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The new auto graft technique in anterior cruciate ligament reconstruction

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ABSTRACT

OBJECTIVE: In our study, our aim was to compare the clinical outcomes of utilizing a 6-stranded hamstring autograft (HAG) lacking tibial attachment site separation in Anterior Cruciate Ligament Reconstruction (ACLR), an approach previously unreported in literature, with alternative methodologies.

METHODS: A total of 85 patients admitted to our Orthopedics and Traumatology clinic between April 2019 and July 2022 with Anterior Cruciate Ligament (ACL) rupture, who underwent surgical treatment, were retrospectively analyzed. ACLR was initiated using HAG in all patients. The surgical procedure was determined based on the length of the HAG used during ACLR. In all cases, femoral fixation was performed with an adjustable loop endobutton. 3 methods were applied to all patients. These are: repair with a 6-strand hamstring tendon graft without severing the tibial insertion (new method), repair with 4-strand hamstring tendon graft without severing the tibial insertion and repair with 4-strand hamstring tendon graft without protecting the tibial insertion. Preoperative and postoperative International Knee Documentation Committee (IKDC) subjective evaluation score, Lysholm score and Tegner activity score were used in the evaluation of the patients. Comparisons between groups were made according to these scores.

RESULTS: 78 patients were included in the study. There were 31 patients in Group 1, 23 in Group 2 and 24 in Group 3. The mean age of the patients was 29 (19–40) in Group 1, 32 (16–49) in Group 2 and 31 (18–54) in Group 3. In the comparison of the groups, there was a significant increase in tendon thickness in Group 1 ($p<0.001$) and a significant decrease in the rate of re-rupture as a complication ($p<0.05$). There was no statistically significant difference between the groups in terms of age, side of surgery, follow-up period, and length of hospital stay. There was statistical significance between Group 1 and Group 2 in terms of tendon diameter ($p<0.05$) and re-rupture ($p<0.05$). In the comparison of Group 2 and Group 3, there was statistical significance between Group 2 and Group 3 in terms of tendon thickness and length of hospital stay ($p<0.05$), while no significant difference was found in terms of re-rupture ($p>0.05$).

CONCLUSION: ACLR with 6-strand tendon graft with preservation of the HAG insertion is not a method described in the literature. As a result of our study, it was concluded that the functional results of this newly described method are as good as other methods and have lower re-rupture rates.

Keywords: ACL reconstruction; graft diameter; tibial attachment site.

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The knee is a weight-bearing joint that is stabilized by several supporting structures [1]. The greatest stabilizing force in the knee is provided by the cruciate ligaments [2]. Injury to the anterior cruciate ligament (ACL) causes instability in the knee, leading to meniscal and cartilage damage. This can lead to accelerated degeneration [3]. Several graft options are available for ACL rupture. Hamstring autograft (HAG) is the most commonly used graft in the surgical technique for Anterior Cruciate Ligament reconstruction (ACLR) [4]. Graft diameter is a major concern when using HAG in reconstruction [5–7]. One of the major causes of failure in ACLR is a graft diameter of less than 8 mm [8]. Another matter of concern when using HAG in ACLR is the inadequate strength of tibial fixation. The density of cancellous bone in the proximal tibial epiphysis is lower than in the distal femoral epiphysis. Moreover, the tensile forces are aligned with the axis of the tibial tunnel, as opposed to the angle of the graft and femoral tunnel [9]. Suggestions have been proposed that HAG tibial insertion should be preserved in order to maintain vascular supply to the tendons [10, 11].

In our study, our aim was to compare the clinical outcomes of utilizing a 6-stranded HAG lacking tibial attachment site separation in ACLR, an approach previously unreported in literature, with alternative methodologies.

Highlight key points

- Anterior Cruciate Ligament reconstruction with 6-strand tendon graft with preservation of the Hamstring Autogreft insertion is not a method described in the literature.
- The functional results of this newly described method are as good as other methods and have lower re-rupture rates.
- The new surgical technique we describe should be applied because of the lower rate of re-rupture.

