European **Rev**iew for **Med**ical and **Pharmacol**ogical **Sci**ences 2022; 26: 8289-8302

Tibial graft fixation in anterior cruciate ligament reconstruction: multiple tibial tunnel technique (collateral tunnel technique)

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Abstract. – OBJECTIVE: This study aimed to compare the outcomes of patients with an anterior cruciate ligament (ACL) rupture who underwent tibial fixation using the multiple tibial tunnel fixation (MTTF) and standard tibial fixation methods.

PATIENTS AND METHODS: This retrospective study was conducted between January 1, 2020, and August 1, 2021. MTTT was applied to 43 patients diagnosed with ACL rupture. Of the 43 patients who met the study criteria, 38 were classified as Group 1. In the clinic where the study was conducted, 40 of 57 patients who underwent standard ACL reconstruction by opening a single tibial tunnel were assigned to Group 2. The Endobutton technique was used for fixation of the graft to the femur in both groups. Bioabsorbable and postfix screws were used for the tibial fixation of the patients in Group 2. For patients in Group 1, a bioabsorbable screw, a postfix screw, and an additional MTTT fixation were performed for tibial fixation. Lachman, anterior drawer, Pivot-Shift test results, Lysholm and IKDC knee evaluation scores of the patients in both groups were compared.

RESULTS: In this study, there was no significant difference between the groups for the anterior drawer, Lachman, and Pivot-Shift test results at the final control ($p > 0.05$). There was a significant difference between the two groups for the Lysholm and IKDC scores at the final controls ($p < 0.05$). There was a significant difference in the Lysholm and IKDC scores between the groups ($p < 0.05$).

CONCLUSIONS: In conclusion, ACL reconstruction was performed using the MTTF technique in this study. Due to the additional fixation, it was observed that the patients had a more successful knee function after the surgery.

Key Words:

Anterior cruciate ligament tear, Tibial fixation, Arthroscopy, Anterior cruciate ligament.

Introduction

Reconstruction of the anterior cruciate ligament (ACL), the most injured knee ligament is among the most performed knee surgeries. While the incidence of ACL cases was found to be 33 per 100,000 people in 1994, it was determined that this rate increased to 40-60 per 100,000 in people 2014[1,2]. Approximately 200,000 ACL reconstructions are performed in the United States every year and this number is expected to increase due to the popularity of sports activities among adolescents[1-4].

Several factors affect the success of ACL reconstruction, including the patient's age, low bone mineral level, presence of additional ligament injuries, graft selection, and the implant used for fixation. The inadequacy of tibial soft tissue graft fixation is thought to be the main cause of failure and loosening in the early stage of ACL reconstruction[5-7]. Therefore, many tibial soft tissue graft fixation methods have been developed[5-7]. In the Tetsumura study, four types of tibial fixation of the graft were compared using a biomechanical study. This study shows that the initial fixation strength of the hamstring tendon can be increased by using an interference screw combined with a double spike plate for tibial fixation[6].

Graft integration into the bone tunnel occurs approximately at the 12th week after surgery, and early physical therapy has an important effect on the clinical outcome of ACL reconstruction surgery[8]. Therefore, secure fixation is required to prevent displacement and disruption of the graft integration process in the postoperative period[8,9]. Patel et al[10] stated that the graft fixation method has an important place in the initial stability of ACL reconstruction and the tibial fixation area is the weakest point of graft fixation. The in-tunnel technique, the extra-tunnel technique (suspended

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fixation) and hybrid fixation techniques are used to increase tibial fixation[10]. However, biomechanical studies showed that there was no significant difference between these fixation methods[10]. In this study, an additional fixation was made for tibial soft tissue graft fixation. It is proposed that soft tissue grafts can be fixed to the tibia more stably using the Multiple Tibial Tunnel Technique (MTTT). This study aimed to compare the outcomes of patients with an ACL rupture who underwent tibial fixation using the MTTT and standard tibial fixation methods.

Patients and Methods

This retrospective study was conducted between January 1, 2020, and August 1, 2021, with patients aged over 18 years with an ACL rupture. Patients who did not continue their follow-up, had a follow-up period of less than 12 months, and who had incomplete records were excluded from the study.

MTTT was applied to 43 patients diagnosed with ACL rupture in the clinic where the study was conducted since January 1, 2020. Of these, three patients were excluded due to incomplete follow-ups and two patients were excluded due to missing records. Thus, 38 out of 43 patients were finally included in the study and were classified as Group 1. Of the 57 patients who underwent standard ACL reconstruction by opening a single tibial tunnel in the clinic, 10 patients were excluded from the study due to incomplete follow-ups and seven patients were excluded due to missing records. Therefore, 40 out of the 57 patients were included and classified as Group 2. The examination and clinical results of the patients were evaluated by two orthopedic specialists. Anterior drawer, Lachman, and Pivot-Shift tests were performed. The anterior drawer test was evaluated as negative and positive, and the Lachman and Pivot-Shift tests were evaluated as negative, +1, +2, and +3.

Two scoring systems were used to evaluate knee function. Lysholm's knee score considered a score of 92-100 out of 100 points as excellent, 84-94 as good, 65-83 as medium, and less than 65 as bad[11]. The IKDC score is an important parameter that is used to determine the success of knee injury treatments[12]. A high IKDC score indicates that the patients' postoperative functions are at the desired level.

This study was approved by the Ethics Committee on November 3, 2021 (Decision No.: 2021/91). Informed consent was obtained from all participants included in the study. After obtaining consent to perform anesthesia, the patients underwent the elective surgery. The semitendinosus and gracilis tendons were used as autografts, and the Endobutton system was used for femur stability in both groups. Regarding the patients in Group 2, bioabsorbable and washer screws were used for the tibial fixation. For the patients in Group 1, a bioabsorbable screw, a washer screw, and an additional MTTT fixation were performed for the tibial fixation.

Creating Main Tunnels and Collateral Tunnels with MTTT

In MTTT, after the creation of femoral and tibial main tunnels in accordance with standards, a loop rope was threaded into the femoral tunnel (Figure 1). The Endobutton technique was used for MTTT consisting of a metal plate and a loop suture for the femur.

For MTTT, the tibial tunnel band was placed in the footprint of the ACL (lateral to the medial tubercle at the level of the anterior and posterior borders of the lateral meniscus) at an angle of 55°, as in the standard technique. For the external entrance hole of the tibial tunnel, a guide wire was inserted 1.5 cm medial and 0.5 cm proximal to the tibial tubercle. Tibial and femoral tunnels were opened (Figure 1), and a tibial aimer was threaded through the tibial tunnel (Figure 2). The tip of the tibial aimer in the

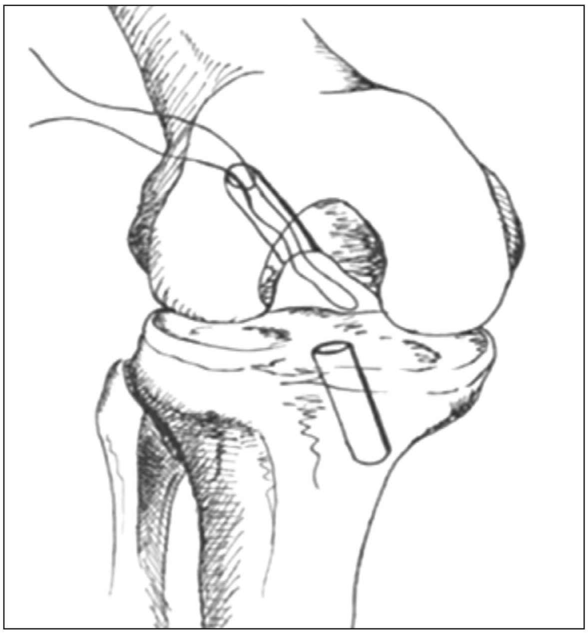

Figure 1. Standard femoral-tibial tunnel.

