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Original Article

A Comparative Study of Transtibial, Modified Transtibial, and Transportal Techniques in ACL Reconstruction

Gokmen Deniz,[1] Mehmet Baris Ertan[2]

[1]Department of Orthopedics and Traumatology, Mavi Deniz Surgical Center, Izmir, Türkiye
[2]Department of Orthopedics and Traumatology, Medikum Private Hospital, Antalya, Türkiye

ABSTRACT

Objective: This retrospective study compares the functional and radiological outcomes of conventional transtibial (cTT), modified transtibial (mTT), and transportal (TP) femoral tunnel drilling techniques in arthroscopic single-bundle anterior cruciate ligament (ACL) reconstruction.

Materials and Methods: A total of 229 patients (79 cTT, 79 mTT, and 71 TP) were included, with a mean follow-up of 32.8±7.0 months. Functional outcomes were evaluated using the Lysholm Knee Score (LKS) and Lachman test. Femoral tunnel length and graft diameter were recorded intraoperatively. ACL integrity was assessed via knee magnetic resonance imaging (MRI) at the final follow-up.

Results: The cTT group had significantly lower LKS scores compared to the mTT and TP groups (p=0.0001). Lachman test results showed greater knee stability in the mTT and TP groups compared to the cTT group (p=0.001), with no significant difference between mTT and TP (p=0.823). Femoral tunnel length was longest in the cTT group, followed by the mTT group, and shortest in the TP group (p=0.0001). MRI revealed a lower re-rupture rate in the mTT and TP groups compared to the cTT group (p=0.001), with no difference between mTT and TP (p=0.870).

Conclusion: The mTT technique yields clinical outcomes and re-rupture rates that are superior to the cTT technique and comparable to the TP technique. Additionally, the mTT technique allows for a longer femoral tunnel compared to the TP technique. Therefore, the mTT technique can be used as an alternative to the TP technique.

Keywords: Anterior cruciate ligament reconstruction, modified transtibial technique, transportal technique, transtibial technique

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Address for correspondence:
Mehmet Baris Ertan.
Department of Orthopedics and Traumatology, Medikum Private Hospital, Antalya, Türkiye
E-mail:
mehmetbarisertan@gmail.com

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INTRODUCTION

It is widely accepted that the location of the tibial and femoral tunnels, and thus the three-dimensional orientation of the reconstructed anterior cruciate ligament (ACL) graft, determines the ultimate kinematics of the knee joint [1]. A non-anatomic and isometric single-bundle ACL reconstruction may provide anteroposterior stability but may not control rotational stability [2]. ACL reconstruction techniques do not impede the onset of early osteoarthritis following ACL injury [3,4]. In light of these considerations, novel techniques have emerged with the objective of performing ACL reconstruction in a more anatomic manner, thereby restoring normal knee kinematics and simulating the native ACL ligaments. In the conventional transtibial (cTT) technique, the intra-articular aperture of the femoral tunnel is reliant upon the tibial tunnel. It has been proposed that in the cTT technique, it is impossible to reach the anatomic footprint without relatively posterior placement of the tibial tunnel aperture, eccentric reaming, or iatrogenic expansion of the tibial tunnel. Consequently, in the cTT technique, the graft is almost always vertical instead of oblique orientation [2,5].

In contrast, the transportal (TP) and outside-in (OI) techniques involve the independent drilling of both femoral and tibial tunnels through the anatomic footprints. This allows for the reconstruction of the anterior cruciate ligament (ACL) in a manner that is consistent with the anatomy of the femoral and tibial footprints. However, both techniques have various disadvantages in comparison to the cTT technique [6]. In the OI technique, an additional incision must be made over the thigh, and specialized instruments, such as retrograde drill bits and guides, are necessary. Although the intra-articular apertures of the tunnels are anatomically aligned, the graft makes a sharp angle (graft tunnel angle) between each fixation point, leading to greater abrasion of the graft at the intra-articular edges of the tunnels. This phenomenon is analogous to the 'killer turn' observed in posterior cruciate ligament (PCL) reconstruction [7,8]. In the TP technique, the medial femoral condyle is susceptible to iatrogenic injury due to the hyperflexion position of the knee joint and the close contact with the drill bit. The femoral tunnel length is typically short, which may restrict the available fixation options. Additionally, posterior wall blow-out and peroneal nerve injury are potential risks during drilling [6,9,10].

