Association Between Knee Flexor Strength and Preservation of the Tibial Attachment of the Sartorial Fascia During Hamstring Tendon Harvest

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Background: During anterior cruciate ligament (ACL) reconstruction, there are various autograft options. Donor-site morbidity is an important consideration while deciding the type of the autograft. Gracilis and semitendinosus autografts are commonly used in ACL reconstruction, resulting in weakness of the hamstring muscle.

Hypothesis: We hypothesized that if we preserved the tibial insertion site of the sartorial fascia (SF) during hamstring tendon harvest, there would be better recovery of knee flexor strength.

Study Design: Case-control study; Level of evidence, 3.

Methods: In this retrospective study, 34 patients (aged 20-59 years) underwent ACL reconstruction using hamstring tendon autograft with 2 different incision techniques on the SF. The tibial attachment site of the SF was preserved in 17 patients. The insertion site of the muscle was incised transversely in 17 patients. The follow-up duration was $\geq$2 years. Patients were recalled to the institute for examination and muscle strength assessment. The results were compared between the groups in terms of flexor and extensor knee isokinetic muscle strength at 60 and 180 deg/s.

Results: There was no statistical difference between the groups in terms of age, sex, or body mass index. When compared with patients whose SF attachment site was incised, patients with a preserved SF tibial insertion were found to have a higher flexion peak torque at the angular speed of 180 deg/s ($P < 002$). No statistically significant difference was noted at 60 deg/s.

Conclusion: During collection of gracilis and semitendinosus autografts, preserving the SF tibial attachment site was associated with better knee flexion peak torque.

Keywords: anterior cruciate ligament reconstruction; sartorial fascia; knee flexion torque; hamstring; incision

Hamstring tendon (HT) autograft, bone–patellar tendon–bone, fascia lata, and quadriceps tendon are the most commonly used grafts in anterior cruciate ligament (ACL) surgery, with similar functional outcomes[1,9,13,19] while each type of autograft has specific complications related to the harvesting site.[2] Avoiding donor-site morbidity is an important consideration underpinning tendon graft use.[11,23]

Because the main function of the hamstring muscles is flexion and internal rotation at the knee joint,[4] HT autograft harvest may cause weakness of knee flexion and internal rotation.[17,18,24] Flexion and internal rotation strength deficits were reported in patients who had 2 HTs harvested (gracilis and semitendinosus) up to 1 year postoperatively.[14]

Deep flexion torque is also affected in cases where the hamstring muscle group is harvested.[5,17,27] In the literature, there are several reports of decreased knee flexion peak torque (PT) value after ACL reconstruction.[3,8,17]

In this study, it was hypothesized that unlike the typical method[10] with an inverted L–shaped incision dissecting the sartorial fascia (SF) in line with the HTs, nonremoval of the SF tibial attachment site during graft harvesting would have a positive effect on postoperative knee joint flexion muscle strength.

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METHODS

Approval for the study was granted by the local ethics committee (reference No. 64/02). Power analysis was performed to determine the adequate sample size. Given the available resources, the minimum required sample size was found to be 17 for each study group with statistical power set at 85%. A retrospective screening was made up of 131 patients aged 20 to 59 years who underwent ACL reconstruction using HT autograft between January 2015 and January 2017. Two experienced knee specialists (M.F.C. and Y.K.) performed all of these surgeries in the same clinic. Those with ACL rerupture, contralateral knee injury, inflammatory arthritis or osteoarthritis, meniscopathy and pathologies other than ACL rupture or lesions in both knees, conditions that might interfere with the standard postoperative rehabilitation protocol, and patients with a <2-year follow-up were excluded from the study. Preliminarily, 49 patients with minimum 2-year follow-up who underwent ACL reconstruction using HT autograft and were 20 to 59 years old were recalled to the clinic for a physical examination by an independent specialist (D.D.) to identify the integrity of the ACL using the anterior drawer and Lachman tests. Only those with either normal or mild (grade 1) scores were considered to have met the secondary inclusion criteria. They were informed about the study and invited to participate in further examination. Of 40 eligible patients, 34 volunteered to be enrolled in the study, guaranteeing the minimum sample size of 17 for each group, in conformity with the power analysis. There were no professional athletes among the patients.

