Double-Layered Quadriceps Tendon Autografts Provide Lower Failure Rates and Improved Clinical Results Compared With Hamstring Tendon Grafts in Revision ACL Reconstruction

Lena Eggeling,*,†,‡ MD, Stefan Breer,* MD, Tobias Claus Drenck,* MD,
Karl-Heinz Frosch,*,‡ MD, and Ralph Akoto,*,†,§,‖ MD
Investigation performed at Asklepios Clinic St Georg, Hamburg, Germany

Background: We developed a quadriceps-tendon graft technique using a double-layered, partial-thickness, soft tissue quadriceps tendon graft (dlQUAD) for anterior cruciate ligament reconstruction (ACLR). This technique allows simple femoral loop button fixation and a limited harvest depth of the quadriceps tendon.

Purpose: To evaluate the outcome of patients undergoing revision ACLR using the dlQUAD technique compared with a hamstring tendon graft (HT).

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

Methods: A total of 114 patients who underwent revision ACLR between 2017 and 2018 were included in this retrospective case series. At a mean follow-up of 26.9 ± 3.7 months (range, 24-36), 89 patients (dlQUAD: n = 43, HT: n = 46) were clinically examined. In addition, patients completed the Lysholm score, Tegner activity scale, subjective International Knee Documentation Committee (IKDC), Knee injury and Osteoarthritis Outcome Score, and visual analog scale (VAS) for pain. Postoperative failure of the revision ACLR was defined as a side-to-side difference (SSD) in Rolimeter testing ≥ 5 mm or a pivot-shift grade of 2 or 3.

Results: Nine patients (10.1%) were identified with a failed revision ACLR. There was a significantly lower failure rate with dlQUAD versus the HT group (2.3% vs 17.4%; $P = .031$). The mean postoperative SSD was significantly less in the dlQUAD group (1.3 ± 1.3 mm [range, 0-5] vs 1.8 ± 2.2 mm [range, 0-9]; $P = .043$). At the latest follow-up, Tegner and IKDC scores significantly improved in the dlQUAD group compared with the HT group (Tegner: 5.8 ± 1.8 vs 5.6 ± 1.5; $P = .043$; IKDC: 83.8 ± 12.2 vs 78.6 ± 16.8; $P = .037$). The pain VAS score was also significantly reduced in the dlQUAD group compared with the HT group (0.9 ± 1.1 vs 1.6 ± 2.0; $P = .014$).

Conclusion: The dlQUAD and HT techniques both demonstrated significant improvement of preoperative knee laxity and satisfactory patient-reported outcome measures after revision ACLR. Compared with the HT grafts, the dlQUAD technique showed lower failure rates and small increases in Tegner and IKDC scores.

Keywords: revision anterior cruciate ligament reconstruction; soft tissue; quadriceps tendon graft

There has been increased focus on the use of quadriceps tendon autografts in anterior cruciate ligament (ACL) reconstruction (ACLR), especially after Scandinavian register studies reported increased failure rates for hamstring tendons (HT) in comparison with bone-patellar-bone (BPB) grafts.[9,30,35] As an alternative to HT and BPB grafts for ACLR, quadriceps tendon grafts have shown equal patient-reported outcomes based on stability and functional

scores, with a lower number of complications.[8,10,11,23] Additionally, quadriceps tendon grafts have resulted in lower donor-site morbidity than BPB and HT grafts.[26] Furthermore, studies have shown that ACLR with HT grafts resulted in impaired muscle strength in knee extension and flexion 1 year after surgery, while quadriceps tendon grafts led to impairment in only knee extension.[19,36]

The choice of grafts is important, particularly in revision ACLR, when remaining graft options may be limited. Literature regarding the use of quadriceps tendon grafts in revision ACLR is limited, and there is a need for studies that evaluate the differences between grafts in revision

ACLR.[2,15,32] We have developed a quadriceps tendon technique using a double-layered, partial-thickness, soft tissue quadriceps tendon (dlQUAD) graft for revision ACLR, which allows for easy femoral loop button fixation and limits the harvest depth in the quadriceps tendon.

The aim of this study was to evaluate the outcome of patients after revision ACLR using the dlQUAD technique compared with HT autografts. We hypothesized that the dlQUAD technique would be associated with lower failure rates and better clinical outcomes compared with HT grafts.