Several authors have attempted to modify the TT technique in order to reach the anatomic femoral attachment point [11–18]. A modification of the TT technique has recently been described. In this modification, the femoral tunnel was drilled with the knee flexed to approximately 80° and with varus and internal rotation of the tibia. This position exploits the elasticity of the lateral knee ligaments, thereby enabling the surgeon to reach the anatomic footprint of the ACL on the femoral attachment [12,13]. However, in the current literature, few studies have examined these modifications using cTT and TP techniques [19]. This retrospective study aims to compare the functional and radiological results of cTT, modified mTT, and TP arthroscopic single-bundle ACL reconstruction techniques in a consecutive series of patients.

MATERIALS AND METHODS

Patients and Study Design

A retrospective review was conducted on 250 patients with anterior cruciate ligament (ACL) rupture who underwent arthroscopic single-bundle ACL reconstruction at the authors' institutions between 2010 and 2016. All relevant radiological imaging files were obtained from the institutional patient database and used to extract the demographic information, clinical findings, and imaging findings. These files were stored in the picture archiving and communication system (PACS), as well as in the patients' charts, medical records, operation notes, arthroscopic video files, and notes taken during follow-up visits. Patients lacking requisite imaging data, incomplete or improper clinical data, those who developed postoperative infection, and those who did not adhere to the recommended postoperative treatment and rehabilitation regimen were excluded from the study. The study was conducted in accordance with the principles set forth in the Declaration of Helsinki and received approval from the institutional ethics committee (approval number: 23.06.2017-11/16).

Surgical Techniques

In all cases, surgery commenced with diagnostic arthroscopy and joint debridement utilizing standard anteromedial (AM) and anterolateral (AL) portals for the evaluation of all intra-articular pathologies. Following confirmation of the anterior cruciate ligament (ACL) rupture, the ipsilateral hamstring tendons were harvested through an oblique incision in the skin, extending from the crease over the medial aspect of the proximal tibia. Irrespective of the surgical technique employed, a four-stranded graft of the hamstring tendon (comprising the semitendinosus and gracilis tendons) was utilized for single-bundle ACL reconstruction.

Conventional TT Technique

ACL reconstruction with the cTT was performed through standard AM and AL portals. The first step involved debriding the ACL stump to identify the anatomic footprints on both the tibial and femoral sides while taking care to preserve as much of the remnant as possible. A 55-degree tibial ACL guide was utilized, with tibial tunnels being drilled through the central part of the anatomic footprints with a diameter identical to that of the harvested graft. In the event that the tibial footprint could not be identified with sufficient clarity, the tibial aperture was positioned in close proximity to the anterior horn of the lateral meniscus at a distance of 7 to 8 mm from the posterior cruciate ligament. A 7-mm femoral offset guide was then inserted through the tibial tunnel and placed in the over-the-top position at an angle of 70-90 degrees flexion of the knee. The guide pin was positioned at the 10 and 10:30 o'clock positions for the right knee and between the 13 and 14 o'clock positions for the left knee. The femoral tunnel was then drilled with appropriately sized cannulated reamers through the tibial tunnel. The femoral hamstring tendon was fixed in place using an extracortical EndoButton, while the tibial fixation was achieved through the use of biodegradable interference screws and U-staples.

Modified TT Technique

The modified technique involved all the same procedures as the conventional TT technique, with the exception of those pertaining to femoral tunnel drilling. During the drilling of the femoral tunnel, a 7-mm femoral offset guide was inserted through the tibial tunnel and directed to the previously marked femoral footprint, with the knee in a position of flexion between 60 and 70 degrees and in a figure-of-four position. In this position, the knee is forced into a varus and internal rotation, which provides an oblique orientation of the guide within the knee joint. Subsequently, the appropriately sized cannulated reamer was advanced over the guide pin to the desired location. It is of the utmost importance to exercise caution and avoid forcing the knee to an excessive degree, as this could potentially result in an iatrogenic tibial plateau fracture. The fixation of the graft was identical to that of the standard TT technique.

Transportal Technique

Once the femoral footprint of the ACL had been identified and marked (situated below the lateral intercondylar ridge and slightly posterior to the lateral bifurcate ridge), the location of the accessory medial portal was determined by means of spindle needle localization. The needle was positioned in a manner that enabled the desired location to be reached without contact with the medial femoral condyle. The guide pin was then inserted through the newly created portal, with its tip subsequently positioned within the previously marked footprint, situated centrally between the AM and PL bundles. The femoral tunnel was created by reaming along the inserted guide pin with the knee in a position of approximately 120–130 degrees flexion. The tibial tunnel was prepared in a manner consistent with the aforementioned description. The graft was also fixed in the same manner as that used for the TT technique.