Patients were equally divided into 2 groups according to the incision type of the superior edge of the sartorial muscle adjacent to the medial side of the proximal tibia during hamstring graft harvesting: the SF-preserved group and the SF-detached group. Both groups involved surgeons (M.F.C. and Y.K.) who performed the operations using both methods. In the earlier operations, a typical reverse L–shaped incision was the preferred method. During this time, the SF tibial attachment–preserving technique was adopted for the later cases to reduce donor-site morbidity.

In the SF-preserved group, patients underwent ACL reconstruction that was performed with a 2-cm vertical incision into the skin centered on the SF, followed by incision into the SF in line with its oblique course to reach the gracilis and semitendinosus tendons, respecting the integrity of the tibial attachment site of the SF. This method was referred to as the SF tibial attachment–preserving technique. In the SF-detached group, patients underwent ACL reconstruction with a reverse L–shaped incision parallel to the axis of the HT, dissecting the SF and protecting the infrapatellar branch of the saphenous nerve (Figure 1). This method was referred to as the SF tibial attachment removing technique.

Figure 1. Inverted L–shaped incision in the sartorial fascia.

Surgical Procedure

Patients underwent surgery under general anesthesia in the supine position. Arthroscopy-assisted single-bundle anatomic ACL reconstruction was applied to all patients. A TightRope II RT button implant (Arthrex Inc) was used for femoral fixation in all patients. To achieve tibial fixation, a bioabsorbable screw (Arthrex Inc.) and U-staple (Arthrex Inc.) were used for both groups.

The patients in the SF-detached group underwent ACL reconstruction using HT autograft with an inverted L–shaped incision. In this technique, it was attempted to

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Ethical approval of this study was obtained from Ministry of Health of the Republic of Turkey, University of Health Sciences (reference No. 64/02).

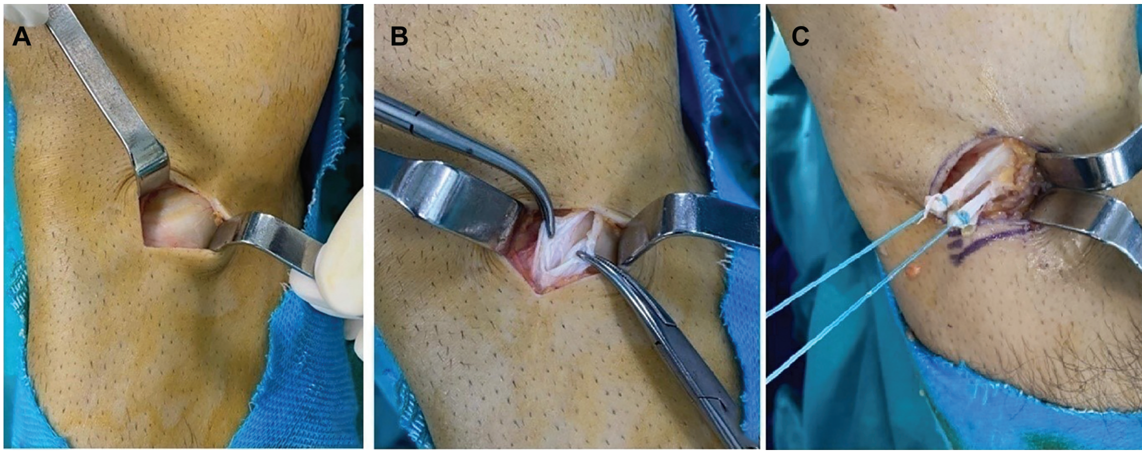

Figure 2. (A) A 2-cm incision made centered on the sartorial fascia. (B) Second incision made centered into the sartorial fascia in line with the oblique course of the gracilis and semitendinosus tendons. (C) Identified gracilis and semitendinosus tendons sutured and sectioned proximally to their insertion site.

Figure 3. (A) Free ends of the graft at the tibial tunnel were reached through the incision on the sartorial fascia (SF) and pulled distally. (B) Supplementary fixation and cushioning of the free ends in the SF with a U-staple. (C) Sutured closure of the incision on the SF. (D) Preserved SF tibial attachment.

palpate the HT at 4 cm inferior to the joint line and 2 cm medial of the medial edge of the tibial tuberosity.[7] A 2-cm skin incision was made parallel to the axis of the HT. To be able to reach the gracilis and semitendinosus tendons, a reverse L–shaped incision was made in the SF as described by Frank et al[10] (Figure 1).

