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Aims & Scope

Sports Traumatology and Arthroscopy is an international, peer-reviewed journal dedicated to the latest advances and research in sports traumatology, arthroscopy and related surgical techniques. Our aim is to serve as a premier platform for the dissemination of significant new findings and the exchange of evidence-based knowledge and experience that highlight progress in all areas of sports traumatology and arthroscopy. Three issues are released every year in April, August, and December.

Aim

The primary aim of Sports Traumatology and Arthroscopy is to improve the care of patients with sports injuries by promoting the understanding of the pathophysiology of sports injuries, improving diagnostic techniques, and advancing treatment and rehabilitation methods. The journal aims to bridge the gap between sports traumatology research and clinical practice by providing a forum for the exchange of information relevant to clinical orthopedics, sports medicine and the science of sports injury and repair.

Scope of the Journal

The scope of the journal includes, but is not limited to, the following areas

Arthroscopy: Innovative techniques, clinical outcomes, and advances in arthroscopic surgery for the treatment of sports injuries.

Sports Orthopedics: Articles on surgical and non-surgical treatment options for sports injuries, including the use of novel techniques, materials, and implants.

Injury Prevention and Management: Studies on the prevention, diagnosis, treatment, and rehabilitation of sports-related injuries.

Regenerative Medicine: Treatment methods that involve the process of replacing, engineering, or regenerating human cells, tissues, or organs to restore or establish normal function after sports injuries, including ligaments, cartilage, menisci, and bone.

Biomechanics and Kinesiology: The study of the biomechanics of exercise and its effects on the body, with the goal of improving injury prevention strategies and rehabilitation approaches.

Rehabilitation and Physical Therapy: Evidence-based practices for rehabilitating athletes after injury or surgery, including physical therapy techniques and recovery protocols.

Performance Enhancement: Studies on optimizing athletic performance through innovative training techniques, nutrition, and injury prevention strategies.

Musculoskeletal Anatomy: Studies that focus on the anatomical and biomechanical aspects of sports injuries in order to develop better prevention and treatment strategies, such as new surgical techniques and modifications.

Diagnostic Techniques and Imaging: Research on imaging and diagnostic techniques for sports injuries.

Systematic Review and Metanalysis: Comprehensive reviews of the current literature that use explicit, systematic methods to identify, select, and critically appraise relevant research on a specific topic or question.

Case Reports: Detailed reports of individual cases, clinical experiences, and studies that contribute to the understanding of sports injuries and their management.

Sports Traumatology and Arthroscopy invites submissions from researchers, clinicians, and allied health professionals in sports medicine, orthopedic surgery, physical therapy, and related fields. We are committed to providing our readers with high-quality, impactful articles that contribute to the advancement of sports traumatology, arthroscopy, and injury management. Through rigorous peer review and a commitment to excellence, we aim to assist orthopedic surgeons and all physicians who care for patients with sports injuries in improving patient outcomes and advancing the field of sports traumatology and arthroscopy.

Owner: On behalf of the Turkish Sports Traumatology Arthroscopy and Knee Surgery Society:

Prof.Dr. Yavuz KOCABEY

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Contact information of the corresponding author

The name of the **department and institution** in which the work was done

Declarations

Acknowledgments

Ethics approval and consent to participate: The name of the ethical committee or institutional review board, Date of approval, and the number of approvals.

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Every research paper should adhere to appropriate standards for research reporting. This ensures that editors, peer reviewers, and readers have sufficient information to understand the research methodology and assess the reliability of the results. We recommend the use of standard reporting templates for various studies, which you can find at <https://www.equator-network.org/>.

Preparation of Declarations in the Abstract Page

Acknowledgements

List all contributors who do not meet the criteria for authorship, such as technical assistants, assistants in data collection and entry, illustrators, writing assistants, or heads of departments who provided only general support. Financial and other material support should be disclosed and acknowledged.

Author Contribution Statement

All authors' contributions to the manuscript should be listed under the authors' contribution categories using their initials (e.g., ML). It should also be noted that all authors have read the final version of the submitted manuscript and agree with its accuracy.

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The institution from which the ethics committee approval was obtained and the date and number of the approval should be reported. For studies where ethics committee approval is not required, the reason why it is not required should be reported. It should also be stated that informed consent was obtained from the participants.