MATERIALS AND METHODS

Clinical research ethics committee approval was obtained for this study. Gaziantep University Clinical Research Ethics Committee (date: 29.08.2023, number: 203/2023). Our study was carried out in accordance with the Declaration of Helsinki. A total of 85 patients admitted to our Orthopedics and Traumatology clinic between April 2019 and July 2022 with ACL rupture, who underwent surgical treatment and were retrospectively analyzed. The subsequent follow-up and treatment were also conducted in our clinic. Surgical treatment was indicated for patients exhibiting a positive (+) Lachman test during physical examination, instability complaints (e.g., feeling of falling into a gap, feeling of insecurity) and confirmed ACL rupture in the MRI report. All patients underwent surgery performed by the same surgeon. The study excluded patients with previous ACLR surgery, those who had undergone repair of knee ligaments other than the ACL, and those with chondral damage. Records of identified patients were consulted and they were subsequently contacted via telephone for their final examination at the outpatient clinic. The patients were given a full explanation of the study and their informed consent was obtained. The study recorded age, gender, surgical side, and the presence of meniscal pathology if applicable. Additionally, the procedure performed on the meniscus, duration of the operation, the patient's length of stay in hospital, and intraoperative tendon thickness were noted.

International Knee Documentation Committee (IKDC) subjective evaluation score, Lysholm score, and Tegner activity score from the preoperative evaluation at the initial visit were recorded in the patients' files. Thereafter, the scores at the 6-month postoperative visit were also documented. Finally, the score at the last visit was recorded. Higher scores on the IKDC subjective assessment score, Lysholm score, and Tegner activity score indicate better function [4]. Patients exhibiting symptoms of pain and a sensation of instability, or who tested positive on the Lachman or Pivot-shift tests during their last visit or periodic check-ups, were requested to undergo a follow-up Magnetic Resonance Imaging (MRI). The rate of re-rupture was then calculated.

Surgical Technique

The surgical procedure was determined based on the length of the HAG used during ACLR. Diagnostic arthroscopy was initially carried out on all patients to confirm ACL rupture and investigate other pathologies. Any concomitant pathology was identified and treated arthroscopically, following which ACLR was initiated using HAG in all patients. In all cases, the Grasilis and Semitendinosus tendons were accessed via a 4 cm oblique incision medial to the tuberosity tibia, directly over the pes anserinus. The HAG was extracted using an open-ended tendon stripper without separating the tibial insertion. Tendons were cleared of muscle tissue. The points of insertion in the tibia were connected and secured by a suture (Fig. 1). The measurement of the length of the HAG was subsequently taken.