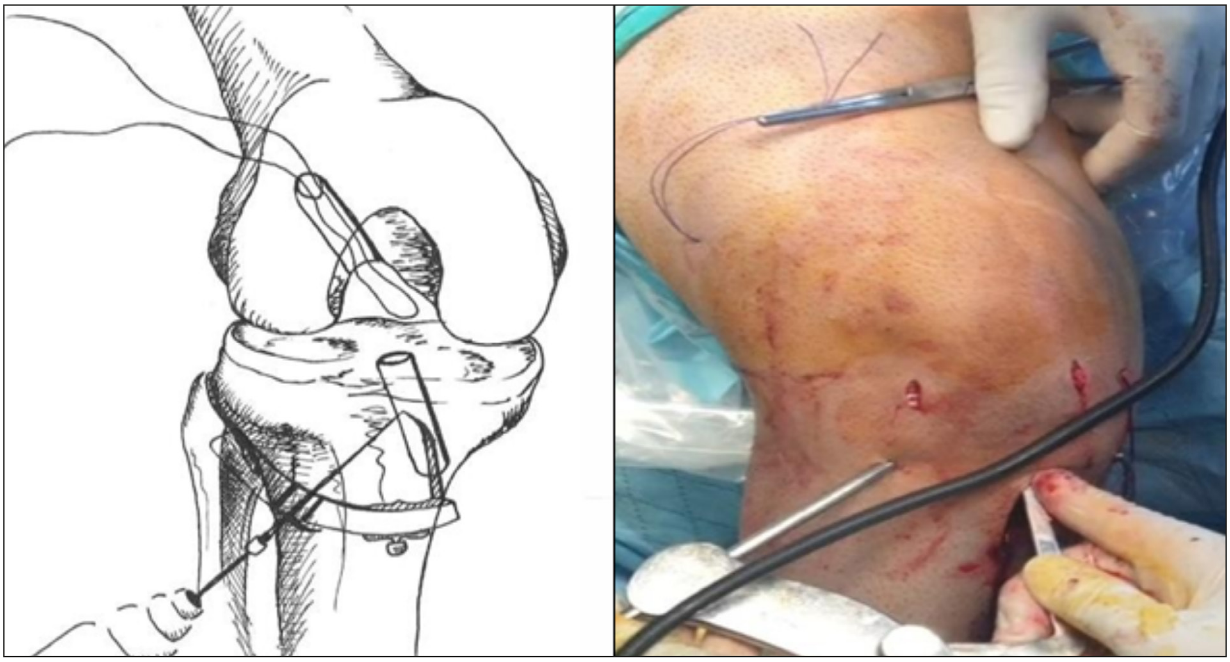

Figure 2. 1. Collateral tunnel.

tunnel was placed two-thirds proximal to the tibial tunnel. The cannulated tip of the tibial aimer was placed at least 2 cm lateral and posterior to the tibial tubercle, and a skin incision was made (Figure 2).

A camera was placed in the tibial main tunnel, and the inner surface of the tibial tunnel was exited two-thirds proximally using Kirchner wire (K wire) (Figure 3). The first collateral tunnel (CT1)

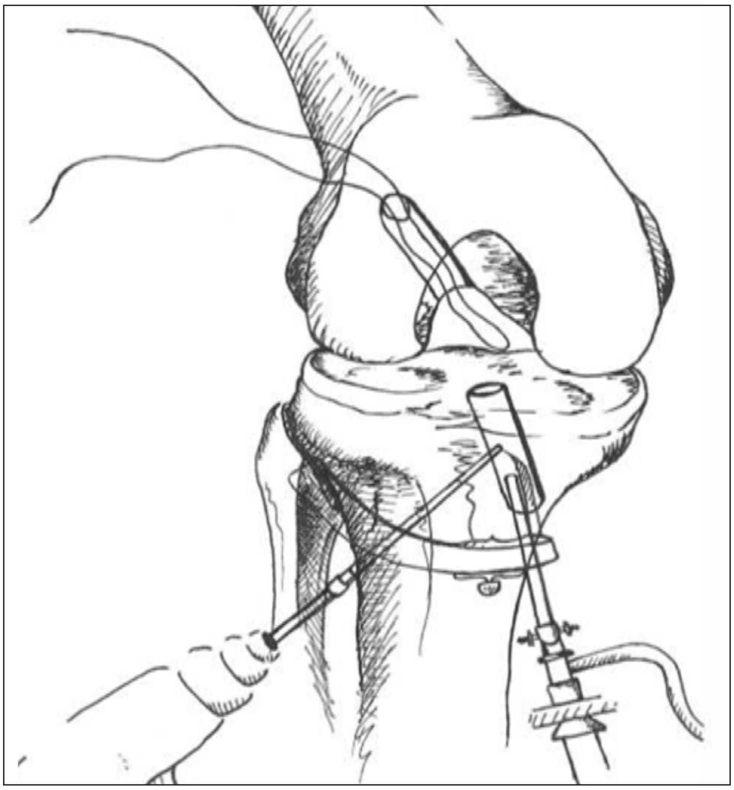

Figure 3. Drilling of 1. collateral tunnel.

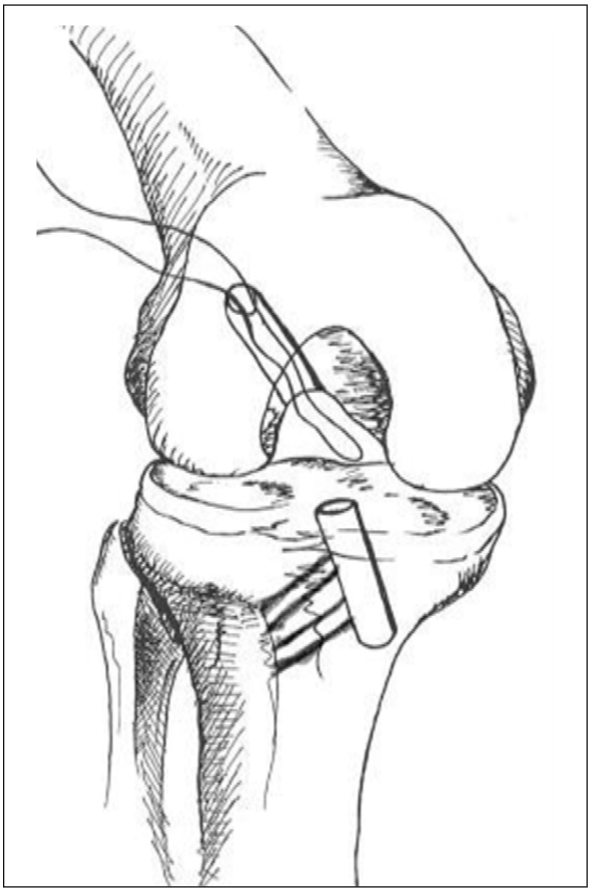

Figure 4. 1. and 2. collateral tunnel.

was created from the K wire with a 4.5 mm drill (Figure 3). The tip of the tibial aimer was placed one-third distal of the tibial main tunnel, and the second collateral tunnel was created using the same method (Figure 4). With this surgery, two collateral tunnels were created that opened into the tibial main tunnel (Figure 4).

A passing pin with a loop suture at the end was threaded through both collateral tunnels (Figure 5). The loop ropes threading through the collateral tunnels were held by the rope holder and removed through the outer hole of the tibial main tunnel (Figure 5). As a result, two loop sutures with one end in the outer hole of the main tibial tunnel and the other end in the outer hole of the collateral tunnels were obtained (Figure 6). The loop suture threaded through the femoral tunnel, knee joint, and tibial main tunnel was removed through the outer hole of the tibial main tunnel for pulling the Endobutton required for standard femoral fixation, and three loop sutures were obtained in the outer hole (Figure 7) (loop suture of the first collateral tunnel, loop suture of the second collateral tunnel, and loop suture of the femoral tunnel).