Postoperative Rehabilitation

It was recommended that patients who had undergone isolated ACL reconstruction should bear weight immediately with the use of crutches. The commencement of active range of motion exercises was initiated on the second postoperative day, with subsequent increases in intensity conducted under the guidance of a physiotherapist. It was advised that patients should refrain from returning to competitive sports involving jumping, pivoting, or sidestepping for a period of at least one year following surgery. Nevertheless, full weight bearing was not permitted until the fourth to sixth postoperative week in patients who had undergone simultaneous chondral and meniscal lesions treatment with microfracture and meniscal repair.

Final Follow-up and Outcome Assessments

At the final follow-up, all patients underwent comprehensive clinical and imaging assessments. The functional outcomes were evaluated using the Lysholm knee score [20]. The physical examination of the knee included the Lachman test. The Lachman test was graded on a scale of 0 (negative), 1 (1- to 5-mm laxity), 2 (6- to 10-mm laxity), or 3 (>10-mm laxity). Of the 250 patients included in the study, 229 completed the final clinical follow-up and MRI examination, representing a follow-up rate of 91.6%.

MR Imaging and Interpretation at The Final Follow-up

All patients underwent a knee MRI examination at the final follow-up on the MRI unit (Symphony 1.5T, Siemens, Germany). MRI examinations were performed in the supine position with a dedicated knee coil. The following sequences were used on each patient; sagittal T1 weighted (TR/TE 443/12ms, slice thickness 3mm with a 10mm gap, number of images 12); sagittal proton density weighted with fat saturation (TR/TE 2690/22ms, slice thickness 3mm with a 20mm gap, number of images 20); coronal T2 weighted (TR/TE 2000/29ms, slice thickness 3mm with a 10mm gap, number of images 15); axial T2 weighted (TR/TE 2290/34ms, slice thickness 4mm with a 10mm gap, number of images 17). Subsequently, the images were transferred to a workstation (NovaPACS Diagnostic Viewer, Novarad Corporation, USA). The integrity and tension of the ACL tendon were evaluated and graded by a radiologist with expertise in musculoskeletal radiology. The grading system employed was as follows: total rupture, intact and tight, and intact but loose.

Statistical Analysis

Continuous variables were expressed as mean and standard deviation, while categorical variables were presented as percentages and frequency distribution. The comparison of continuous variables between independent groups was conducted using a t-test and ANOVA, while the comparison of categorical data was performed using the Chi-square test. A p-value of less than 0.05 was considered to be statistically significant.

RESULTS

A total of 250 patients were reviewed, of whom two exhibited septic arthritis during the early postoperative period (within the first 15 days). Bone patellar tendon bone graft was employed in five patients, and two patients developed deep venous thrombosis, resulting in their exclusion from the study. A further 12 patients were excluded from the final analysis due to the absence of imaging data. Consequently, the final sample size comprised 229 patients who had completed all evaluations. The cohort comprised eight female and 217 male patients, with a mean age of 30.1±6.1 years (range 18–46). The mean duration of follow-up was 32.8±7.0 months (range, 24–50). Of the 229 patients, 79 underwent reconstruction of the anterior cruciate ligament using the cTT technique, 79 underwent reconstruction using the mTT technique, and 71 underwent reconstruction using the TP technique. The mean diameter of the graft was 8.2±0.6 mm. The demographic and clinical characteristics of the three groups were found to be similar, with the exception of the duration of follow-up (Table 1).

Comparison of Clinical Results

The final LKS in cTT technique exhibited a lower score than both the mTT and TP techniques (p=0.0001). Conversely, the LKS in patients treated with modified TT and TP techniques was found to be comparable (p=0.565). The Lachman tests revealed inferior results for the cTT technique in comparison to the mTT and TP techniques (p=0.001). No significant differences were observed between the mTT and TP techniques in relation to the knee examination (p=0.823). The clinical results are presented in Table 2.