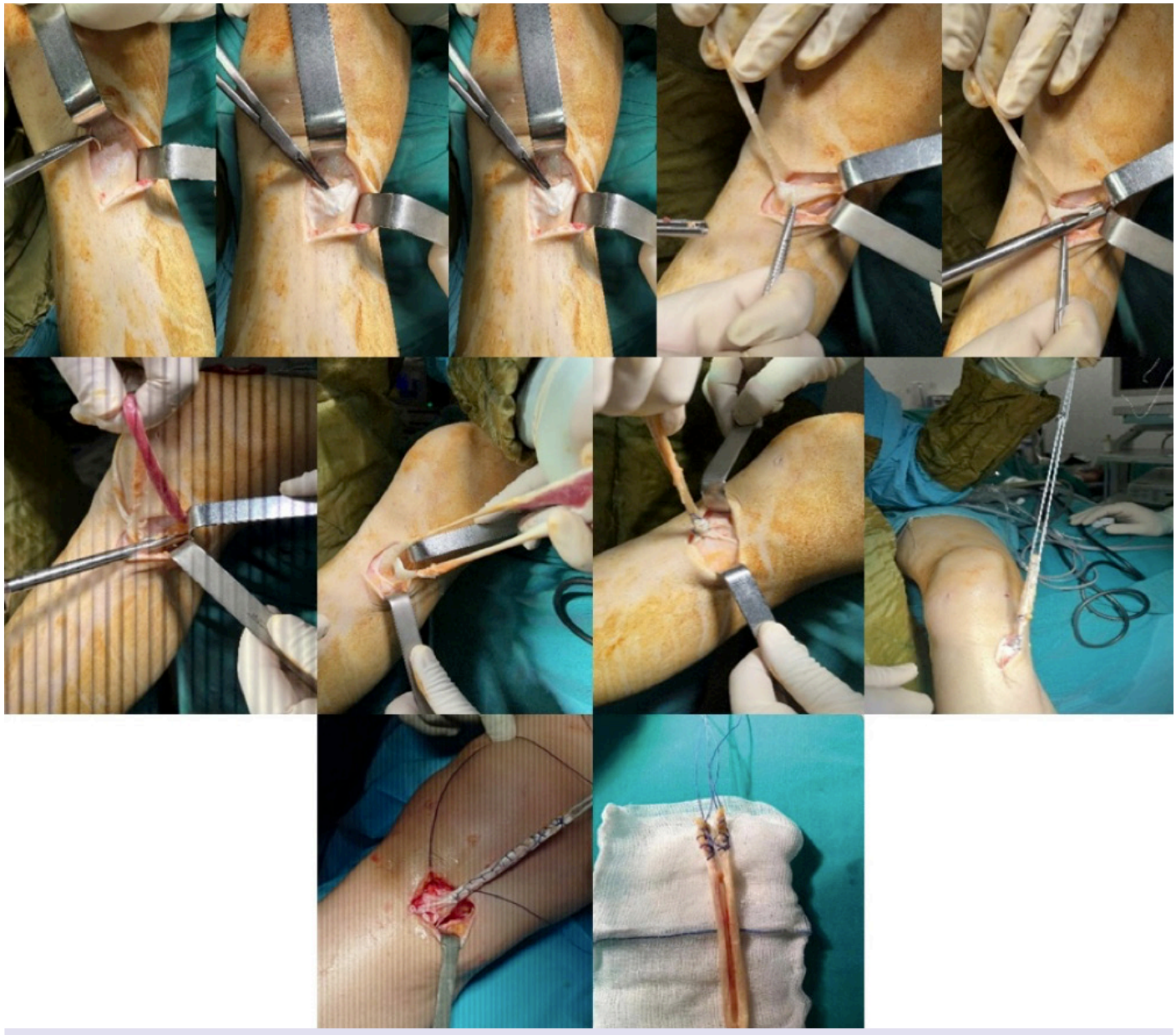

FIGURE 1. The new auto graft technique in anterior cruciate ligament reconstruction.

In all cases, femoral fixation was performed with an adjustable loop endobutton (ZipTight Fixation device (Biomet, Warsaw, IN)) (hereafter referred to as endobutton). In all cases, the femoral tunnel was first opened with a 5 mm drill, which was necessary for the button of the endobutton to pass through. Afterward, a 30 mm deep tunnel entrance in the thickness of the tendon graft was enlarged with a drill. Then, starting 2.5 cm distal to the joint space and 1.5 cm medial to the tuberosity of the tibia, the tibial tunnel was opened with the help of a 55° tibial guide from the anterior horn of the lateral meniscus 6 mm in front of the posterior cruciate ligament to the end of the ACL stump. Afterward, the femoral tunnel entrance from the HAG insertion and the tibial tunnel exit from the femoral tunnel entrance (length of the graft in the joint) were measured. In all cases, 2 cm tendon was calculated in the femoral tunnel. In the tibial tunnel, the same tendon of at least 2 cm was required. Therefore, according to the calculations as 3x femoral tunnel length (6 cm) + 3x intra-articular distance (femoral tunnel entrance-tibial tunnel exit) (average 9 cm) + distance between tibial tunnel exit and HAG insertion (average 6 cm) + 2x maximum graft amount in tibial tunnel (4 cm), the repair technique with 6-strand tendon graft without separating the HAG and tibial insertion was applied (new method) (average 25 cm and above).

According to the calculations of double femoral tunnel length (4 cm) + 2x intra-articular distance (femoral tunnel entrance-tibial tunnel exit) (average 6 cm) + 2x tibial tunnel distance (average 10 cm) + HAG insertion and tibial tunnel insertion (average 2 cm), the repair technique was performed with 4-threaded tendon graft without tearing the tibial insertion with the HAG of the length matching the result (average 22 cm and above).

The tendon grafts of the patients whose HAG length was not suitable for the above two methods were separated from the insertion and repair technique was applied with a 4-threaded tendon graft that did not protect the tibial insertion.