Preparing the Hamstring Tendon Graft in MTTT

After harvesting, semitendinosus and gracilis hamstring tendons were obtained using 5-strand grafts. The Endobutton system was located at the end of the graft entering the femur. There are reinforced sutures at the end of the graft (Figure 8). The most proximal location of the graft to remain in the tibial tunnel was determined, and the tendon layers at the tibial end of the graft were sutured with 2-0 ethibond sutures. It was then sutured from the distal location to the marked location in the proximal tibial end of the graft using the Krackow method with a 2-0 ethibond suture and passed to the opposite edge. The suturing from proximal to distal was continued using the Krackow method, and the tip of the suture was removed (Figure 9). Thus, a rectangular suture structure remained in the tibial tunnel at the tibial end of the graft (Figure 9). Then, two grafts were sutured with No. 5 ethibonds sutures in the area of the graft that settled in the tibial main tunnel (may vary depending on the length

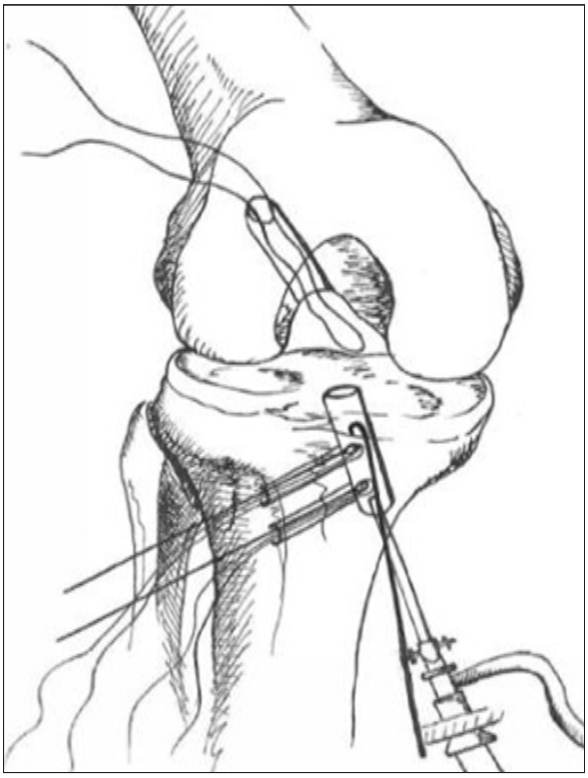

Figure 5. Threading pin through collateral tunnels.

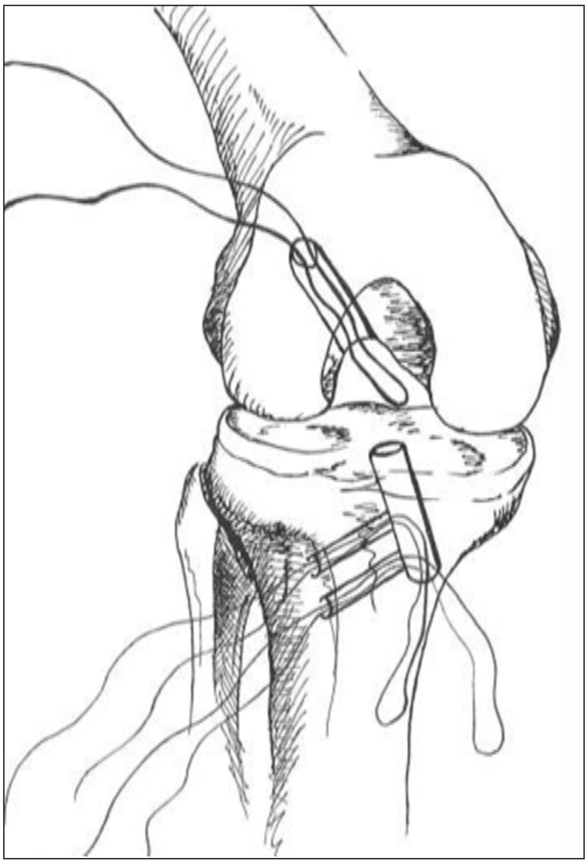

Figure 6. Threading ropes through collateral tunnels.

of the graft tip that will remain in the tibial main tunnel) perpendicular to the rectangular suture. It was entered from the lateral edge of the tendon and exited from the opposite edge and was sutured with a Krackow suture from the proximal location to the distal location using two No. 5 ethibonds sutures (Figure 10). By knotting these ropes into the tendon in pairs, two ropes were formed in a binary state (Figure 11).

Placing the Graft in the Tunnels in MTTT

Three loop sutures existed in the outer hole of the tibial main tunnel. One of them was a loop suture that was threaded through the femoral Endobutton, and the other two were the loop sutures that were threaded through two collateral tunnels (Figure 7). First, two double threads of No. 5 ethibonds, located on the lateral end of the graft to be placed in the tibial main tunnel, were placed in the loop threading through one collateral and then pulled (Figure 11). In this way, the No. 5 ethibonds were removed from the outer hole of the two collateral tunnels (Figure 12). Threads of the Endobutton were placed in the femoral loop suture, pulled, and removed from the lateral aspect of the femur (Figure 13). The graft was threaded through the tibial tunnel and inserted into the knee joint and then into the femoral tunnel in the standard manner (Figure 14). After inserting the graft fully into the femoral and tibial tunnels, the knee was stretched with tension ropes at a flexion of 20°, and a bioabsorbable screw was inserted (Figure 15). The No. 5 ethibonds located in the hole outside the collateral tunnel were then stretched and knotted together, and these threads were crossed using a passing pin with a hole opening from the lateral side to the medial side that were clamped together with the tension threads of the graft to the scaly screw (Figure 16). The surgery was terminated after proper suturing of the wounds.

Postoperative Rehabilitation

On postoperative day 1, the drains of the patients were removed and exercises were started. Knee braces were not used, and patients were allowed to bear as much weight as they could on the leg with the assistance of crutches. The patients were discharged from the hospital on the fourth postoperative day. The follow-ups were

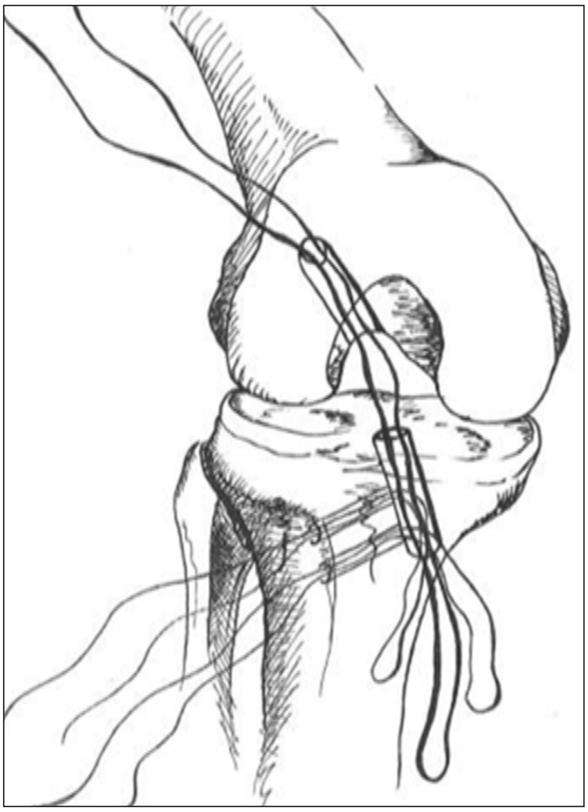

Figure 7. Loop threads in tibial main tunnel outer hole.