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Data Availability Statement

A data availability statement in an article informs readers about the location and method of accessing data underpinning the findings and analyses. This might encompass links to datasets that are open to the public and were examined or created as part of the research, details about the available data, and/or instructions for obtaining data that isn't openly accessible. We strongly recommend uploading the raw data as a Supplementary file.

References

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Authors should always try to read and cite the original work (the primary source) in the manuscript. In cases where this is not possible, secondary sources citing the primary original source may be cited. However, this situation is undesirable and should be used unexceptionally. Self-citations may be used if the content of the article is related to the submitted manuscript. However, authors, editors, and peer-reviewers should not abuse this option to promote their own papers.

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There is no limit to the number of references. However, authors should cite only the necessary articles.

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Reference citations in the text should be identified by numbers in square brackets, such as [5], [7,8], and [4-9, 11]. The reference list should be numbered consecutively.

Journal Article

Grimberg J, Duranthon LD, Bellaïche L, Petrover D, Kalra K. The time for functional recovery after arthroscopic rotator cuff repair: Correlation with tendon healing controlled by computed tomography arthrography. *Arthroscopy*. 2008;24:25-33.

If there are more than 6 authors, provide first six authors and use 'et al.' at the end of author list. Digital Object Identifier (doi) number should be added to the end of the reference (if available).

Cvetanovich GL, Gowd AK, Liu JN, Nwachukwu BU, Cabarcas BC, Cole BJ, et al. Establishing clinically significant outcome after arthroscopic rotator cuff repair. *J Shoulder Elbow Surg*. 2019;28:939-48.

Book

Newton ML. Current practice of pain. 1st ed. St. Luis, MO: Mosby; 1990.

Book Chapter

Jurkovich GJ. Duodenum and pancreas. In: Mattox KL, Feliciano DV, Moore EE, editors. Trauma. 4th ed. New York: McGraw-Hill; 2000. pp. 735–62.

Online Document

Cartwright J. Big stars have weather too. IOP Publishing PhysicsWeb. <http://physicsweb.org/articles/news/11/6/16/1>. Accessed 26 June 2007.

Dissertation

Trent JW. Experimental acute renal failure. Dissertation, University of California; 1975.

Case Reports

New, interesting and rare cases can be reported. They should be unique, describing a great diagnostic or therapeutic challenge and providing a learning point for the readers. Cases with clinical significance or implications will be given priority. These communications could be of up to 1500 words (excluding Abstract and references) and should have the following headings: Abstract (unstructured), Key-words, Introduction, Case report, Discussion, Reference, Tables and Legends in that order. The manuscript could be of up to 1500 words (excluding references and abstract) and could be supported with up to 20 references. Case Reports could be authored by up to 4 authors.

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Figure legends for all images must be included at the end of the manuscript text file, after the References section. Explain what each figure shows. Identify machine settings for magnetic resonance and computed tomography images and give the magnification of all photomicrographs. Define all arrows and other such indicators appearing on the figure.

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Editorial

Is Peroneus Longus Tendon the Ideal Graft for ACL Reconstruction?

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The peroneus longus tendon (PLT) was first introduced as a graft option for anterior cruciate ligament (ACL) reconstruction in 1997 by Prof. Dr. Ahmet Uğur Turhan and colleagues at Karadeniz Technical University. Between 1997 and 2008, ACL reconstruction using the PLT autograft was performed in 64 patients, with the outcomes of these cases published in 2008 [1]. Since then, the PLT has gained growing popularity as a graft choice in ACL surgery, as reflected by a steady increase in related publications.

This growing interest in the PLT as a graft option naturally brings several critical considerations and questions to the forefront of surgeons' evaluations. When evaluating a new graft option for ACL reconstruction, four key questions typically arise: Is the graft biomechanically strong enough? What are the clinical outcomes associated with its use? How easy is it to harvest? And does its use lead to a high rate of donor site morbidity that causes considerable discomfort or functional impairment for the patient?

To address these questions, recent studies have focused on evaluating the clinical and functional outcomes of using PLT in ACL reconstruction. Meta-analyses comparing the peroneus longus graft with hamstring tendons have demonstrated similar or even superior clinical and functional outcomes for the PLT [2–4]. Additionally, a review of the literature suggests

that the peroneus longus graft offers promising results comparable to other graft choices in ACL reconstruction [2,5,6].