Repair with a 6-Strand Hamstring Tendon Graft without Severing the Tibial Insertion (New Method)

After deciding the method according to the length of the HAG, the tendon graft was hanged on the endobutton. The tendon graft was folded at the calculated measurement (distance between the insertion and femoral tunnel entrance + 2 cm for femoral tunnel) and 1 suture was placed. Then, while the endobutton was suspended in the air and the graft was stretched, the remaining part of the graft was folded in half and the layers were fixed to each other continuously with absorbable sutures. The thickness of the graft was then measured. Afterward, the femoral and tibial tunnel diameter was remeasured again in accordance with the graft diameter. The knee was then flexed to 120°. Afterward, the threads of the endobutton were passed first through the tibial tunnel and then through the femoral tunnel and removed from the lateral thigh. The knee was flexed to 90° and the threads used to slide the endobutton into the femoral tunnel were removed from the anteromedial portal. The threads were retracted in accordance with the axis of the femoral tunnel and the graft was placed in the tibial and femoral tunnel. The marker suture on the graft was observed with an optical camera and the graft was slid through the tunnels until it was completely placed in the femoral tunnel. The tension of the graft was checked. Then the knee was flexed 30° and the distal part of the graft was fixed with a bioabsorbable screw suitable for the width of the tibial tunnel. Then the threads in the medial port were cut at the femoral tunnel entrance. Finally, the placement of the graft and the position of the graft during knee movements were evaluated arthroscopically.

Repair with 4-Strand Hamstring Tendon Graft without Severing the Tibial Insertion

After the method was decided according to the length of the HAG, the tendon graft was hanged on the endobutton. The tendon graft was folded from the calculated measurement (distance between the insertion and femoral tunnel entrance + 2 cm for femoral tunnel) and the layers were fixed to each other continuously with absorbable sutures. The thickness of the graft was then measured. Afterward, if necessary, the femoral and tibial tunnel diameter was remodeled again in accordance with the graft diameter. Then the graft was fixed through the tunnels as described above.

Repair with 4-Strand Hamstring Tendon Graft without Protecting the Tibial Insertion

According to the length of the HAG, this method was applied to patients in whom the other 2 methods would not be applied. The HAG was separated from its insertion. Afterward, it was passed through the endobutton, folded in 2, and the distal ends were fixed with continuous non-absorbable sutures. The thickness of the graft was then measured. Afterward, if necessary, the femoral and tibial tunnel diameter was remodeled according to the graft diameter. The graft was then passed through the tunnels as described above. With the knee in 10°–20° flexion, the distal part of the graft was fixed to the tibial tunnel with a bioabsorbable screw while keeping the graft in tension. Then, the distal fixation of the HAG was strengthened with U staple application. If the HAG was too short to exit from the tibial tunnel, non-absorbable sutures used for distal fixation were wrapped around the U staple legs.

In addition, in all cases, the distal part of the HAG was fixed with a 35 mm long bioabsorbable screw correlated with the tunnel diameter. Finally, intra-articular flushing was performed in all methods. Hemovac drains were placed in the graft area and the joint. Portals and skin incisions were sutured. Post-operative angle-adjustable knee brace was used in all patients. Patients without meniscal suturization were given partial load with crutches on post-operative day 1 and full load was planned to be given 2 weeks later. Knee exercises were started. Patients who underwent meniscal suturization were started to give partial load after 3 weeks and full load was planned to be given after 5 weeks. Knee range of motion (ROM) was planned to be completed gradually in 4 weeks. Skin sutures were removed at 2 weeks of age.

Table 1. Demographic and operative data of the cases according to groups

	Group 1 (n=31)	Group 2 (n=23)	Group 3 (n=24)	p
Age	29 (19–40)	32 (16–49)	31 (18–54)	0.268
Gender (%)				
Male	13	35	67	**<0.001**
Female	87	65	33	
Side (%)				
Right	52	148	58	0.764
Left	48	52	42	
Follow-up period (month)	14 (12–17)	14 (12–24)	16 (12–36)	0.131
Stay in hospital (day)	2 (1–7)	1 (1–3)	2 (1–5)	0.264
Operation time (min)	117 (84–164)	108 (73–163)	97 (62–135)	**0.007**
Tendon thickness (mm)	9 (8–10)	8 (7–9)	8 (7–9)	**<0.001**
Meniscus tear (%)				0.239
Medial	45	33	33	
Lateral	6	13	0	
Meniscus operation (%)				**0.002**
Meniscectomy	7	4	29	
Suturation	45	44	4	
Complications (%)				
Re-rupture				**0.038**
0–3 month			8	
1–6 month			21	
1–9 month		9	25	
1–12 month		13	29	
>12 month			4	
Infection (%)	3		4	0.636
Deep vein thrombus (%)	3			0.464
Total (%)	7	13	38	

Routine follow-up visits were performed at 4, 6, 8 and 12 weeks and at 3 and 6 months. Patients who underwent ACLR were allowed to climb stairs after 8 weeks, run on flat surfaces after 3 months, and participate in pivot sports after 6 months.