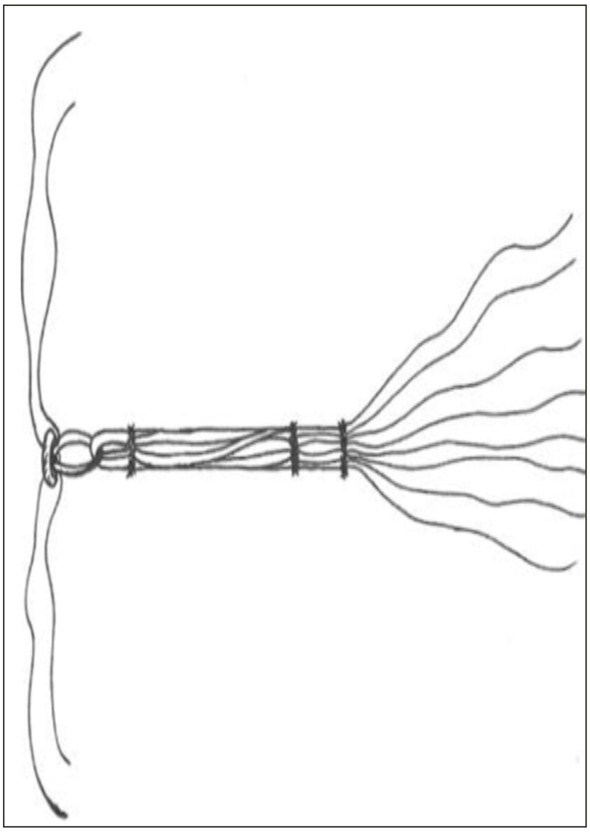

Figure 8. Sturation of the femoral and tibial fixation areas of the graft.

done weekly during the first month and every two weeks in the following months. After the sutures were removed, the patients were directed to the physical therapy and rehabilitation center. The same physical therapy protocol was applied to both groups. Patients without quadriceps muscle atrophy were allowed to walk without crutches from the 4th postoperative week. The patients started to run straight after the 12th postoperative week and were allowed to participate in sports activities at the end of the 5th month.

Statistical Analysis

The analysis of the obtained data was carried out using the Statistical Program in Social Sciences 25 program (IBM Corp., Armonk, NY, USA). Whether the data fitted the normal distribution was determined using the Shapiro-Wilk Test[13]. The significance level (p) for comparison tests was 0.05. Since the variables were normally distributed ($p > 0.05$), the analysis was continued using parametric test methods.

To compare independent pairs, the significance test of the difference between the two means was performed. Significance testing of the difference between the two means was performed to compare independent pairs. In repeated measurements, repeated ANOVA measurements were used and multiple normal distributions and homogeneity of variance were checked in the analyses.

In the analysis of independent categorical data, a chi-square analysis was performed by creating cross tables. In the analysis of dependent categorical data, cross tables were created, and Kendall W analysis was performed.

Results

The demographic characteristics of these patients are presented in Table I. There was no statistically significant difference between the groups according to gender, etiology, age, BMI, and follow-up period ($p > 0.05$, Table I).

The patients' complications data are shown in Table II. Superficial infection developed in one patient in Group 1 (2.6%) and in one patient in Group 2 (2.5%). A mean of 10° of flexion limitation at the last control was found in two patients in Group 1 (5.3%) and in one patient in Group 2 (2.5%), whereas one patient in Group 1 (2.6%) and in one

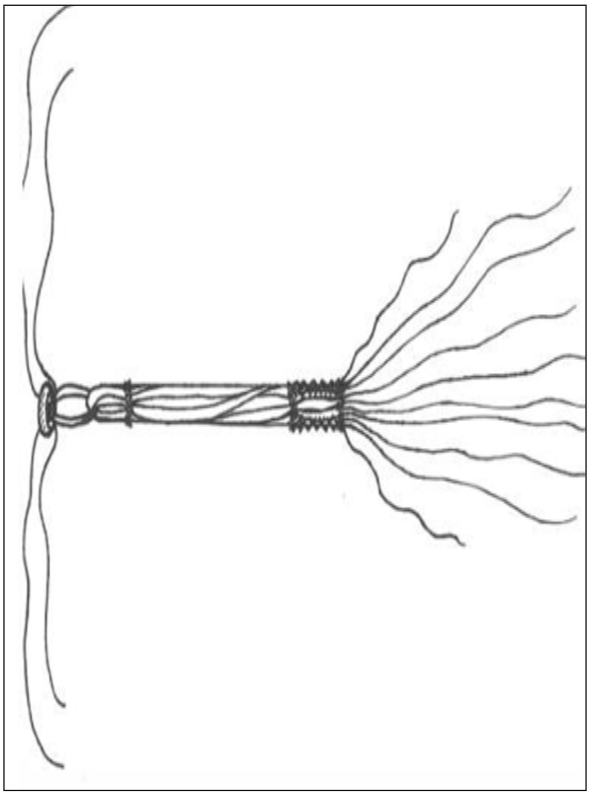

Figure 9. Rectangular suturation of the tibial area of the graft.

Table I. Demographic characteristics of the patients.

	Group 1	Group 2	*p*-value
Gender (male/female)	28/10	27/13	0.726*
Etiology (S/F/T)	25/9/4	26/10/4	0.991*
Age	33.08 ± 8.57	33.38 ± 7.58	0.872**
BMI (Kg/m²)	23.12 ± 1.09	22.86 ± 0.93	0.259**
Follow-up time (month)	18.42 ± 3.02	18.48 ± 3.09	0.939**
Total patients	38	40	

*Chi-square test value (χ^2), *p*-value: statistical significance, **two independent sample *t*-test, S: Sport, F: Tall, T: Trauma, BMI: Body Mass Index.

Table II. Intergroup complications.

	Group 1	Group 2	*p*-value
Infection	1 (2.6%)	1 (2.5%)	0.971*
Revision surgery	0 (0.0%)	1 (2.5%)	0.246*
Flexion limitation	2 (5.3%)	1 (2.5%)	0.964*
Extension limitation	1 (2.6%)	1 (2.5%)	0.971*

*: Chi-square Test value (χ^2), *p*-value: statistical significance.

patient in Group 2 (2.5%) had 5° of extension limitation. While revision surgery was not performed in Group 1, revision surgery was performed in one patient in Group 2 (2.5%) because the patient's ACL ruptured while doing sports. When complications were compared between the groups, no significant difference was found ($p > 0.05$, Table II).

The Lysholm and IKDC scores, and anterior drawer, Lachman, and Pivot-Shift tests' data of the groups at the final control are shown in Table III. At the final control, there was no significant difference between the groups in the anterior drawer, Lachman, and Pivot-Shift tests ($p > 0.05$, Table III). There was a significant difference between the two groups in the Lysholm and IKDC scores at the final controls ($p < 0.05$, Table III).

When the final control Lysholm, IKDC, and Tegner scores of Groups 1 and 2 were compared with the preoperative values, a statistically significant change was found ($p1 < 0.05$, $p2 < 0.05$, Table IV). There was a significant difference in the Lysholm and IKDC scores between the groups ($p < 0.05$, Table IV), but there was no significant difference in Tegner activity score ($p > 0.05$, Table IV).

Discussion

Several surgical techniques and implants have been used for graft implantation to the femur and tibia in ACL reconstruction. In the graft implantation to the bone, femoral implantation provides more successful results than tibial implantation. Since the cancellous structure of the tibia is weaker than the structure of the femur, the tibia bone has limited fixation strength[14]. Tibial fixation is

Table III. Lysholm Knee, IKDC, Anterior drawer, Lachman and Pivot-Shift scores in the final control.

	Group 1	Group 2	*p*-value
Lysholm Knee Score (M±SD)	94.61 ± 3.4	90.03 ± 3.93	0.039*
IKDC Score (M±SD)	89.46 ± 2.1	86.22 ± 3.25	0.009*
Anterior Drawer (-/+)	34/4	29/11	0.053**
Lachman (-/+1/+2/+3)	35/3/0/0	30/8/2/0	0.065***
Pivot-Shift (-/+1/+2/+3)	37/1/0/0	36/4/0/0	0.169***

SD: Standard Deviation, M: Mean, *p*-value: statistical significance, *Repeated Measure of ANOVA Test, **Chi-square test value (χ^2), ***Kendall W test.

