunnels, which involves using an interference screw.

Conclusion

The central part of the quadriceps tendon is a viable autograft option for primary ACL reconstruction with good mid-term functional results, and minimal adverse effects on the donor site as compared with the standard most commonly used hamstring tendon autografts.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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