Patients who underwent ACLR with 6-strand HAG without separating the tibial insertion (new method) were grouped as Group 1. Patients who underwent ACLR with 4-thread HAG without separating the tibial insertion were grouped as Group 2. Patients who underwent ACLR with 4-thread HAG with separation of the tibial insertion were grouped in Group 3. The difference between Groups 1 and 2 was the tendon thickness (4-thread and 6-thread). The difference between groups 2 and 3 was whether the insertion of the HAG used was separated or not.

Statistical Analysis

Statistical analyses were performed using the Statistical Package of the Social Sciences (IBM SPSS 28.0.1.0; Corp., Armonk, NY, USA). The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov-Simirnov/Shapiro-Wilk's test) to determine whether or not they are normally distributed. Descriptive analyses were presented using means and standard deviations for normally distributed variables, medians and interquartile range (IQR) for the non-normally distributed variables. The Chi-square test or Fisher's exact test was used to compare proportions in different groups. One-way ANOVA was used to compare the groups. The correlation between the groups was measured with the help of the Pearson correlation test. These

Table 2. Evaluation of functional outcomes of patients

	Group 1 (n=31)	Group 2 (n=23)	Group 3 (n=24)	p
Pre-operation				
Lysholm Knee Scoring Scale	34 (22–54)	38 (26–48)	32 (22–46)	**0.021**
Tegner Activity Level Scale	1 (0–4)	1 (0–3)	1 (0–2)	0.256
2000 IKDC Subjective Knee Evaluation Form	31 (22–50)	34 (22–50)	26 (20–34)	**0.001**
Post-operation 6th month				
Lysholm Knee Scoring Scale	56 (32–78)	62 (40–76)	63 (44–84)	**0.045**
Tegner Activity Level Scale	3 (0–7)	3 (0–6)	3 (0–6)	0.756
2000 IKDC Subjective Knee Evaluation Form	51 (28–72)	55 (34–68)	52 (32–72)	0.531
The last follow-up				
Lysholm Knee Scoring Scale	85 (58–100)	83 (46–100)	83 (47–100)	0.801
Tegner Activity Level Scale	6 (0–10)	6 (1–10)	7 (3–10)	0.401
2000 IKDC Subjective Knee Evaluation Form	72 (41–88)	71 (52–82)	70 (45–83)	0.903

IKDC: International Knee Documentation Committee.

tests were chosen within the framework of the general rules in statistics, depending on the characteristics of the dependent and independent variables. The significance level was set at $p<0.05$.

RESULTS

78 patients were included in the study. There were 31 patients in Group 1, 23 in Group 2 and 24 in Group 3. The mean age of the patients was 29 (19–40) in Group 1, 32 (16–49) in Group 2 and 31 (18–54) in Group 3 (Table 1). The mean follow-up period was 14 (12–17) months in Group 1, 14 (12–24) months in Group 2 and 16 (12–36) months in Group 3 (Table 1).

In the comparison of the groups, there was a significant increase in tendon thickness in Group 1 ($p<0.001$) and a significant decrease in the rate of re-rupture as a complication ($p=0.038$) The groups were statistically different in terms of operation time ($p=0.007$), procedure performed on meniscal pathologies ($p=0.002$), and re-rupture as a complication ($p=0.038$) (Table 1).

There was no statistically significant difference between the groups in terms of age, side of surgery, follow-up period, and length of hospital stay. There was a statistically significant difference between the groups in terms of gender ($p<0.001$) (Table 1).