METHODS

Patient Population

Between 2017 and 2018, a total of 114 patients underwent revision ACLR at our institution. One-stage revision was performed in case of a bone tunnel size <12 mm (including the sclerotic zone of the bone tunnel wall) and the opportunity of a guaranteed satisfactory new tunnel positioning without overlapping the original tunnel. One-stage revisions were performed with patellar tendon grafts, because the sclerotic zone of the bone tunnel was removed during the revision, and with the resulting tunnel diameters, a bone-block fixation was technically easier. Two-stage revisions were performed with dlQUAD or HT grafts. The study design was approved by the local ethics committee, and informed consent was obtained from each patient.

Inclusion criteria were revision ACL surgery with dlQUAD or HT graft between 2017 and 2018 and written informed consent for participation in the study. Exclusion criteria were revision ACLR with any other grafts except dlQUAD or HT, an additional lesion of the posterior cruciate ligament, additional osteotomy (axis correction in the coronal plane, slope reduction), infection of the knee, or signs of generalized hypermobility based on a Beighton score of ≥5 out of 9.[37]

Seven patients were excluded because of the use of a patellar tendon autograft, 3 patients because of additional posterior cruciate ligament lesion, 7 patients because of additional osteotomies, 2 patients because of generalized hypermobility, and 6 patients who were lost to follow-up, leaving 89 patients with a mean follow-up was 26.9 ± 3.7 months (range, 24-36) who were included in this retrospective study. Of these, 46 patients were treated with an HT, and after we introduced dlQUAD in revision
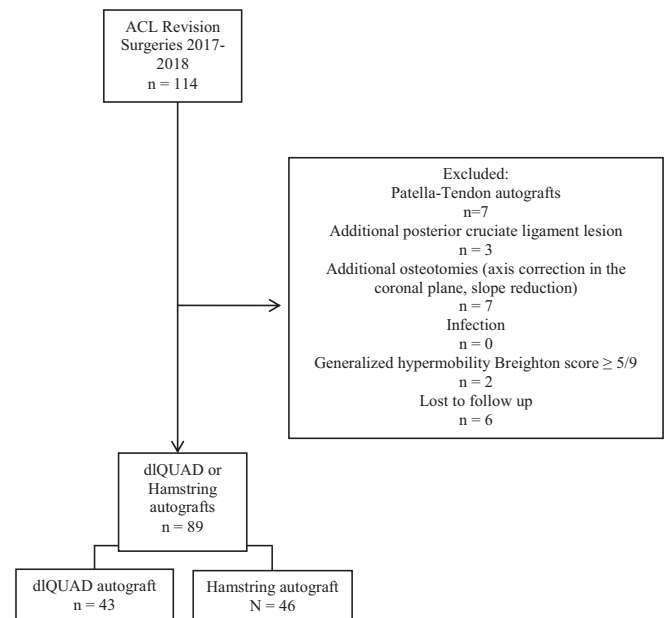

Figure 1. Flowchart of the selection of study participants. ACLR, anterior cruciate ligament reconstruction; dlQUAD, double-layered, partial-thickness soft tissue quadriceps tendon; PCL, posterior cruciate ligament.

ACLR, 43 patients were treated with the dlQUAD technique (Figure 1).

PATIENT OUTCOMES

Patient-related variables before revision ACLR included the Lysholm and Tegner scores and physical examination under anesthesia at the time of revision ACLR.[33,39]

Two years after revision ACLR, patients were invited for an examination in which range of motion, medial and lateral laxity, Lachman test, pivot-shift test, and side-to-side difference (SSD) in laxity as measured by Rolimeter (Aircast) were recorded.[40] The Lachman, pivot-shift, and Rolimeter tests were used to determine the anterior and anterolateral laxity of the knee. The pivot-shift test was graded as 1 (glide); 2 (clunk); or 3 (gross) and the Lachman test as 1 (2-5 mm); 2 (6-10 mm); or 3 (>10 mm).[14] In addition, patients completed the Lysholm, Tegner, subjective International Knee Documentation Committee (IKDC),

||Address correspondence to Ralph Akoto, MD, BG Hospital Hamburg, Bergedorfer Str 10, 21033, Hamburg, Germany (email: rakoto@me.com) (Twitter: @RalphAkoto).

*Department of Trauma and Orthopaedic Surgery, Sports Traumatology, BG Hospital Hamburg, Hamburg, Germany.

†Asklepios Clinic St Georg, Hamburg, Germany.