Table 1. Comparison of demographic and clinical characteristics of patients in each group

Variables	cTT (n=79)	mTT (n=79)	TP (n=71)	p
Age (years±SD)	30.4±6.3	30.6±6.2	28.6±5.4	0.540
Sex (M/F)	77/2	76/3	68/3	0.839
Side (R/L)	48/31	54/25	47/24	0.588
Simultaneous meniscal injuries (n)				
Lateral meniscus tear	5	8	5	0.644
Medial meniscus tear	17	27	17	0.164
Simultaneous ligamentous injuries (n)	1 MCL	1 MCL	2 MCL	0.709
Simultaneous chondral lesions (n)	1	2	0	0.395
Graft diameter (mm±SD)	8.2±0.5	8.2±0.5	8.1±0.6	0.546
Follow-up duration (months±SD)	37.2±7.9	30.5±5.1	30.5±5.1	0.0001

cTT: Conventional transtibial technique; mTT: Modified transtibial technique; TP: Transportal technique; M: Male; F: Female; R: Right; L: Left.

Table 2. Comparison of clinical results

Variables	cTT (n=79)	mTT (n=79)	TP (n=71)	p	Subgroup comparisons mTT vs. TP
Lysholm Knee Score (score±SD)	90.3±9.6	94.7±6.8	94.7±7.0	0.001	0.565
Excellent >90	42	54	51	0.027	0.953
Good 84-90	21	21	16		
Fair 65-83	14	3	3		
Poor <65	2	1	1		
Lachman Test				0.001	0.823
Grade 3	6	2	1		
Grade 2	2	1	2		
Grade 1	22	6	4		
Grade 0	49	70	64		

cTT: Conventional transtibial technique; mTT: Modified transtibial technique; TP: Transportal techniqu; SD: Standard Deviation.

Comparison of MR Imaging Findings

At the final MRI examination, nine patients (3.9%) had experienced a re-rupture, 31 patients (13.5%) exhibited an intact but loose anterior cruciate ligament (ACL), and 189 patients (82.5%) demonstrated an intact and tight ACL. The incidence of re-rupture and graft loosening (elongation) was higher in the cTT technique compared to the mTT and TP techniques (p=.001), but no significant difference was observed between the mTT and TP techniques (p=0.870) (Table 3).

DISCUSSION

The objective of this study was to perform a comparative analysis between three distinct femoral drilling techniques (Fig. 1) employed in single-bundle anterior cruciate ligament (ACL) reconstruction. The findings of our study indicate that the utilization of the mTT technique during femoral tunnel drilling can yield functional and radiological outcomes that are comparable to those of the TP technique. The modified technique yielded superior graft orientation, thereby reducing the incidence of re-rupture and instability in comparison to the cTT method. Moreover, the mTT technique allows for the preparation of a longer femoral tunnel than the TP technique [19].

While a range of implants may be employed for graft fixation, recent practice has seen the widespread adoption of suspension systems incorporating cortical buttons. It has been proposed that a minimum femoral tunnel length of 25 mm is required to achieve secure graft fixation with a suspension system. A short femoral tunnel may result in the formation of a small bone block in which the cortical button is situated. This may subsequently lead to the fracture and failure of the suspension system during graft tensioning. Secondly, the quantity of graft material within the femoral tunnel is reduced in the case of a shorter tunnel, which subsequently diminishes the pull-out strength. Therefore, any femoral tunnel preparation technique that provides a longer tunnel may be preferable to the others. Prior research has demonstrated a direct correlation between the femoral tunnel length obtained through the TP technique and knee flexion. In a cadaver study conducted by Basdekis et al. [21], the femoral tunnel length at 90 degrees of knee flexion was found to be 27.1 mm, while the tunnel lengths at 110 and 130 degrees were 38.9 mm and 39.2 mm, respectively. In order to obtain an adequate femoral tunnel length using the TP technique, it is necessary to maintain a knee flexion of greater than 110 degrees. However, this position presents challenges for intra-articular visualization and is believed to elevate the