The mean IKDC subjective evaluation score, Lysholm score and Tegner activity scores were obtained preoperatively, post-operative 6th month and at the last visit. Statistical analysis was also performed according to the scores of the groups (Table 2). Afterward, statistical analyses were performed between the HAG diameters of the patients and their preoperative, postoperative and final visit activity scores. In addition, sta-

Table 3. Comparison of tendon thickness and functional outcomes

	Tendon thickness 'p'
Re-rupture	0.819
Pre-operation	
Lysholm Knee Scoring Scale	0.821
Tegner Activity Level Scale	0.114
2000 IKDC Subjective Knee Evaluation Form	0.484
Post-operation 6th month	
Lysholm Knee Scoring Scale	0.379
Tegner Activity Level Scale	0.957
2000 IKDC Subjective Knee Evaluation Form	0.760
The last follow-up	
Lysholm Knee Scoring Scale	0.225
Tegner Activity Level Scale	0.354
2000 IKDC Subjective Knee Evaluation Form	0.548

IKDC: International Knee Documentation Committee.

Table 4. Operation data in group 1–2

	Group 1 (n=31)	Group 2 (n=23)	p
Follow-up period (month)	14 (12–17)	14 (12–24)	0.614
Stay in hospital (day)	2 (1–7)	1 (1–3)	0.365
Operation time (min)	117 (84–164)	108 (73–163)	0.201
Tendon thickness (mm)	9 (8–10)	8 (7–9)	**<0.001**
Complications (%)			
Re-rupture			**0.039**
0–3 month			
1–6 month			
1–9 month		9	
1–12 month		13	
>12 month			
Infection (%)	3		0.385
Total (%)	3	13	

Table 5. Evaluation of functional outcomes of patients in group 1–2

	Group 1 (n=31)	Group 2 (n=23)	p
Pre-operation			
Lysholm Knee Scoring Scale	34 (22–54)	38 (26–48)	0.052
Tegner Activity Level Scale	1 (0–4)	1 (0–3)	0.462
2000 IKDC Subjective Knee Evaluation Form	31 (22–50)	34 (22–50)	0.221
Post-operation 6th month			
Lysholm Knee Scoring Scale	56 (32–78)	62 (40–76)	**0.047**
Tegner Activity Level Scale	3 (0–7)	3 (0–6)	0.496
2000 IKDC Subjective Knee Evaluation Form	51 (28–72)	55 (34–68)	0.291
The last follow-up			
Lysholm Knee Scoring Scale	85 (58–100)	83 (46–100)	0.505
Tegner Activity Level Scale	6 (0–10)	6 (1–10)	0.609
2000 IKDC Subjective Knee Evaluation Form	72 (41–88)	71 (52–82)	0.816

IKDC: International Knee Documentation Committee.

tistical analysis was performed between HAG tendon diameter and re-rupture among complications. And no statistical significance was found (Table 3). In addition, statistical analysis was performed between the duration of operation and infection. No statistically significant relationship was found (p=0.213).

Group 1 and Group 2 were compared (Table 4). There was statistical significance between Group 1 and Group 2 in terms of tendon diameter (p<0.001) and re-rupture (p=0.039). In other words, we found that the risk of re-rupture decreased as the tendon diameter increased. In addition, in the evaluation of the functional results of Group 1 and Group 2, there was a statistical difference in the Lysoholm score at the 6th post-operative month (p=0.047), while no difference was detected in all other scores. In other words, it can be said that there was no difference in the functional results of the two methods (Table 5).

Table 6. Operation data of group 2–3

	Group 2 (n=23)	Group 3 (n=24)	p
Follow-up period (month)	14 (12–24)	16 (12–36)	0.223
Stay in hospital (day)	1 (1–3)	2 (1–5)	**0.047**
Operation time (min)	108 (73–163)	97 (62–135)	0.083
Tendon thickness (mm)	8 (7–9)	8 (7–9)	<**0.001**
Complications (%)			
Re-rupture			0.101
0–3 month		8	
1–6 month		21	
1–9 month	9	25	
1–12 month	13	29	
>12 month		4	
Infection (%)		4	0.322
Total (%)	13	38	

Table 7. Evaluation of functional outcomes of patients in group 2–3

	Group 2 (n=23)	Group 3 (n=24)	p
Pre-operation			
Lysholm Knee Scoring Scale	38 (26–48)	32 (22–46)	**0.002**
Tegner Activity Level Scale	1 (0–3)	1 (0–2)	0.389
2000 IKDC Subjective Knee Evaluation Form	34 (22–50)	26 (20–34)	<**0.001**
Post-operation 6th month			
Lysholm Knee Scoring Scale	62 (40–76)	63 (44–84)	0.792
Tegner Activity Level Scale	3 (0–6)	3 (0–6)	0.498
2000 IKDC Subjective Knee Evaluation Form	55 (34–68)	52 (32–72)	0.422
The last follow-up			
Lysholm Knee Scoring Scale	83 (46–100)	83 (47–100)	0.953
Tegner Activity Level Scale	6 (1–10)	7 (3–10)	0.348
2000 IKDC Subjective Knee Evaluation Form	71 (52–82)	70 (45–83)	0.831

IKDC: International Knee Documentation Committee.