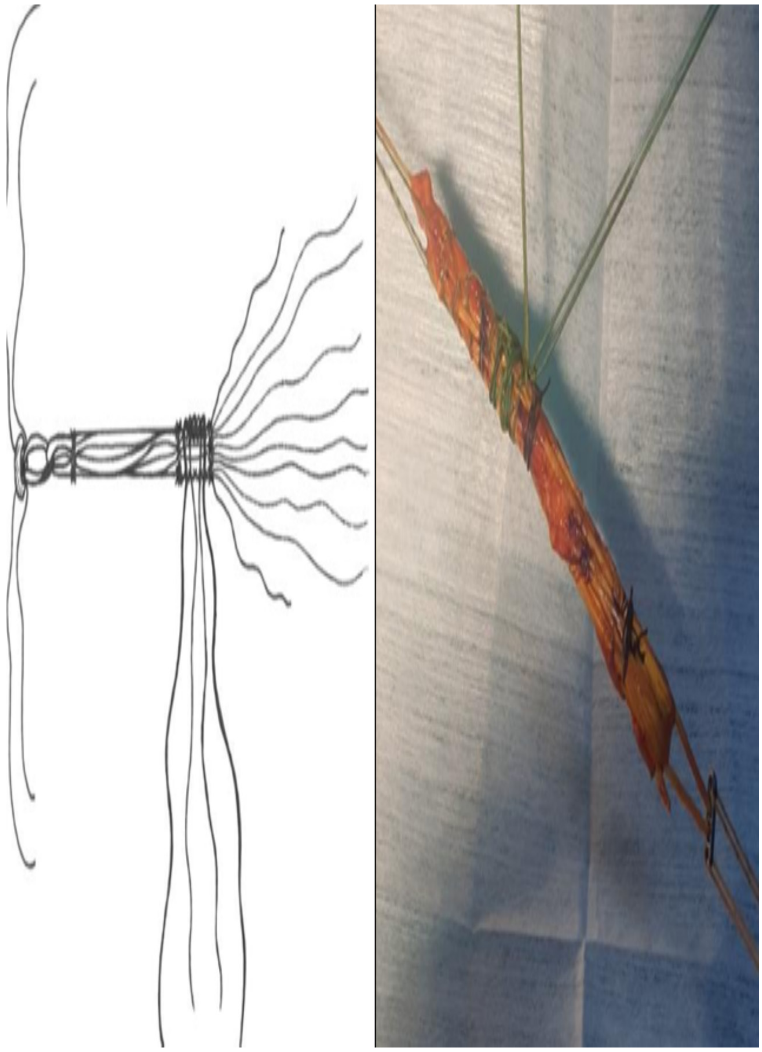

Figure 10. Sturation of the tibial area of the graft with No. Ethibond.

Table IV. Comparison of Lysholm Knee, IKDC and Tegner scores preoperative and final controls.

		Group 1 (M±SD)	Group 2 (M±SD)	p^1	p^2	*p*-value
Lysholm Score	**Preop** **Final**	60.42 ± 7.95 94.61 ± 3.40	59.65 ± 6.65 90.03 ± 3.93	0.001*	0.001*	0.001*
IKDC Score (%)	**Preop** **Final**	32.32 ± 3.41 89.46 ± 2.13	31.77 ± 3.44 86.22 ± 3.25	0.001*	0.001*	0.001*
Tegner Score	**Preop** **Final**	5.18 ± 1.23 4.97 ± 1.20	5.05 ± 1.2 4.6 ± 1.1	0.036*	0.001*	0.087*

SD Standard Deviation, M: Mean, *p*-value: Intergroup statistical significance, p^1 statistical significance of Group 1, p^2: statistical significance of Group 2, Preop: Preoperatif Control, Final: Final Control, *Repeated Measure of ANOVA Test.

usually performed at a weaker point compared to femoral fixation due to the lower density of the tibial bone and the parallel graft fixation associated with the tunnel. Accordingly, it creates a shear force in distal fixation, which can result in its failure at an early stage[7]. MTTT provides additional fixation against this shear force in the tunnel and prevents the graft from slipping in the tunnel.

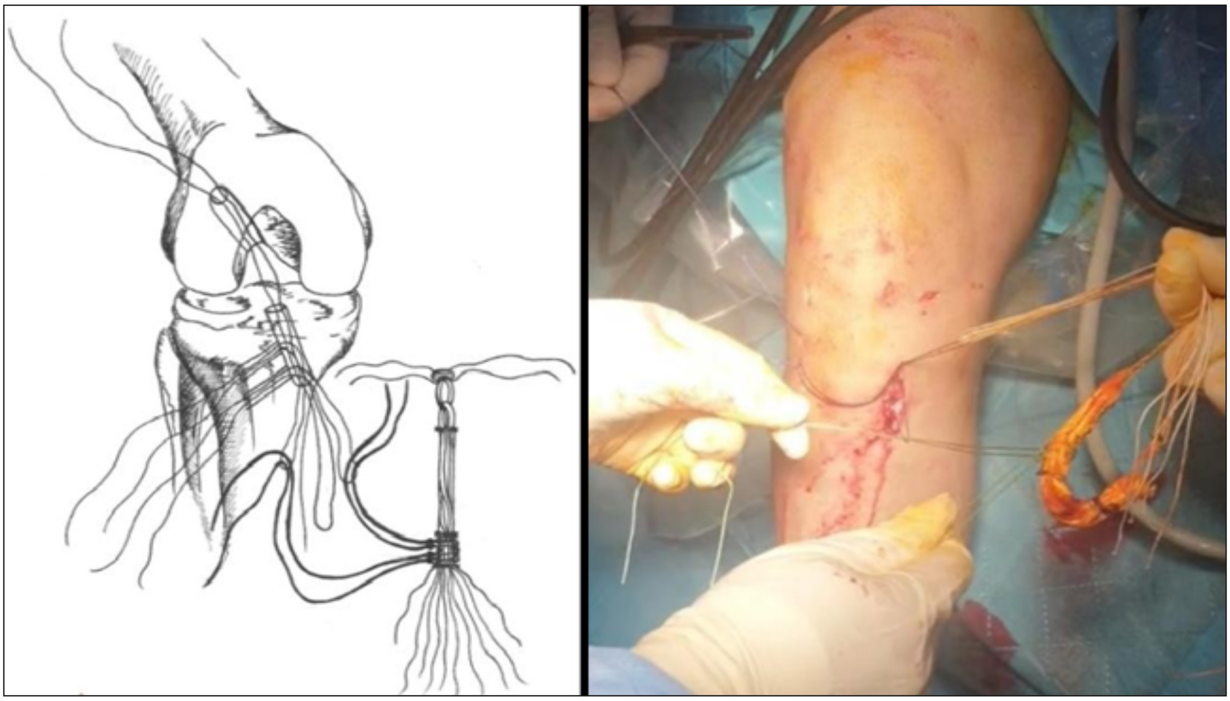

Figure 11. Placing graft threads on loop stures.

The inadequacy of tibial fixation for soft tissue grafting is thought to be one of the key causes of early failure and loosening in ACL reconstruction[5,6]. Kurosaka et al[15] stated that the success of ACL reconstruction was dependent on many other factors and that the surgical fixation method was the main factor affecting the mechanical properties of the graft in the postoperative period. Therefore, many studies have been conducted to ensure that patients who have undergone surgery can return to rehabilitation early and to ensure stable fixation of the graft in the tibia in the period before biological fixation. Pasque et al[16] created a tunnel from medial to lateral approximately 2 cm distal to the exit hole of the tibial tunnel, threaded the sutures connected to the graft through these tunnels and tied them together. It was stated that this method provided a fast, simple, safe, and reproducible alternative to tibial graft fixation. Taher El-Satar Eid et al[17] created a second tibial tunnel distal to the tibial tunnel exit hole, threaded some of the tensioner threads distal to the tendon through the other hole, and tied them together or fixed them with a bone graft. Ethan et al[18] emphasized that sutures should be added to the tissue-screw-bone interface when performing soft tissue ACL al-