After achieving fixation through a bioabsorbable interference screw in the tibial tunnel, 4 free ends of the graft were additionally inserted distal to the screw to further secure the graft within the subcortical cancellous bone at the opening of the tibial tunnel using a fixation staple.

Patients in the SF-preserved group underwent ACL reconstruction using HT autograft with the alternative incision technique that preserved the SF tibial attachment site as described by Lanternier et al.[16] In this technique, a 2-cm vertical incision was centered on the SF covering the gracilis and the semitendinosus wihout any injury to the infrapatellar branch of the saphenous nerve (Figure 2A). A second incision was then made into the center of the SF, considering the oblique course of the muscle (Figure 2B). The cut ends were grasped with 2 clamps, and the gracilis and semitendinosus tendons were visualized beneath. The caught tendons were secured close to their insertion site at the medial side of the proximal tibia using a Krakow suturing technique and sectioned using scissors without impairing the integrity of the pes anserinus. The tendons were then pulled using a closed stripper (Figure 2C).

Tibial fixation was achieved in a slightly different manner from the SF-detached group. After fixation with a bioabsorbable interference screw (Arthrex Inc.) in the tibial tunnel, the freed ends sutured with polyester were reached through the vertical incision previously made on the SF using a dissection forceps. Once caught, they were pulled distally to the screw and cushioned in the SF (Figure 3A). For supplemantary fixation, a staple was inserted on the free ends of the graft, also securing the incision on the SF (Figure 3B). The cut ends of the SF were sutured to cover up the staple (Figure 3, C and D).

Postoperative Management

During the first 2 postoperative days, each patient's operated knee was immobilized in an extension splint to control pain, swelling, and inflammation. Patients then met with

Figure 4. Patient muscle strength measurements with the Biodex device.

a physical therapist before being discharged to review their rehabilitation protocol. Both groups were given the same standardized, progressive rehabilitation protocol.[6,12]

In addition to medication, the rehabilitation protocol for the first 2 weeks allowed for immediate weightbearing (as tolerated), elevation, ice bags, strengthening (active quadriceps setting in extension), and knee range of motion (ROM) exercises—namely, passive extension with a heel pad and assisted flexion with heel slides. The goal was full weightbearing without crutches within 10 days.

From 3 to 8 weeks postoperatively, gradual flexion was increased while maintaining full extension and patellar mobility. The protocol for this period included specific exercises: walking on a treadmill, cycling on an ergometer, swimming from week 3, stair-stepping from week 4, and jogging in a straight line. From 9 to 16 weeks postoperatively, the main goal of rehabilitation was to obtain and maintain full ROM with closed- and open-chain exercises, such as running with gradually increased duration and outdoor jogging from week 13. From 17 to 24 weeks postoperatively, sport-specific exercises were advised with a goal to optimize neuromuscular control with plyometric exercises.

Patients were allowed to return to active lifestyle if they achieved full ROM, the hop tests and strength of the hamstrings and quadriceps were $\geq$85% compared with the contralateral side, and the patient could tolerate sport-specific activities with no increase in pain and swelling.[1,15]

Evaluation of Muscle Strength

The Biodex System 3 Isokinetic Dynamometer (Biodex Corp) was used to measure the knee flexor and extensor isokinetic muscle strength of the patients to determine the PT value. Each patient sat upright on the testing chair with the knee and hip in a 90° position; straps were used to wrap around the patient's shoulder, waist, thigh, and ankle to minimize movement of the knee. Dynamometer and chair adjustments were done to find the midline. For the knee joint, the angular velocities were set to 60 and 180 deg/s. Three warm-up and practice repetitions were performed at submaximal effort before each testing. Then, patients were asked to perform 5 maximal concentric contractions for knee extensors and flexors at the 2 angular velocities; following a 1-minute interval, the last 10 maximal concentric contractions were performed at each velocity (Figure 4). There was a 5-minute rest between successive repetitions of 10. All tests were performed on both extremities, starting with the unoperated side. The patients were instructed to straighten the leg as forcefully and as fast as possible. Isokinetic knee extensor and flexor mean PT values were determined and were then standardized to body weight (PT/BW, %). All the tests were performed by a single observer (D.D.). Patients did not note any discomfort while testing.