In the comparison of Group 2 and Group 3, there was statistical significance between Group 2 and Group 3 in terms of tendon thickness and length of hospital stay (p=0.047), while no significant difference was found in terms of re-rupture (p=0.101) (Table 6). In addition, in the evaluation of the functional results of Group 2 and Group 3, the scores at post-operative 6th month and at the last visit were statistically similar (Table 7).

DISCUSSION

We use hamstring autograft in all patients included in our study. If the length of the HAG is sufficient, we try to perform the insertion without separation. Previously, we used to take a third HAG from the other knee (semitendinosus or gracilis, we usually try to obtain a graft over 8 mm) for patients with less tendon thickness. However, we abandoned this because of the comorbidity of the in-

tact knee. If the length of our existing graft is sufficient, we thought of increasing the diameter by folding it on itself. In current study, we wanted to determine whether there is a difference in ACL reconstructions performed by making the HAG 6-stranded without separating its insertion, which has not been encountered in the literature before.

In our study, there were patients who underwent ACLR with 4-fold or 6-fold grafts with preservation of the HAG insertion and patients who underwent ACLR with 4-thread HAG repair without preservation of the HAG insertion. The main difference between the patients with 4-thread and 6-thread tendon grafts was tendon thickness. There was a statistically significant difference between these two groups in terms of re-rupture. Our new surgical method, ACLR with 6-strand HAG without separation of the tibial insertion, had a significantly lower re-rupture rate than the others (none).

Another major concern for all of us when using hamstring tendons is the graft diameter. The literature reports that the results after ACLR are less than optimum in 20% of cases. It states that one of the reasons for failure is grafts with a diameter less than 8 mm. Therefore, larger graft diameter (greater than 8 mm) is preferred to achieve better graft survival and stability [6, 12–15]. In addition, Spragg et al. [7] reported that in the range of 7.0–9.0 mm, each 0.5 mm increase in graft diameter decreased the risk of revision by 0.82 times. On the other hand, Wernecke et al. [16] found no significant correlation between graft diameter and revision rate or clinical outcomes. In our study, in accordance with the literature, it was observed that the patient group with a larger graft diameter had less revision or less re-rupture.

In ACLR, it is known that the free graft undergoes necrosis within 4 weeks and then revascularizes and ligamentizes. During this period, the graft is weak and there is a possibility of rupture. It merges with bone tunnels around 6 to 12 weeks postoperatively. Concerns about potential failure of the graft used in reconstruction include tunneling out before graft-tunnel healing occurs or rupture before ligamentation occurs [17–19]. Tibial fixation of the tendon graft is a weak point in ACLR. The ability of the interference screw used for distal fixation to prevent the HAG from exiting the tibial tunnel is directly related to bone quality. The density of cancellous bone in the proximal tibial epiphysis is less than in the distal femoral epiphysis. In addition, tensile forces are angled in the femoral tunnel. In contrast, tensile forces are parallel to the tunnel axis in the tibial tunnel [9, 20, 21]. Therefore, preservation of the HAG tibial insertion has both mechanical and biological advantages. Some studies in the literature have shown that when the HAG insertion is preserved, postoperative avascular necrosis does not occur and nutrition is provided, thus increasing graft viability [11, 22]. Hamstring tendons have longitudinal blood vessels located at the distal osteotendinous and proximal musculotendinous junction. With this technique, the proximal musculotendinous portion is harvested while the distal blood vessels are preserved [19].