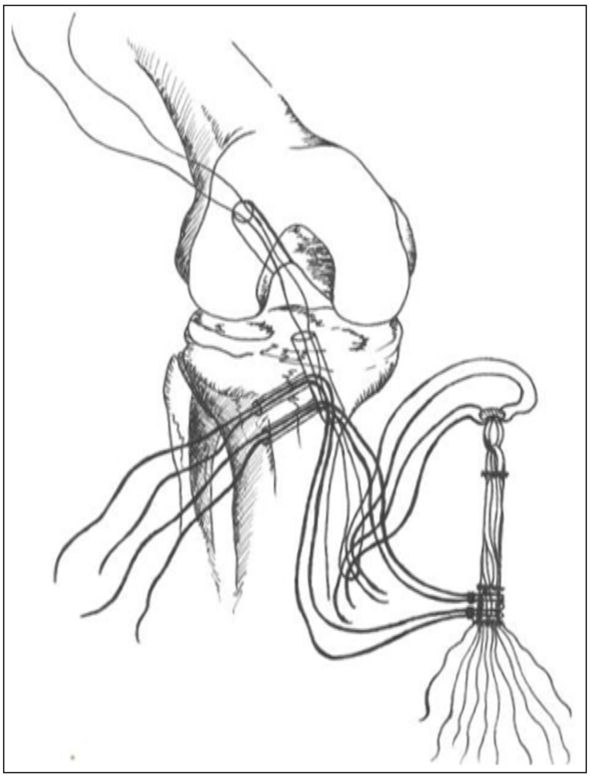

Figure 12. Placing the graft threads in the tunnels.

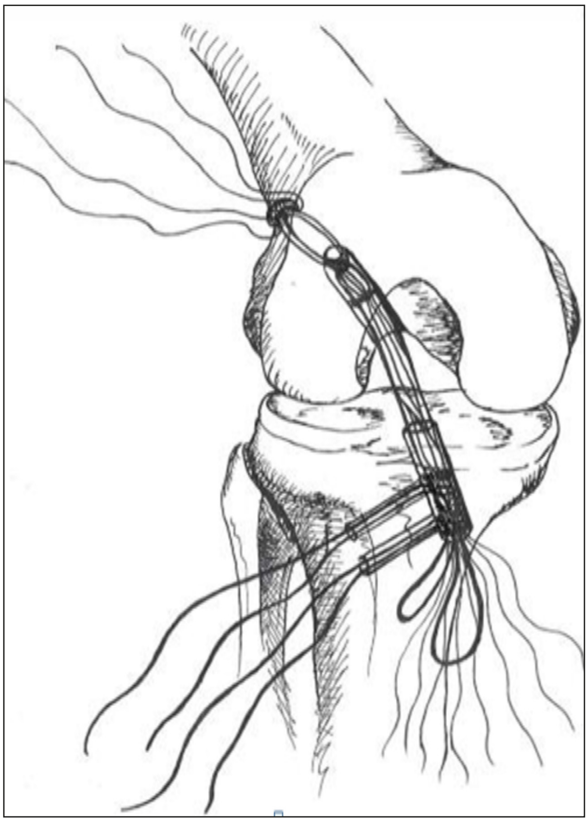

Figure 13. Placing the graft in the tunnels.

lograft reconstructions due to improved biomechanical characteristics. Sarah et al[19] conducted a 2-year review study and compared the clinical performance of ACL reconstruction with polyether ether ketone (PEEK) and titanium interference screws. It was emphasized that PEEK should be preferred over interference screw fixation in ACL reconstruction. In the biomechanical studies of Weiss et al[20], using animal tibia, three groups were formed for tibial fixation, namely Group 1 fixation with an interference screw, Group 2 fixation with a screw post and toothed washer over the knot and suture strand, and Group 3 fixation with a screw post and washer combined with an interference screw (hybrid fixation). In this study, regarding the patients in Group 2, bioabsorbable and washer screws were used for tibial fixation. For patients in Group 1, a bioabsorbable screw, a washer screw, and an additional MTTT fixation were performed for tibial fixation.

In the study of Noh et al[21], the Lachman test was negative in 81.8% of the patients and positive in 18.8% at the final control in ACL reconstruction, while the Pivot-Shift test was negative in 81.8% of the patients and positive in 18.2%. In Geng's study[22], 44 patients (78%) and 12 patients (21.4%) had a negative and +1 Lachman test, respectively, at the last control in the group in which a femoral tunnel was opened from the anteromedial portal. The Pivot-Shift test was negative in 44 patients (78%) and +1 in 12 patients (21.4%)[22]. Dalyaman found that the preoperative Lachman test was +3 in 22 patients (55%), +2 in 16 patients (40%), and +1 in two patients (5%). The Pivot-Shift test was positive in 36 patients (90%) and negative in 4 patients (10%), while ADT was +3 in 24 patients (60%) and +2 in 16 patients (40%). The final control Lachman test of the patients was negative in 35 patients (87.5%), +1 in four patients (10%), and +2 in one patient (2.5%). It was stated that the Pivot-Shift test was negative in all patients; the anterior drawer test was negative in 34 patients (85%) and +1 in six patients (15%)[23]. In the study of Noh et al[24], a bio-interference screw was used for tibial fixation in Group 1 and a washer screw providing additional post-tie fixation to the bio-interference screw in Group 2. In Group 2, the Lachman test was found to be 80% negative and 20% positive, and the Pivot-Shift test was 85.7% negative and 14.3% positive. In this study, no sig-

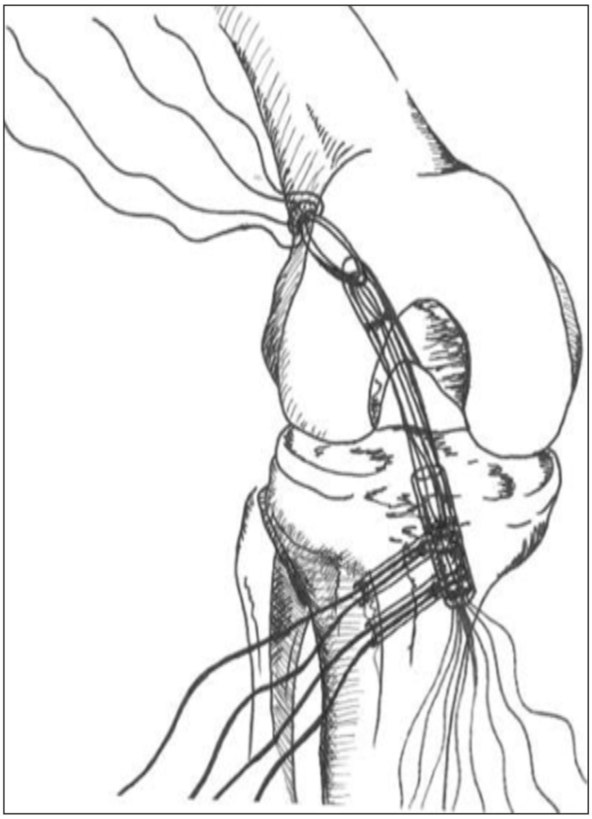

Figure 14. Stretching the collateral tunnel threads.

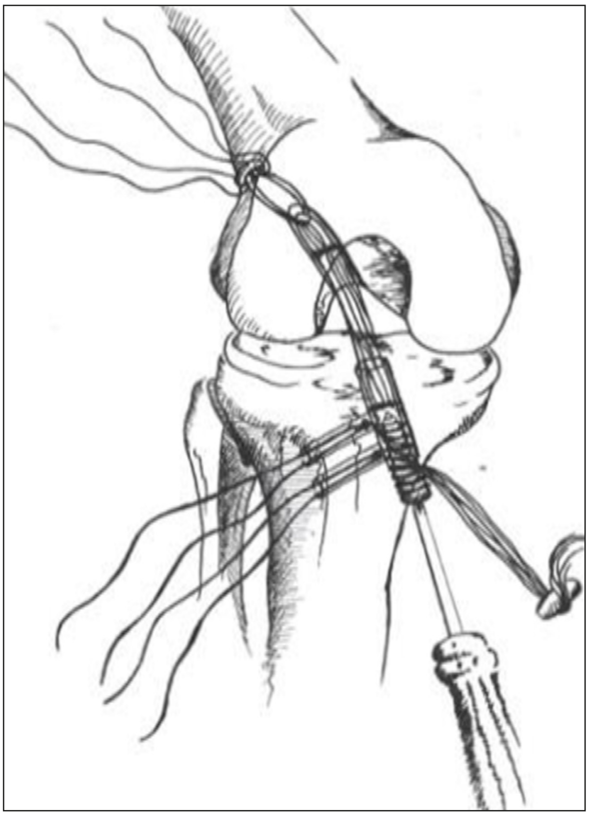

Figure 15. Inserting the bioabsorbable screw.

nificant difference was found in terms of knee laxity tests in both surgical methods ($p > 0.05$).