Statistical Analysis

In the power analysis applied with the benefit of values from similar studies in the literature, the minimum sample size for each group was calculated to be 17 for an effect size of 1.07, test power 85%, and type 1 error of .05.

Conformity of the data to normal distribution was examined using visual (histogram and probability graphs) and analytical methods (Shapiro-Wilk test). For comparisons of data between the SF-preserved and SF-detached groups that showed nonnormal distribution, the Mann-Whitney *U* test was applied. In the comparison of

TABLE 1
Descriptive Characteristics of the Patients Included in the Study (N = 34)[a]

	SF-Preserved Group (n = 17)[b]	SF-Detached Group (n = 17)[c]	*P*
Sex[d]			
Male	15 (88.2)	12 (70.6)	.398
Female	2 (11.8)	5 (29.4)	
Mean ± SD	32.0 ± 8.2	32.6 ± 8.3	.822
BMI, kg/m^2	26.1 ± 2.6	27.1 ± 3.2	.317
BMI group, kg/m^{2}[d]			
<25	4 (23.5)	5 (29.4)	≥.999
25-30	11 (64.7)	10 (58.8)	
>30	2 (11.8)	2 (11.8)	
Operated knee[d]			
Right	13 (76.5)	10 (58.8)	.271
Left	4 (23.5)	7 (41.2)	

[a]Data are shown as n (%) or mean ± SD. BMI, body mass index; SF, sartorial fascia.
[b]SF tibial attachment–preserving technique.
[c]SF tibial attachment–removing technique.
[d]Column percentage was used.

categorical variables between independent groups, the Fisher exact test or chi-square test were used. Analysis of variance was performed to evaluate possible interactions. Data obtained in the study were analyzed statistically using SPSS for Windows 25.0 software (IBM SPSS Inc). *P* values of <.05 were considered statistically significant.

RESULTS

The mean age of the patients was 33.06 ± 10 years (median age, 30 y; range, 20-59 y; 27 male and 7 female). There were no differences between the groups in sex, operated side, mean age, or body mass index (Table 1).

The flexor and extensor knee isokinetic muscle strength analysis were built on the PT/BW ratio. The difference between the PT/BW ratios was examined for each knee joint across both groups. The results showed a significant group difference in the flexor muscle PT/BW value of the operated knee at 180 deg/s, with patients in the SF-preserved group having a higher flexor PT/BW value (0.68% ± 0.13% vs 0.52% ± 0.16% for the SF-detached group; *P* = .002). No statistically significant difference was determined between the groups in terms of extensor muscle strength at each velocity (Table 2).

The muscle strength deficit between the involved and uninvolved sides was also examined between the groups (Table 3). It was found that the deficit in flexor muscle PT/BW at 180 deg/s was significantly less in the SF-preserved group when compared with the SF-detached group (–0.17% ± 0.56% vs 0.23% ± 0.29%, respectively; *P* = .011). No significant differences were found between the groups at other angular velocities.

DISCUSSION

The most important result obtained in this study is that patients who underwent ACL reconstruction with the SF distal attachment preservation technique had better knee flexor strength than the patients who underwent surgery with the method in which the tibial attachment site of the SF was removed.[9] This finding emphasizes the critical role of the sartorius in deep flexion. Olewnik et al[19,20] observed 3 different variations (short, band, fan shape) in a cadaveric study related to the insertion of the pes anserinus. When these variations are taken into consideration, it can be predicted that donor-site morbidity will be increased in patients where a reverse L–shaped incision is made to the SF footprint. This risk of damage is eliminated when the HT is harvested with the technique described by Lanternier et al[16] through the incision made over the fascia without removing the SF footprint.