‡Department of Trauma and Orthopaedic Surgery, University Medical Center, Hamburg-Eppendorf, Germany.

§University of Witten/Herdecke, Cologne Merheim Medical Center, Cologne, Germany.
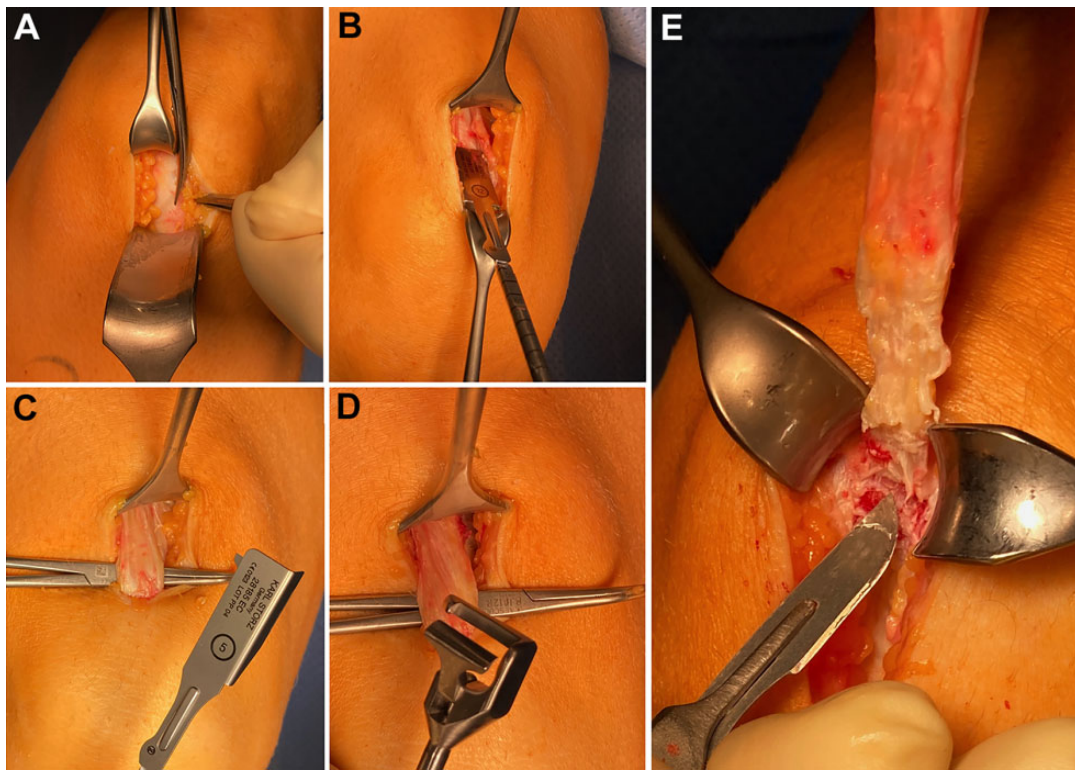
Figure 2. Harvesting a dlQUAD graft. (A) A 2- to 3-cm longitudinal incision was made. (B) Two parallel longitudinal incisions were made up to the insertion of the rectus femoris muscle. (C) Splitting the tendon in the coronal plane. (D) Proximal transection of the graft with the tendon cutter. (E) Dissection of the periosteum from the patella to gain a 14 cm–long tendon-periosteal strip.

and Knee injury and Osteoarthritis Outcome Score.[4,24] Pain was quantified using a 10-point visual analog scale (VAS).[29]

Postoperatively, patients were identified as "failed revision ACLR" based on the definition of Noyes et al[27] (SSD Rolimeter test $\geq$5 mm or pivot-shift grade 2-3) or "stable revision ACLR."[5,6]

Surgical Technique for Revision ACLR. In all patients, a 2-stage revision procedure was performed, because either the diameter of one of the bone tunnels was too large (>11 mm including the sclerotic zone) or the previous position of the bone tunnel did not allow anatomic positioning of the new bone tunnel. Bone tunnel filling was performed using cancellous allograft. Revision ACLR was carried out at a minimum of 4 months after bone tunnel grafting and assessment of the bony incorporation by computed tomography.

We attempted to preserve the meniscus. Peripheral meniscal lesions that could be repaired were sutured. Posterior horn lesions were treated with all-inside sutures, ramp lesions with direct sutures through the posteromedial portal, and lesions of the pars intermedia with outside-in sutures. Stable horizontal tears or tears affecting only the white-white zone were treated conservatively. When meniscal tears were not suitable for repair, a partial meniscectomy was carried out. Cartilage lesions were treated nonoperatively.