In the study of Sun et al[25], the subjective IKDC score was 89 and the Lysholm score was 89 in patients who underwent an autograft. In the study of Noh et al[21], Bio-Interference screw was used for tibial fixation of Group 1 patients. Supplementary fixation was performed with a post-tie using a washer screw in Group 2. In the study of Noh et al[21], the mean Lysholm scores in the autograft group were 54 (44–78) and 98 (85–100), respectively, in preoperative and final follow-up, 67.7% in the subjective IKDC A class, 21.2% in the B class, and 9.1% in the C class at the last follow-up. Those in class D were 0%. In the study by Turkoglu et al[26], the hamstring tendon and the patellar tendon were used in 78 patients, and the Lysholm score was found to be 92.5 at the last control. In the study by Noh et al[24], the IKDC score was 74.3% A, 20% B, 5.7% C and 0% D in Group 2, and the Lysholm score was 56 preoperatively and 95 postoperatively in Group 2 at the last controls. In the study by Başdelioğlu, the mean preoperative and postoperative Lysholm scores were 58 and 96, respectively, in patients using the anatomical femoral single-tunnel technique, and 60 and 92 in patients using the transtibial technique[27]. In addition, the mean preoperative and postoperative IKDC scores were 43 and 94, respectively, in patients using the anatomical femoral single-tunnel technique, and 53 and 90 in patients using the transtibial technique[27]. In the study of Jarvela et al[28], the Tegner activity score increased from 5 ± 1 preoperatively to 6 ± 1 at the last control. In William's study, the Tegner activity score increased from 4 preoperatively to 6 at the final control[29]. In the study of Noh et al[21], preoperative and final control tegner activity scores in both groups changed from 7 to 6. In the study of Chiang et al[30], the group using a bioabsorbable interference screw in tibial fixation and the group using a cortical screw post with a washer were compared. Equivalent clinical function outcomes were noted at two years after surgery in both groups of patients. In this study, MTTT was found to be more successful when evaluated in terms of knee function for both surgical methods ($p < 0.05$).

In the study by Wang et al[31], biodegradable interference screws were used in the tibial tunnel, and a 7 mm slippage was found in the graft of the tibial tunnel. Wiemann et al[32] added additional stable or scaly screws to the interference screw in tibial fixation and concluded that there was a 4.1 mm slippage in the tibial tunnel. Walz et al[33] stated that additional fixation in patients with interference screws in tibia with low bone density could help prevent slippage of the graft. In all studies, tibial fixation was performed parallel to the tensile strength of the graft (in the axillary plane). In this study, an additional fixation was performed in the horizontal plane, which is not parallel to the fixation and stretching force in the axillary plane. Thus, this horizontal fixation can reduce both the sliding of the graft in the tunnel and the relaxation due to the axillary tension force between the graft-bone-screw interface. Through this method, in addition to hybrid fixation with a bio-interference screw and a washer screw, additional fixation is provided in the horizontal plane with ethibond threads. Although there was no significant difference between the two surgical methods in knee laxity tests in this study, the Lysholm and IKDC scores, which enable the evaluation of knee functions, were found to be more successful in MTTT.

Limitations

The limited number of patients and not considering the graft thicknesses are among the main limitations of this study.

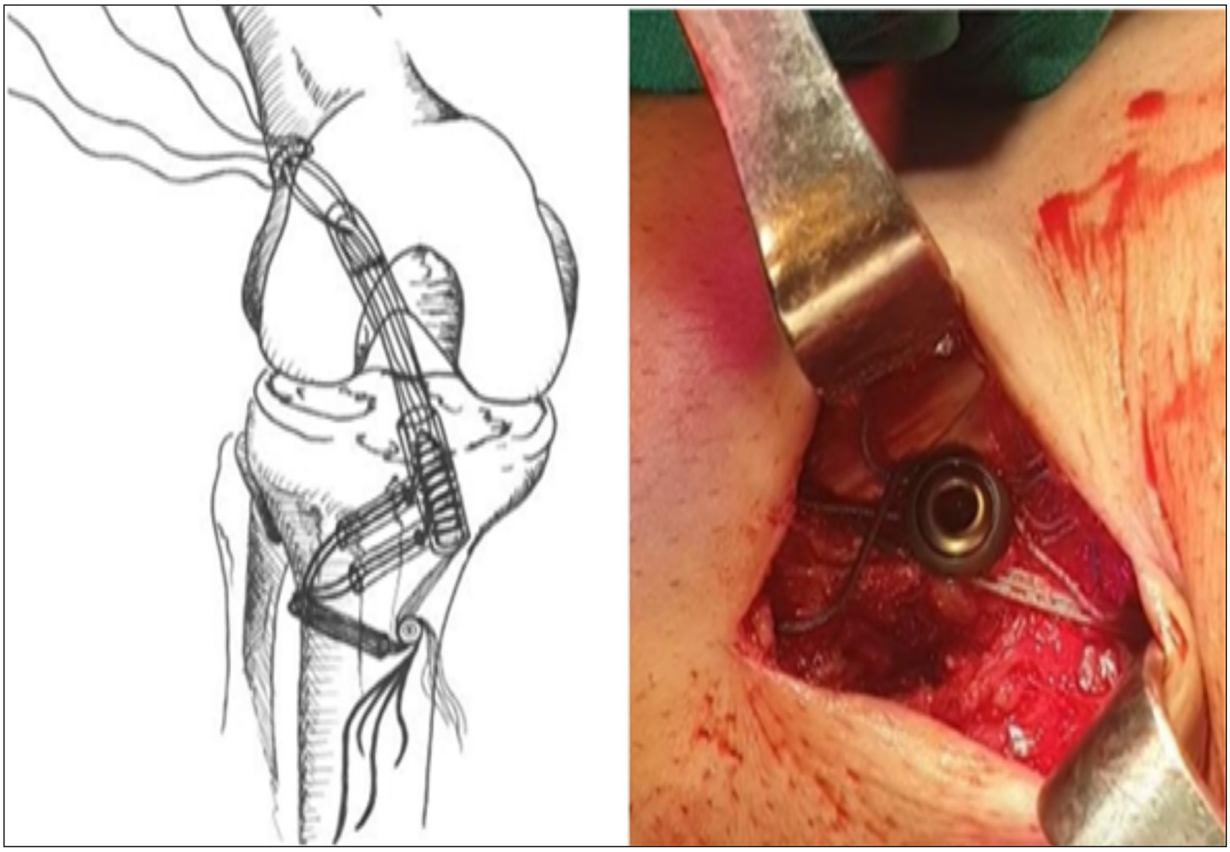

Figure 16. Tibial Fixation of the graft with MTTT.

Conclusions

ACL reconstruction was performed using the MTTT technique in this study. Due to the additional fixation, it was observed that the patients have a more successful knee function after the surgery.

Conflict of Interest
The authors declare that they have no conflict of interest to declare.

Funding
This research received no external funding.

Ethics Approval
This study has been conducted in accordance with the principles set forth in the Helsinki Declaration and obtained the Ethics Committee Approval (Decision No: 2021/91) from Malatya Turgut Ozal University Faculty of Medicine.

Informed Consent
We obtained the informed consent form in writing from all patients before the study.

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References

1) Griffin LY, Agel J, Albohm MJ, Arendt EA, Dick RW, Garrett WE. Noncontact anterior cruciate ligament injuries: risk factors and prevention strategies. J Am Acad Orthop Surg 2000; 8: 141-150.
2) Prodromos CC, Han Y, Rogowski J, Joyce B, Shi K. A meta-analysis of the incidence of anterior cruciate ligament tears as a function of gender, sport, and a knee injury reduction regimen. Arthroscopy 2007; 23: 1320-1325.