ACL reconstruction aims to restore knee stability while maintaining its native kinematics. Therefore, the selected graft must possess biomechanical properties capable of withstanding the loads typically borne by the native ACL. Biomechanical studies have demonstrated that various graft options, including bone–patellar tendon–bone, hamstring tendons, quadriceps tendon, tibialis anterior, tibialis posterior, PLT, Achilles tendon, tensor fascia lata, and iliotibial band, exhibit similar in vitro biomechanical characteristics. Notably, most of these grafts, including the PLT, have been shown to be biomechanically superior to the native ACL [7].

Several techniques for harvesting the PLT have been described in the literature, including single-incision or double-incision approaches with full-thickness tendon harvesting, partial-thickness split harvesting, and harvesting combined with peroneus brevis tenodesis [1,8]. The PLT is particularly notable for being easily palpable beneath the skin, relatively free from adhesions, and thicker and stronger than hamstring tendons. These characteristics make it a convenient option for harvesting, providing a thick, predictable, and robust graft [7,9].



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A key concern in the literature regarding using the PLT as a graft is donor site morbidity. Although numerous studies have reported minimal short- and medium-term donor site morbidity, discussions on this issue remain ongoing ^[10,11].

What is the function of the PLT? The peroneal tendons contribute to foot eversion and plantarflexion of the ankle and play a crucial role in foot biomechanics. Specifically, the PLT stabilizes the first metatarsal head and assists in locking the first metatarsal against the medial cuneiform, providing additional structural support ^[12,13]. Cadaveric studies have demonstrated that the PLT is essential for maintaining the stability of the medial longitudinal arch of the foot, with its insufficiency potentially leading to structural deformities ^[14]. Moreover, one study showed that transecting the PLT significantly increases medial displacement of the transverse arch, resulting in complications such as an increased intermetatarsal angle (IMA) and metatarsus primus varus ^[15]. Some authors have further suggested that PLT insufficiency may lead to severe foot complications, resembling those observed in posterior tibial tendon dysfunction ^[16]. A dynamic pedobarographic study conducted in 2024 evaluated the short-term outcomes of peroneus longus tendon (PLT) harvesting and reported significant alterations in pedobarographic data compared to the non-operated side. However, no significant differences were observed in clinical scoring. The authors highlighted several limitations of their study, including the inability to perform isokinetic strength testing, the absence of gait analysis, a small sample size, and a short follow-up period ^[17].

Are these concerns valid? A thesis by the original group that introduced the PLT graft into clinical practice evaluated 26 of the 64 patients who underwent ACL reconstruction using this graft between 1997 and 2008. With an average follow-up period of 19.5 years, the study found no evidence of structural or functional donor site morbidity in the ankle or foot. Notably, the graft was harvested using a double-incision technique without the application of peroneus brevis tenodesis ^[18]. So, if there is no donor site morbidity in the long term, how can this be explained? The answer may lie in a 2008 MRI study conducted by the same research team. This study demonstrated that following the harvesting of the PLT, MRI scans revealed tendon regeneration within the tendon sheath ^[19]. Although it cannot be definitively stated that the regenerated tissue is identical to the original tendon, its presence suggests that the structural support provided to the ankle and foot is preserved, potentially preventing the long-term structural complications previously mentioned. Furthermore, another study highlighted the complex nature of the PLT's anatomical attachment, which extends from the cuneiform bone to both the first and second metatarsals. This anatomical complexity may contribute to maintaining structural integrity, indicating that grafting the PLT

is unlikely to result in catastrophic structural damage based on this mechanism ^[20].

In the early postoperative period, a decrease in the active range of motion and strength parameters may be expected. However, long-term neuromuscular adaptations are likely to compensate for these impairments, ultimately restoring functional capacity ^[21]. Despite this, studies examining eversion strength have yielded conflicting results. While some studies report no statistically significant differences between the operated and non-operated sides, others have observed reductions in eversion torque. Nevertheless, even when eversion strength is diminished, the remaining capacity typically remains sufficient for daily activities and most sports ^[19, 20]. When reviewing complications associated with graft harvesting, very rare occurrences have been reported, including compartment syndrome, peroneal nerve injury leading to foot drop, and sural nerve injury ^[22,23]. With appropriate surgical technique and a meticulous approach, the incidence of peroneal and sural nerve injuries has been reported to be as low as 0.01% ^[24]. Compartment syndrome may arise from tight closure of the peroneal fascia or bleeding within the compartment. Although nerve injuries are rare, they may occur due to improper surgical technique or uncommon anatomical nerve variations. Injury to the superficial sensory nerve is also quite common with other grafting options, such as saphenous nerve injury after bone-patellar tendon-bone and hamstring tendon harvesting ^[25].