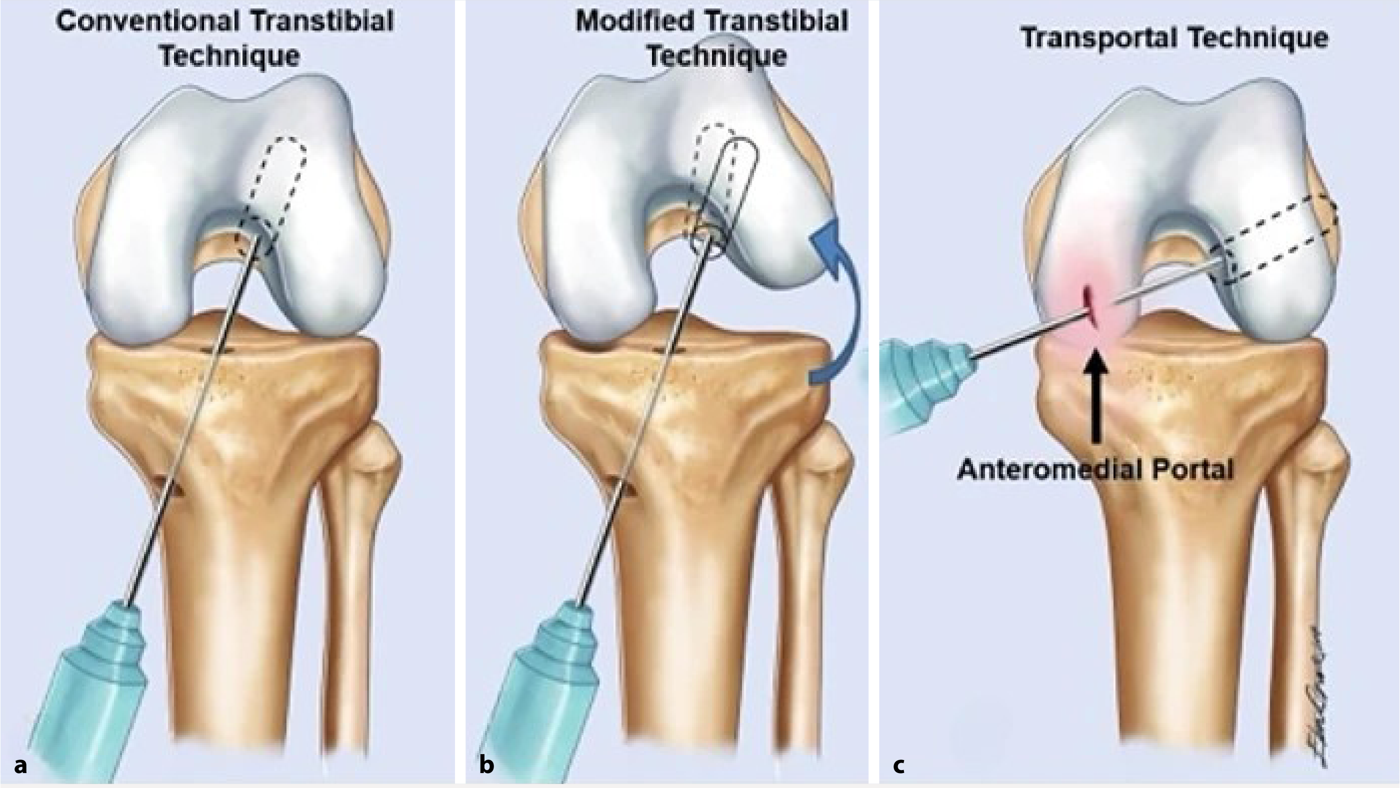

Figure 1. Illustration of femoral drilling techniques. **(a)** Conventional Transtibial, **(b)** Modified transtibial, **(c)** Transportal technique. Note the change in intraarticular femoral aperture in each technique.

Table 3. Comparison of intraoperative femoral tunnel length and MR imaging findings

Variables	cTT (n=79)	mTT (n=79)	TP (n=71)	p	Subgroup comparison mTT vs. TP
Femoral Tunnel length (mm±SD)	63.3±3.7	51.6±3.7	41.5±7.1	0,0001	0.001
Status of ACL on final MRI (n)				0.0001	0.870
Intact and tight	51	72	66		
Intact but Loose	22	5	4		
Re-rupture	6	2	1		

cTT: Conventional transtibial technique; mTT: Modified transtibial technique; TP: Transportal technique; MRI: Magnetic Resonance Imaging; SD: Standard Deviation.

risk of iatrogenic medial femoral condyle cartilage injury, given the further reduction in intra-articular volume [22]. Conversely, the mean femoral tunnel length in the mTT technique was 51.6 mm in our study, which represents a significant advantage over the TP technique in terms of femoral tunnel length [19].