All revision ACLR procedures were performed with autografts during single-bundle ACLR using HT or dlQUAD grafts. If the hamstrings had already been harvested from the ipsilateral side, hamstrings were taken from the contralateral or quadriceps tendon from the ipsilateral side; there was no previous quadriceps removal in any of the cases. Patients were informed about the advantages and disadvantages of the 2 grafts, including specific complication risks and donor-side morbidity, and the choice of graft was then made by the patient.

dlQUAD Technique

For harvesting the dlQUAD, the distal quadriceps tendon was exposed via a 2- to 3-cm longitudinal incision. The paratenon was left intact, as it is strongly attached to the tendon, especially proximally, and detaching it could reduce the thickness of the tendon (Figure 2A). Using a 12 mm–wide and 6 mm–deep double knife (Karl Storz), 2 parallel longitudinal incisions were made in the quadriceps tendon extending proximally to the insertion of the rectus femoris muscle. Care was taken not to damage the muscle fibers of the rectus femoris (Figure 2B). The double knife was passed 10 to 12 cm proximally at the insertion of the rectus femoris, so that a correspondingly long tendon strip was obtained (Figure 3).
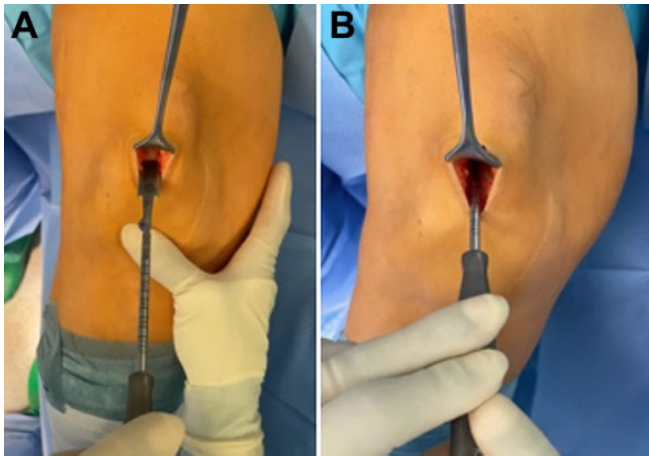
Figure 3. (A) Two parallel longitudinal incisions were made in the quadriceps tendon using a 12 mm–wide and 6 mm–deep double knife. (B) The double knife was passed 10 to 12 cm proximally up to the insertion of the rectus femoris.

The rectus femoris insertion can be felt while passing the double knife or separator forward through resistance; likewise, the arthroscope can be used to visualize this region. When making the longitudinal incisions, care was taken not to cut into the medial or lateral vastus muscle. If the tendon between the 2 muscle bellies was narrower than 12 mm, the muscle bellies were dissected from the medial and lateral edges and retracted. With 2 artery forceps, a transverse tunnel was prepared through the distal central tendon proximal to the insertion to the patella to ensure that the graft was not full-thickness. The thickness of the graft was assessed manually and visually. A 5-mm tendon separator (Karl Storz) was inserted into the tunnel in the tendon, and the tendon was split in the coronal plane to the insertion of the rectus femoris muscle (Figure 2C). This can also be visualized with the arthroscope. The tendon strip was then transected proximally with a tendon cutter (Karl Storz) (Figure 2D). The tendon was mobilized distally by sharp dissection under manual traction to the insertion at the patella. The parallel longitudinal insertions were continued through the periosteum of the patella, and the full thickness of the periosteum was dissected from the patella in a distal direction; 2 to 4 cm–long periosteal strips were obtained, and a 14 cm–long tendon-periosteal graft was achieved (Figure 2E). The paratenon was closed over the tendon defect.

Any remnants of muscle tissue left on the graft were removed with a rasp. The graft was folded over the loop of an adjustable button (TightRope RT; Arthrex) (Figure 4A). The 2 free ends were sutured together with No. 2 Fiberwire (Arthrex) using the baseball stitch technique (Figure 4B). Before implantation, the graft was wrapped in a compress soaked with normal saline solution and vancomycin.