When the contralateral and ACL-reconstructed knees were compared in this study, there was, as expected, a decrease in knee flexor PT values in both techniques and at both angular velocities. In studies by Makihara et al[17], Sinding et al[24], and Tadokoro et al[25] a decrease in knee flexion PT values was observed after ACL

TABLE 2
Comparison Between Groups of Knee Flexor and Extensor Peak Torque/Body Weight (PT/BW) Ratio at 2 Angular Velocities[a]

	Involved Knee			Uninvolved Knee		
Muscle Strength	SF-Preserved Group	SF-Detached Group	*P*	SF-Preserved Group	SF-Detatched Group	*P*
Flexor PT/BW ratio, %						
60 deg/s	0.76 ± 0.33	0.77 ± 0.26	.946	0.91 ± 0.27	0.88 ± 0.30	.743
180 deg/s	0.68 ± 0.13	0.52 ± 0.16	**.002**	0.66 ± 0.18	0.66 ± 0.15	.919
Extensor PT/BW ratio, %						
60 deg/s	1.89 ± 0.51	1.75 ± 0.61	.483	2.13 ± 0.51	2.13 ± 0.68	.998
180 deg/s	1.16 ± 0.25	1.11 ± 0.35	.178	1.34 ± 0.35	1.27 ± 0.35	.372

[a]Boldface *P* value indicates statistically significant difference between groups (*P* < .05). SF, sartorial fascia.

TABLE 3
Comparison Between Groups of the Deficit Between the Involved and Uninvolved Sides[a]

Muscle Strength Deficit	SF-Preserved Group	SF-Detached Group	P
Flexor PT/BW ratio, %			
60 deg/s	0.16 ± 0.39	0.13 ± 0.31	.759
180 deg/s	–0.17 ± 0.56	0.23 ± 0.29	**.011**
Extensor PT/BW ratio, %			
60 deg/s	0.10 ± 0.30	0.10 ± 0.30	.305
180 deg/s	0.13 ± 0.29	0.16 ± 0.26	.774

[a]Boldface *P* value indicates statistically significant difference between groups ($P < .05$). SF, sartorial fascia.

reconstruction despite hamstring morphological regeneration. Results such as these have encouraged surgeons to attempt new methods to reduce donor-site morbidity in ACL reconstructions. In a study of 36 patients by Sasahara et al,[22] isometric measurements were taken after ACL repair using ST graft only, and it was reported that the deep knee flexion torque loss was reduced due to the partial harvesting technique partially protecting the footprint.

The results obtained in the current study with the protection of the anatomic integrity of the SF demonstrate that the knee flexor muscle strength loss created after ACL reconstruction can be reduced. Different rehabilitation protocols might have been effective to improve hamstring strength in both groups.

In a systematic review by Sharma et al,[23] higher knee flexion PT values were recorded for patients with ACL reconstruction performed using the semitendinosus only compared with those where both semitendinosus and gracilis were used. In the isometric measurements of 46 patients taken 1 year after ACL reconstruction, Yosmaoglu et al[28] observed that in comparison with the contralateral side, the flexion deficit in the semitendinosus-gracilis group was significantly greater than that of the semitendinosus group. Adachi et al[1] reported that harvesting of both HTs caused loss of strength and a decrease in deep knee flexion power. Future studies could show minimized knee flexion strength loss in ACL reconstruction made using only the semitendinosus and the SF tibial attachment–preserving technique. The results in our study could be meaningful for those engaged in sports and functional activities that require high hamstring strength such as American football, wrestling, and gymnastics.[21]

In the SF distal insertion preservation technique, a slightly different approach was used for tibial fixation, where the cut ends of the SF were sutured to cover up the staple, which could help to minimize the risk of irritation.[26,27]

Strengths and Limitations

This is the first study in the literature that has evaluated the SF tibial attachment–preserving technique in ACL reconstruction by comparing muscle strength measurements of patients. The strengths of the study are that the patient groups were homogeneous with respect to age and sex and that patients were evaluated at postoperative 2-year follow-up, which was considered sufficient for regeneration.

There were some limitations of this study. Although the patient groups were homogeneous, it was not a randomized controlled study. The type of sport played by the participants, along with the frequency and intensity of the hamstring and knee flexor dominance involved during sport performance, were not documented during the rehabilitation period. Details regarding the likely role played by sports in rehabilitation were not specified in the study because the composition of the patient groups was not solely sports professionals. Even though no statistically significant difference was determined in other comparisons, a clear weakness of flexors and extensors was noted between the SF-preserved and SF-detached groups. The small sample size could also be seen as a limitation. Further studies with larger patient groups using the same parameters would strengthen the evidence of the SF tibial attachment–preserving technique.

CONCLUSION

The results of this study demonstrated that ACL reconstruction using the SF tibial attachment–preserving technique was associated with better knee flexor strength.

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