3) Mall NA, Chalmers PN, Moric M, Tanaka MJ, Cole BJ, Bach Jr BR, Paletta Jr GA. Incidence and trends of anterior cruciate ligament reconstruction in the United States. Am J Sports Med 2014; 42: 2363-2370.

4) Pearle AD, McAllister D, Howell SM. Rationale for strategic graft placement in anterior cruciate ligament reconstruction: I.D.E.A.L. femoral tunnel position. Am J Orthop (Belle Mead NJ) 2015; 44: 253-258.

5) Wright RW, Huston LJ, Spindler KP, Dunn WR, Haas AK, Allen CR, Cooper DE, DeBerardino TM, Lantz BB, Mann BJ, Stuart MJ; MARS Group. Descriptive epidemiology of the Multicenter ACL Revision Study (MARS) cohort. Am J Sports Med 2010; 38: 1979-1986.

6) Tetsumura S, Fujita A, Nakajima M, Abe M. Biomechanical comparison of different fixation methods on the tibial side in anterior cruciate ligament reconstruction: a biomechanical study in porcine tibial bone. J Orthop Sci 2006; 11: 278-282.

7) Brand Jr J, Weiler A, Caborn DN, Brown Jr CH, Johnson DL. Graft fixation in cruciate ligament reconstruction. Am J Sports Med 2000; 28: 761-774.

8) Rodeo SA, Arnoczky SP, Torzilli PA, Hidaka C, Warren RF. Tendon healing in the bone tunnel. A biomechanical and histological study in the dog. J Bone Joint Surgery Am 1993; 75: 1795-1803.

9) Eguchi A, Ochi M, Adachi N, Deie M, Nakamae A, Usman MA. Mechanical properties of suspension fixation devices for anterior cruciate ligament reconstruction: comparison of fixed-length ring device and adjustable-length ring device. Knee 2014; 21: 743-748.

10) Patel NA, Choi JH, Wang D. Tibial fixation techniques in soft tissue grafts in anterior cruciate ligament reconstruction. JBJS Rev 2019; 7: 7.

11) Briggs KK, Kocher MS, Rodkey WG, Steadman JR. The reliability, validity, and responsiveness of the Lysholm kneescore and Tegner activity scale for patients with meniscal injury of the knee. J Bone Joint Surg 2006; 88: 698-705.

12) Anderson AF, Irrgang JJ, Kocher MS, Mann BJ, Harrast JJ. The International Knee Documentation Committee Subjective Knee Evaluation Form: normative data. Am J Sports Med 2006; 34: 128-135.

13) Alpar R. Applied Statistics and Validity-Reliability with Examples in Sports, Health and Education Sciences, 6th Edition, Detay Publishing, Ankara 2020; 147.

14) Matsumoto A, Howell MS. The WasherLoc and bone dowel: a rigid, slippage-resistant tibial fixation device for a soft tissue anterior cruciate ligament graft. Techniques in Orthopaedics 2005; 20: 278-282.

15) Kurosaka M, Yoshiya S, Andrish JT. A biomechanical comparison of different surgical techniques of graft fixation in anterior cruciate ligament reconstruction. Am J Sports Med 1987; 15: 225-229.

16) Pasque CB, De la Garza S. Transtibial tubercle fixation without hardware for anterior cruciate ligament and posterior cruciate ligament reconstruction: a new technique. Arthroscopy 2004; 20: 164-170.

17) El-Satar Eid TA, Morsy ES. Tibial fixation without hardware for anterior cruciate ligament reconstruction: a new technique. Egypt Orthop J 2017; 52: 180-183.

18) Bernstein E, Taniguchi K, Tompane T, Kirby H, Ponton R, McDonald LS. Incorporation of Whipstitch suture in tibial interference fixation improves pullout in anterior cruciate ligament soft tissue grafts. Military Med 2022; 187: 89.

19) Shumborski S, Heath E, Salmon LJ, Roe JP, Linklater JP, Facek M, Pinczewski LA. A randomized controlled trial of PEEK versus titanium interference screws for anterior cruciate ligament reconstruction with 2-year follow-up. Am J Sports Med 2019; 47: 2386-2393.

20) Weiss FP, de Aguiar Possoli FA, Costa IZ, Borges PC, Filho ES, Kubrusly LF. Fixation of the anterior ligament graft at the tibial pole: biomechanical analysis of three methods. Rev Bras Ortop (Sao Paulo) 2019; 54: 697-702.

21) Noh JH, Yi SR, Song SJ, Kim SW, Kim W. Comparison between hamstring autograft and free tendonAchilles allograft: minimum 2-year follow-up after anteriorcruciate ligament reconstruction using EndoButton and Intrafix. Knee Surg Sports Traumatol Arthrosc 2011; 19: 816-822.

22) Geng Y, Gai P. Comparison of 2 femoral tunnel drilling techniques in anterior cruciate ligament reconstruction: a prospective randomized comparative study. BMC Musculoskelet Disord 2018; 19: 454.

23) Dalyaman E. Our Early Period Results of Arthroscopic Anterior Cruciate Ligament Reconstruction with Autogenous Hamstring Tendon Graft, Specialization Thesis, 2009.

24) Noh JH, Yang BG, Yi SR, Roh YH. Hybrid tibial fixation for anterior cruciate ligament reconstruction with achilles tendon allograft. Arthroscopy 2012; 28: 1540-1546.

25) Sun K, Zhang J, Wang Y, Xia C, Zhang C, Yu T, Tian S. Arthroscopic reconstruction of the anterior cruciate ligament with hamstring tendon autograft and fresh-frozen allograft: a prospective, randomized controlled study. Am J Sports Med 2011; 39: 1430-1438.

26) Türkoğlu K. Surgical Treatment Results of Anterior Cruciate Ligament Injuries, Specialization Thesis, 2010.

27) Basdelioglu K, Meric G, Punduk Z, Akseki D, Atik A, Sargin S. Outcomes of isokinetic tests and functional assessment of anterior cruciate ligament reconstruction: transtibial versus single anatomic femoral tunnel technique. Acta Orthop Traumatol Turc 2019; 53: 86-91.

28) Jarvela T, Kannus P, Jarvinen M. Anterior cruciate ligament reconstruction in patients with or without accompanying injuries: a re-examination of subjects 5 to 9 years after reconstruction. Arthroscopy 2001; 17: 818-825.

29) Williams 3rd RJ, Hyman J, Petrigliano F, Rozental T, Wickiewicz TL. Anterior cruciate ligament reconstruction with a four-strand hamstring tendon autograft. J Bone Joint Surg Am 2004; 86-A: 225-232.

30) Chiang ER, Chen KH, Lin ACC, Wang ST, Wu HT, Ma HL, Chang MC, Liu CL, Chen TH. Comparison of tunnel enlargement and clinical outcome between bioabsorbable interference screws and cortical button-post fixation in arthroscopic double-bundle anterior cruciate ligament reconstruction: a prospective, randomized study with a minimum follow-up of 2 years. Arthroscopy 2019; 35: 544-551.

31) Wang JL, Liu YJ, Wang AY, Yang YM, Li HF, Li ZL, Wang ZG. Biomechanical evaluation of tendon graft fixation at the tibial site in anterior cruciate ligament reconstruction with Intrafix and bioabsorbable interference screw. Zhonghua Yi Xue Za Zhi 2009; 89: 886-889.

32) Weimann A, Rodieck M, Zantop T, Hassenpflug J, Petersen W. Primary stability of hamstring graft fixation with biodegradable suspension versus interference screws. Arthroscopy 2005; 21: 266-274.

33) Walz B, Nyland J, Fisher B, Krupp R, Nawab A. Supplemental bio-tenodesis improves tibialis anterior allograft yield load in extremely low density tibiae. Arch Orthop Trauma Surg 2012; 132: 343-347.