The ACLR was performed by drilling the femoral tunnel via the anteromedial portal. Before the femoral and tibial bone tunnels were created, a fluoroscopy was used to check the position of the guide wires. Femoral fixation was achieved with an adjustable button (TightRope RT), and tibial fixation was achieved with a combination of a
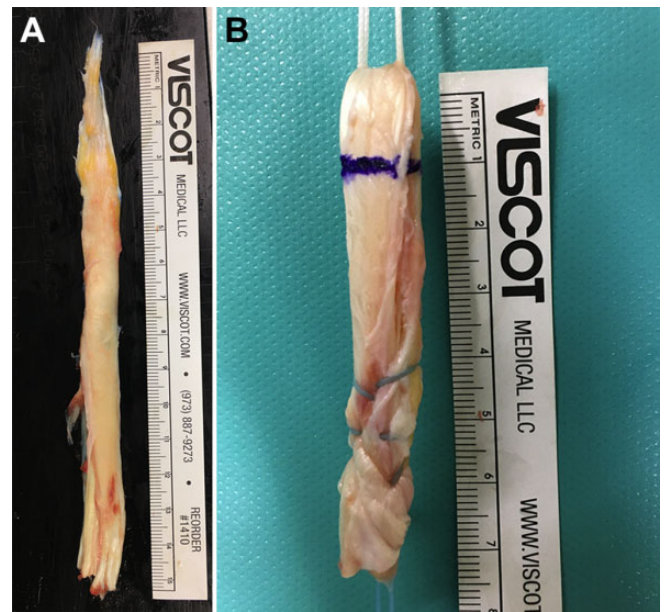

Figure 4. (A) Quadriceps tendon graft 14 cm in length. (B) Double-layered quadriceps tendon graft, TightRope RT suture button femoral, tibial sutured with baseball stitches.

bioabsorbable interference screw (Genesys; ConMed) and extracortical suture fixation using No. 2 Fiberwire via a button (Suture Washer; Smith & Nephew).

HT Technique

For the HT technique, the quadruple ipsilateral or, in the case of previous hamstring harvesting, the contralateral semitendinosus graft, was used. If the thickness of the graft was <7 mm, the gracilis tendon was also harvested. Fixation was the same as for the dlQUAD: femoral fixation with an adjustable button (TightRope RT), and tibial fixation with interference screw (Genesys) and an extracortical button (No. 2 Fiberwire and Suture Washer).

A preoperative SSD >6 mm was defined as high-grade anterior knee laxity. When preoperative, high-grade, knee laxity occurred, the patient received an additional lateral extra-articular tenodesis (LET). An approximately 7 cm–long and 5 mm–wide strip starting from the Gerdy tubercle was fixed with an interference screw (Genesys) femorally, in the position described by Lemaire.[18] The LET was placed superficial to the lateral collateral ligament. The harvesting defect in the iliotibial tract was closed using No. 2 vicryl sutures (Ethicon). When medial knee instability grade 2 or 3 was diagnosed preoperatively,[13] medial collateral ligament (MCL) reconstruction with an autologous graft was performed. MCL reconstruction was performed according to the descriptions of Preiss et al.[31] A gracilis tendon or peroneus tendon split graft of at least 15 cm in length was placed in a doubled fashion in a femoral tunnel positioned at the intersection of an imaginary extension of the posterior edge of the tibia with the Blumensaat line, creating 2 free branches. The ventral branch was placed in the center of the tibial superficial MCL insertion 3 to 5 mm above the

TABLE 1
Patient Demographics and Pre- and Intraoperative
Findings (N = 89)[a]

Characteristic	dlQUAD Group (n= 43)	HT Group (n= 46)	P
Female sex	16 (37.2)	19 (41.3)	0.828
Age, y	32.9 ± 9.1 (25-44)	27.6 ± 8.6 (18-41)	0.619
Affected knee, left	10 (23.3)	21 (45.7)	**0.044**
Number of previous ACLR	1.5 ± 0.7 (1-3)	1.3 ± 0.6 (1-4)	0.139
BMI, kg/m^2	25.9 ± 4.5 (18-36)	26.2 ± 5.2 (18-42)	0.463
Varus malalignment	0 (0)	2 (4.3)	0.495
Valgus malalignment	4 (9.3)	2 (4.3)	0.424
Posterior tibial slope, deg	8.8 ± 1.8 (5-16)	9.8 ± 2.3 (6-16)	**0.08**
Medial meniscal lesion	29 (67.4)	28 (60.9)	0.659
Lateral meniscal lesion	4 (9.3)	10 (21.7)	0.147

[a]Data are reported as mean ± SD (range) or n (%). ACLR, anterior cruciate ligament reconstruction; BMI, body mass index; dlQUAD double-layered quadriceps tendon; HT, hamstring tendon; bolded P value indicates significant difference between groups.

pes anserinus, and the posterior branch was placed in the tibial insertion of the posterior oblique ligament just above the semimembranosus insertion. Both branches were passed below the fascia. Medial knee instability was assessed clinically according to Hughston et al[13] (grade 1, 0-5 mm; grade 2, 6-10 mm; grade 3, >10 mm).