The majority of studies that have compared the radiographic outcomes of the TP technique with those of the cTT technique have reached the same conclusion: that the cTT technique is unable to provide the desired anatomic reconstruction with regard to femoral tunnel positioning on radiographs [23–25]. Nevertheless, there are studies that have demonstrated the possibility of achieving anatomic reconstruction through modifications to the TT technique. In a cadaver study by Piasecki [26], it was reported that if the tibial tunnel entry is drilled from slightly proximal to the anteromedial cortex of the tibia, the femoral tunnel can be opened from the anatomic footprint. Similarly, Lee et al. [16] demonstrated anatomic femoral tunnel drilling by modifying the TT techniqueMetin girmek için buraya tıklayın veya dokunun. In both of these modifications, the intra-articular aperture of the tibial tunnel has been modified.

The study by Youm et al. [13] demonstrated that the mTT technique produces outcomes at least comparable to those of the TP technique [27]. However, our modification has employed the elasticity of knee ligaments and forced the knee into a varus position to reach the ACL footprint. The technique of drilling the femoral tunnel at the ACL footprint by forcing the knee to varus was also described in a recent study by Youm [12]. The aforementioned study differed from the current one in that the tibial tunnel was opened while the knee was forced to varus at 80° with the tibia in internal rotation. The discrepancy is believed to be attributable to the differing angles employed in the opening of the tibial tunnel, with the current study utilizing a more lateral approach. The tibial tunnel was drilled with the tibia in internal rotation at 80° knee flexion, which was 15° less than the angle applied in the previous study.

A review of studies with a minimum follow-up period of 10 years revealed that the re-rupture or loosening of the reconstruction occurred in 1 in 9 patients who had undergone ACL reconstruction [28]. Incorrect femoral tunnel placement is widely accepted as the primary cause of re-rupture. Nevertheless, no notable discrepancy was identified between the mTT technique and the TP techniques in the long-term follow-up period [27]. In a retrospective study by Inderhaug et al. [29], the re-rupture rate was determined to be 3.6% over a 10-year follow-up period with the TT techniqueMetin girmek için buraya tıklayın veya dokunun.. In long-term outcomes of TP portal technique lower rates were determined [30–33].

The findings of the present study diverge from those of previous literature, with the failure rates of the TT technique exhibiting a notable discrepancy when compared to those of the other two methods. No significant difference was identified between the TP portal and mTT techniques with regard to failure rates or re-rupture. Therefore, it can be posited that both of these methods may be employed for anatomic reconstruction. Re-rupture is a common occurrence within the first two years following surgery [34]. Although the follow-up period in our study was relatively brief, it was sufficiently long to allow for the definition of the failure rate.

This study has both strengths and limitations. The present study offers a valuable contribution to the field by providing a comparative analysis of the radiological and functional outcomes associated with three distinct femoral drilling techniques. The fixation materials and graft used in all patients were identical, and all operations were conducted by the same surgical team. Evaluations were performed by a team that was blinded to the surgical methods used. The number of patients and the follow-up period for each of the three techniques are sufficient for the evaluation of clinical and radiological results. The determination of re-rupture was based on both clinical findings and magnetic resonance imaging (MRI) results. The retrospective nature of the data collection represents a significant limitation.

CONCLUSION

In conclusion, the results of this study demonstrate that the mTT technique allows for anatomic femoral tunnel drilling when the knee is forced into varus at 60° flexion. A comparison of the mTT with the cTT technique revealed significantly superior radiological and functional outcomes, comparable to those observed in the TP technique. Furthermore, in comparison with the TP technique, the femoral tunnel is of an adequate length and there is no risk of posterior wall blow-out. It is unlikely that iatrogenic injury to the medial meniscus or medial femoral condyle will occur. It is recommended that the mTT technique be considered as an alternative to the TP technique.

DECLARATIONS

Ethics Committee Approval: The Antalya Training and Research Hospital Clinical Research Ethics Committee granted approval for this study (Date: 23.06.2017, number: 11/16).

Author Contributions: Idea/Concept – MBE, GD; Design – MBE, GD; Control/Supervision – MBE, GD; Data Collection and/or Processing – MBE, GD; Analysis and/or Interpretation – MBE, GD; Literature review – MBE, GD; Writing – MBE, GD; Critical Review – MBE, GD.

Data Avaliability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

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ABBREVIATIONS

ACL - Anterior Cruciate Ligament

cTT - Conventional Transtibial Technique

mTT - Modified Transtibial Technique

TP - Transportal Technique

OI - Outside-In Technique

LKS - Lysholm Knee Score

MRI - Magnetic Resonance Imaging

PCL - Posterior Cruciate Ligament

AM - Anteromedial

AL - Anterolateral

PACS - Picture Archiving and Communication System

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