In conclusion, the PLT appears to be an attractive autograft option for ACL reconstruction due to its ease of harvesting, predictable size, tensile strength, and positive functional outcomes, as evidenced by existing literature ^[17]. Further long-term dynamic pedobarographic analyses and gait studies with larger patient cohorts are needed to define donor site morbidity after PLT harvesting better. Another area for future research involves clinical and functional outcomes as well as donor site morbidity studies in elite athletes. While the peroneus longus graft seems to be advancing as an ideal graft option, several unresolved issues remain. As with all aspects of science, time and continued research will ultimately reveal the truth.

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Original Article

Knees With Severe Varus Deformities End Up With More Oblique Joint Lines After Total Knee Arthroplasty

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ABSTRACT

Objective: Achieving optimal mechanical alignment and precise component positioning is critical for the success of total knee arthroplasty (TKA). It is also essential to consider the orientation of the joint line, particularly in relation to the ground, in the postoperative period. This study aimed to evaluate the postoperative knee joint line orientation in patients with severe preoperative varus deformities compared to those with mild to moderate deformities.

Materials and Methods: This retrospective study included 60 knees from 59 patients, divided into two groups: 30 knees with mild to moderate varus deformities (mechanical axis deviations $<20^\circ$, Group 1) and 30 knees with severe varus deformities (mechanical axis deviations $\geq 20^\circ$, Group 2). A comparison was made between the preoperative and postoperative radiographs to analyze the mechanical axes, femoral and tibial component positioning, and joint line orientation in relation to the ground.

Results: The preoperative mean mechanical axis deviations were $11.13^\circ \pm 4.07^\circ$ in Group 1 and $22.60^\circ \pm 2.24^\circ$ in Group 2. While femoral and tibial component positioning did not significantly differ between the groups, joint line orientation relative to the floor showed significant differences. The mean tibial component inclination was $4.73^\circ \pm 2.58^\circ$ in Group 2, compared to $3.07^\circ \pm 1.77^\circ$ in Group 1 ($p=0.005$). Similarly, the mean femoral component inclination was $5.24^\circ \pm 2.36^\circ$ in Group 2 and $3.69^\circ \pm 1.87^\circ$ in Group 1 ($p=0.007$). In knees with severe varus deformities, joint line obliquity was significantly greater postoperatively.

Conclusion: Routine instrumentation for TKA is less reliable in severely deformed knees due to soft tissue contractures and the need for extensive release procedures. Severe varus deformities result in the inclination of components being more lateral and an increased obliquity of the joint line following mechanically aligned TKA. Further research is necessary to determine the long-term impact of this lateral inclination on prosthesis survival and clinical outcomes.

Keywords: Joint line obliquity, joint line orientation, severe varus deformity, total knee arthroplasty



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INTRODUCTION

The alignment of the lower limb in the coronal plane and the orientation of the joint line are critical factors in both the onset and progression of knee osteoarthritis, as well as the success of total knee arthroplasty (TKA) [1,2]. Evaluating the joint line orientation relative to the floor is a key method for assessing knee alignment and implant positioning. Its significance lies in its direct biomechanical impact, particularly in terms of shear stress and load distribution [3–5].

Parameters of knee joint orientation, such as joint line tilt, are essential in preventing component malposition during TKA or secondary realignment surgeries. Misalignment of the knee joint line can influence the extent of bone resection at the distal femur and proximal tibia. When joint line obliquity is used as the sole reference for axial alignment at the femoral posterior condyle, it can affect the rotation of the femoral components, leading to suboptimal outcomes [1,2,6].

Correcting severe varus deformities during TKA can be particularly challenging in cases involving medial compartment bone loss, a significantly contracted medial collateral ligament, or lateral structure laxity [7]. Consequently, achieving optimal joint line orientation and alignment in knees with severe varus deformities may be technically more demanding than in knees with milder deformities [8].

Restoration of the knee joint line orientation is widely considered an essential factor in successful knee arthroplasty. Postoperatively, patients with minimal deviation from a parallel joint line orientation tend to achieve the best functional outcomes, including greater range of motion, reduced patellofemoral pain, and fewer mechanical complications [1].