Statistical Analysis

For continuous variables, the mean ± SD was used. The mean differences between the 2 groups (dlQUAD and HT) were compared with the unpaired Student *t* test for normally distributed parameters and the Kruskal-Wallis test for nonnormally distributed parameters. Categorical parameters were compared using the chi-square test. In case of small subgroups (n < 5), the Fisher exact text was used for categorical parameters. $P < .05$ was considered significant. All statistical analyses were performed using SPSS Version 25 (IBM).

A post hoc power analysis was performed with G*Power Version 3.1.9.6 for Mac (HHU Düsseldorf) to assess the validity of the proportions of failed revision ACLR in patients with HT or dlQUAD. Based on our proportions of failure of 0.023/0.174 in 43 patients using dlQUAD and 46 patients using HT with 9 revision ACLR failures, a post hoc power of 0.7 was achieved at a significance level of 5%.

RESULTS

Preoperatively, there was no significant difference between the groups in age, sex, body mass index, coronal alignment, or number of meniscal lesions. The posterior tibial slope was increased in the HT compared with the dlQUAD group,

TABLE 2
Preoperative Clinical Findings and Functional Scores[a]

Characteristic	dlQUAD Group	HT Group	P
Extension deficit 3°-5°	2 (4.7)	2 (4.3)	0.667
Flexion deficit 6°-15°	0 (0)	0 (0)	–
Lachman test grade			**0.008**
Absent	0 (0)	0 (0)	
Grade 1 (2-5 mm)	2 (4.7)	12 (26.7)	
Grade 2 (5-10 mm)	31 (72.1)	29 (64.4)	
Grade 3 (>10 mm)	10 (23.3)	4 (8.9)	
Pivot-shift test grade			0.286
Absent	4 (9.3)	1 (2.2)	
Grade 1 (glide)	7 (16.3)	13 (28.3)	
Grade 2 (clunk)	20 (46.5)	17 (37)	
Grade 3 (gross)	12 (27.9)	15 (32.6)	
VAS pain	3.6 ± 2.5 (0-8)	4.1 ± 2.4 (0-10)	0.334
Lysholm score	54.9 ± 15.1 (10-77)	51.3 ± 25 (7-77)	0.255
Tegner score	3.2 ± 1.3 (1-6)	2.9 ± 1.4 (0-6)	0.311

[a]Data are reported as mean ± SD (range) or n (%). dlQUAD, double-layered quadriceps tendon; HT, hamstring tendon; VAS, visual analog scale; bolded P value indicates significant difference between groups.

TABLE 3
Surgical Details[a]

Characteristic	dlQUAD Group	HT Group	P
Graft size, mm	8.2 ± 0.6 (7-9)	8.5 ± 0.9 (7-10)	0.377
Additional lateral extra-articular tenodesis	32 (74.4)	29 (63.0)	0.264
Additional MCL graft reconstruction	19 (44.2)	15 (32.6)	0.283
Medial meniscus repair	16 (37.2)	14 (30.4)	0.511
Partial medial meniscus resection	12 (27.9)	14 (30.4)	0.820
Total medial meniscus resection	1 (2.3)	0 (0)	0.483
Lateral meniscus repair	2 (4.7)	6 (13.0)	0.268
Partial lateral meniscus resection	2 (4.7)	4 (8.7)	0.678
Total lateral meniscus resection	0 (0)	0 (0)	

[a]Data are reported as mean ± SD (range) or n (%). dlQUAD, double-layered quadriceps tendon; HT, hamstring tendon; MCL, medial collateral ligament.

but the difference was not significant (9.8 ± 2.3 vs 8.8 ± 1.8; $P = .08$) (Table 1). Compared with the HT group, more patients in the dlQUAD group had a grade 3 Lachman test in the preoperative assessment (23% vs 9%; $P = .008$). There were no significant differences between the groups on any of the other preoperative clinical or functional results (Table 2).