Zaffagnini et al. [23] reported that the tibial insertion of HAG tendons has abundant vascularization and innervation. Ruffili et al. [11] used MRI to compare the effects of preservation versus detachment of the HAG tibial insertion on its ligamentation at 6 months postoperatively. It was suggested that preservation of the HAG insertion increased intra-articular ligamentation. Sever and Cankus [4] also stated that preservation of the HAG insertion does not impair graft nutrition and increases graft incorporation. Liu et al. [10] found a significant change in MR signal intensity in the first 2 years of ACLR in the group in which the HAG insertion was preserved compared to the group in which it was not preserved. The difference was most significant in the post-operative 6^{th} and 12^{th} months. In our study, we tried to preserve the insertion as much as the length of the HAG permitted. There are many publications in the literature regarding the preservation of the insertion to maintain graft viability and to reduce the rate of re-rupture [4, 10, 11, 22, 23]. However, in our study, although it was not statistically significant between those whose insertion was preserved and those whose insertion was not preserved, numerically more ruptures were observed in those whose insertion was not preserved. This may be due to the small number of patients in our study and the short follow-up period.

Complications such as injury of the medial collateral ligament, early amputation of the tendon, and injury of the infrapatellar branch of the saphenous nerve may occur during hamstring tendon removal [24]. In the literature, the prevalence of injury to the infrapatellar branch of the saphenous nerve has been reported between 21–83% [1]. Likewise, in the literature, it was stated that applying the Figure 1 position with the patient's knee flexion, hip abduction and external rotation during HAG harvest reduces the risk of injury by allowing the saphenous nerve located on the gracilis to relax [25]. Two meta-analyses found that the risk of in-

jury to the infrapatellar branch of the saphenous nerve during ACLR was significantly higher with vertical incisions than oblique incisions [26, 27]. In our study, we used oblique incision for HG harvesting in all cases and placed the leg in the Figure 1 position. We did not see any saphenous nerve-related complications in any of our patients. Bahlau et al. [9] conducted a biomechanical study on tibial tunnel attachment in ACLR. They found that only the group with preserved HAG insertion was 33% more robust against vertical loading than the group with unprotected insertion + screw fixation. They found a 65% difference between preserved insertion + screw fixation and free graft + screw fixation. In our study, we used bioabsorbable screws suitable for the distal tunnel diameter in all patients.

In all patients in whom we performed ACLR, we used an endobutton with adjustable loop for femoral fixation. Gudas et al. [8] reported that the average intra-articular tendon length was 30 mm and the average intra-tunnel length on the femoral and tibial side was 20 mm. They found an average tibial tunnel length of 45–50 mm. We carved the femoral tunnel 30 mm deep in all our patients. We placed the HAG in a 20 mm femoral tunnel.

One of the biggest concerns, especially in methods where the HAG insertion is preserved, is the adjustment of the tension of the graft. Kim et al. [28] investigated the change in graft length at the exit of the tibial tunnel when the graft was retracted at 30° flexion with a force of 30 Ibs and a change in graft length between 0.4 and 0.6 mm was observed. Therefore, Sever and Cankus [4] found that a 1 cm tension allowance was appropriate for the graft in the femoral tunnel. In our study, a femoral tunnel equal to the diameter of the graft was opened and the graft was placed in the tunnel.

In our study, there was a significant decrease in the re-rupture rate in our results compared to the other types of our new method, which aims to both protect the insertion and increase the graft diameter. Protecting the insertion may help to maintain viability and this may reduce the re-rupture rate. However, according to the results of our study, there was no statistical decrease in the re-rupture rate between the groups in which the insertion was preserved and those in which it was not preserved. However, the graft diameter increased in our new method in which the graft diameter increased. We think that graft diameter is one of the most important factors for the health of the newly reconstructed ACL.

The main limitation of our study is that it is retrospective. One of the limitations of our study is the length of the HAG we used. We had to use other methods in grafts that were not long enough to apply our new method. Another limitation is that some of our patients had meniscal pathology while others did not. Some of the patients with meniscal pathology had undergone meniscal suturization and knee exercises were started late. Therefore, the same rehabilitation could not be applied to all of them.

Conclusion

To our knowledge, ACLR with 6-strand tendon graft with preservation of the HAG insertion is not a method described in the literature. As a result of our study, it was concluded that the functional results of this newly described method are as good as other methods and have lower re-rupture rates. We suggest that the new surgical technique we describe should be applied because of the lower rate of re-rupture. Prospective studies with long-term follow-up in larger patient groups are needed.

Ethics Committee Approval: The Gaziantep University Clinical Research Ethics Committee granted approval for this study (date: 29.08.2023, number: 203/2023).

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