The graft diameter of the revision ACLR was not significantly different between groups (8.2 ± 0.6 mm [dlQUAD] vs 8.5 ± 0.9 mm [HT]). Both groups had equally frequent additional medial or lateral augmentations and meniscal surgery (Table 3).

TABLE 4
Postoperative Clinical Findings, Functional Results and Failure of Revisions[a]

Characteristic	dlQUAD Group	HT Group	P
Extension deficit 3°-5°	0 (0)	3 (6.5)	0.242
Flexion deficit 6°-15°	1 (2.3)	1 (2.2)	0.736
Lachman test grade			0.099
Absent	39 (90.7)	36 (78.3)	
Grade 1 (2-5 mm)	3 (7)	3 (6.5)	
Grade 2 (5-10 mm)	1 (2.3)	7 (15.2)	
Grade 3	0 (0)	0 (0)	
Pivot-shift test grade			1
Absent	41 (95.3)	41 (89.1)	
Grade 1 (glide)	1 (2.3)	2 (4.3)	
Grade 2 (clunk)	1 (2.3)	2 (4.3)	
Grade 3 (gross)	0 (0)	1 (2.2)	
Postoperative Rolimeter SSD	1.3 ± 1.3 (0-5)	1.8 ± 2.2 (0-9)	**0.043**
Donor-site morbidity	2 (4.7)	6 (13)	0.268
VAS pain	0.9 ± 1.1 (0-3)	1.6 ± 2 (0-9)	**0.014**
Lysholm score	85.4 ± 13 (43-100)	83.2 ± 17 (25-100)	0.791
Tegner score	5.8 ± 1.8 (3-9)	5.6 ± 1.5 (1-9)	**0.043**
IKDC score	83.8 ± 12.2 (37-100)	78.6 ± 16.8 (14-100)	**0.037**
KOOS subscale			
Symptoms	87 ± 15.3 (50-100)	87 ± 16.2 (25-100)	0.860
Pain	90.2 ± 11.6 (56-100)	88.7 ± 12.6 (36-100)	0.617
ADL	94.1 ± 8.5 (71-100)	94.2 ± 8.7 (59-100)	0.632
Sports/Rec	80.1 ± 20 (30-100)	75.7 ± 19 (25-100)	0.193
Quality of life	62.5 ± 23 (13-94)	58.4 ± 22 (0-88)	0.502
Failure of revision ACLR	1 (2.3)	8 (17.4)	**0.031**

[a]Data are reported as mean ± SD (range) or n (%). ACLR, anterior cruciate ligament reconstruction; ADL, function in activities of daily living; dlQUAD, double-layered quadriceps tendon; HT, hamstring tendon; IKDC, International Knee Documentation Committee; KOOS, Knee injury and Osteoarthritis Outcome Score; Sports/Rec, function in sports and recreational activities; SSD, side-to-side difference; VAS, visual analog scale; bolded P values indicate significant difference between groups.

Postoperative Outcomes. After revision ACLR, the Lachman and pivot-shift tests significantly improved in both groups ($P < .001$), with no significant difference in improvement between groups. The postoperative SSD in laxity was significantly reduced in the dlQUAD compared with the HT group (1.3 ± 1.3 vs 1.8 ± 2.2 mm; $P = .043$). All patient-reported outcomes improved significantly from pre- to postoperatively in both groups ($P < .001$ for all).

When comparing outcomes between groups, we found that the dlQUAD group had significantly better Tegner and IKDC scores compared with the HT group (Tegner score: 5.8 ± 1.8 vs 5.6 ± 1.5; $P = .043$; IKDC: 83.8 ± 12.2 vs 78.6 ± 16.8; $P = .037$). Pain was also significantly reduced in the dlQUAD group compared with the HT group (VAS score: 0.9 ± 1.1 vs 1.6 ± 2.0; $P = .014$). A comparison of postoperative clinical and functional outcomes by group is shown in Table 4.

Nine patients (10.1%) were identified with a failed revision ACLR. Patients with dlQUAD had a significant lower failure rate compared with HT (2.3% vs 17.4%; $P = .031$).

DISCUSSION

The main findings of this study were that the dlQUAD and HT techniques demonstrate significant improvement of preoperative knee laxity and satisfactory patient-related

outcome measures. Compared with the HT, the dlQUAD technique showed lower failure rates and slightly higher Tegner and IKDC scores after revision ACLR.

Results after revision ACLR are commonly known to be less favorable than those after primary ACLR.[38] Wright et al[41] presented a failure rate of 13.7% after revision ACLR, while Louis et al[22] revealed that 13.5% of their patients showed anterior laxity >5 mm at the latest follow-up. The results of revision ACLR using the dlQUAD technique in this study are similar to those of primary reconstruction, especially regarding the very low failure rates of 2.3%, the significant improvement of a positive Lachman and pivot-shift test, and the low postoperative SSD.[3]

There is currently no consensus in the literature about the superiority of the HT or the quadriceps tendon in terms of failure rates.[19,20] In a systematic literature review and meta-analysis by Nyland et al,[28] quadriceps tendon autografts had less pivot shift and lower failure rates than HT autografts. A meta-analysis by Mouarbes et al[26] showed better functional outcomes for quadriceps tendon autografts versus HT and comparable survival rates. A prospective randomized study by Lind et al[19] showed no difference in function, stability, and failure rates between these 2 grafts. A registry study published by Lind et al[21] showed higher failure rates for quadriceps tendon versus HT, but a study published shortly afterward by the same study group

demonstrated that high-activity clinics, defined as clinics that performed >100 ACLRs per year, showed similar revision outcomes for quadriceps, hamstrings, and patellar tendon grafts, while clinics that performed <100 ACLRs (low-activity clinics) showed higher failure rates for quadriceps grafts.[20] They concluded that the higher failure rates for quadriceps tendon autografts could be due to a lower surgical routine in low-activity clinics.[20] A recent study by our research group in a different study population showed lower, but not statistically significant, failure rates for quadriceps tendon versus HT or BPB (N = 111; failure rates: Quad, 6.7%, HT, 9.4%, BPB, 18.8%).[2] In the largest cohort study published to date by Runer et al,[34] a significantly higher risk of revision surgery was reported for HT autografts. The results of the current study provide further evidence that quadriceps tendon grafts may have lower failure rates than HT grafts. This could be due to a loss of flexion strength and the resulting less favorable hamstring-to-quadriceps ratio that is described after HT harvesting.[36]

The quadriceps tendon can be harvested with or without a patellar bone block and either as a full- or partial-thickness graft.[12,15] There are some potential morbidities after ACLR using patellar bone block including postoperative anterior knee pain, discomfort when kneeling, and, in rare cases, patellar fractures.[7,17] Short, soft tissue, single-strand quadriceps grafts have the disadvantage that both sides of the graft have to be sutured, which can be difficult with the fibrous structure of the quadriceps graft. Many authors prefer interference screws for femoral fixation of these grafts.[12,23,25] The femoral interference screw fixation technique can be challenging, as the graft can twist around the screw and may be damaged. Furthermore, this screw fixation technique of soft tissue grafts is biomechanically weaker than adjustable or fixed button systems.[1,16] Hughes et al[12] described a technique in which they sutured a fixed button system into the femoral end of the graft. Suturing the button system can be technically demanding and carries the risk of a tear out of the sutures due to the longitudinal fibrous structure of the quadriceps tendon. In this study, double-layered, partial-thickness, quadriceps tendon was used. With the additional removal of a periosteal strip, a graft length of 14 cm was achieved, which allows easy fixation via an adjustable or fixed loop. An advantage of the technique described in this study, compared with the technique by Hughes et al, is that the relatively flat dlQUAD was passed through an adjustable button and was then doubled. This makes the femoral graft preparation easier and results in a mean graft diameter of 8.2 ± 0.6 mm.

There are a few limitations in this study. Results from a study of patients with revision ACLR may not necessarily be transferable to the primary situation. Thus, a prospective randomized controlled study of primary ACLR is required to assess possible differences between different types of grafts and the dlQUAD technique in primary ACLR. Another limitation of this study was that the muscular strength at the latest follow-up was not measured with an isokinetic assessment; the quadriceps strength was only clinically evaluated according to the ability of active knee extension. Further limitations of this study are its retrospective study design, relatively small sample size, and lack of randomization.

CONCLUSION

Both HT and dlQUAD autografts resulted in significant improvement in anterior knee laxity and satisfactory patient-related outcome measures. Compared with the hamstring tendon grafts, the dlQUAD technique showed lower failure rates and slightly higher Tegner and IKDC scores after revision ACLR.

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