This study evaluated and compared component positioning and joint line orientation in TKA patients with severe varus deformities and those with mild to moderate varus deformities. We hypothesized that restoring coronal plane alignment of the limb does not necessarily guarantee optimal joint line orientation. Even if the components are implanted perpendicularly relative to the mechanical axis, achieving a parallel joint line orientation with the floor may not be assured.

MATERIALS AND METHODS

Patients and Study Design

This study protocol was approved by the institutional ethics committee (Approval Date/Issue: 24.06.2014, 14-4.2/12). A total of 60 knees from 59 patients (mean age: 70.40 ± 7.73 years) who underwent total knee arthroplasty (TKA) between November 2005 and February 2014 were included in this retrospective study. The patients were randomly selected from those who had undergone TKA; only those with available preoperative

and postoperative long-leg radiographs were included. The patients were categorized into two groups based on their preoperative mechanical axis deviations: Group 1 consisted of patients with mild to moderate varus deformities ($<20^\circ$), while Group 2 comprised patients with severe varus deformities ($\geq 20^\circ$) (Table 1). Each group included 30 knees. The mean follow-up duration was 32.35 ± 25.91 months. The etiology was primary osteoarthritis in 54 patients and rheumatoid arthritis in six. None of the patients had a history of prior surgery. The demographic characteristics of the patients are summarized in Table 1. This study was conducted in accordance with the STROBE guidelines.

Surgical Technique

All surgeries were performed by the two senior authors (S.A. and H.S.) under regional epidural anesthesia. The standard medial parapatellar or subvastus approaches were employed for each procedure. Intramedullary instrumentation was used for both the femoral and tibial sides, and hybrid or cemented posterior cruciate ligament-retaining total knee arthroplasties (TKAs) were performed. In the severe deformity group, five knees received extension stems on the tibial side. An all-polyethylene component was used on the patellar side for all patients. Both surgeons adhered to a predefined, standardized surgical protocol for all procedures, encompassing detailed preoperative planning and uniform intraoperative steps for implant positioning and soft tissue management.

Radiological Measurements

Preoperative and postoperative knee radiographs were obtained using standing weight-bearing long-leg anteroposterior radiographs and standard anteroposterior and lateral short knee radiographs. The standing long-leg

Table 1. Patient characteristics and preoperative mechanical axis deviations

	Group 1 $<20^\circ$ varus (n=30)	Group 2 $\geq 20^\circ$ varus (n=30)
Mechanical Axes	$11.13^\circ \pm 4.06^\circ$	$22.60^\circ \pm 2.24^\circ$
Age (years) (Mean $\pm$ SD)	70.63 ± 7.92 (53–82)	70.17 ± 7.67 (53–83)
Sex	3♂ 27♀	3♂ 27♀
Side (right/left)	13 R 17 L	18 R 12 L
Postoperative duration (months)	36.57 ± 30.44	28.13 ± 20.09
Surgical approach	Subvastus 12 Standard 18	Subvastus 15 Standard 15

radiographs (hip to ankle) were taken unassisted, with the patient standing bipedally in knee extension and the lateral malleoli positioned 20 cm apart. The patient's feet were elevated 5 cm to visualize the ankle joints. To avoid malrotation, the patella was aligned perpendicular to the x-ray source. A digital radiography system (Ysio Max, Siemens, Erlangen, Germany) was used with a focus-to-detector distance of 3 m. Lateral short knee radiographs were taken with the patient in the lateral decubitus position on the operative side, with the knee flexed 20–30° and the contralateral knee fully extended. The patella and epicondyle were positioned perpendicular to the cassette to prevent rotation. The X-ray source was centered at a distance of 100 cm from the medial femoral epicondyle [9,10]. Digital measurements were made using a picture archiving and communication system (syngo; Siemens, Erlangen, Germany), and all patients underwent the same radiographic examination.

Femoral and tibial component positioning on short-leg radiographs was assessed in both the frontal and sagittal planes using the American Knee Society Radiographic Evaluation System [11]. Postoperative mechanical axis deviations and component positioning relative to the femoral and tibial mechanical axes were assessed using standing anteroposterior radiographs [9,12]. Component positioning was then compared between the two groups (Figs. 1 and 2). The posterior tibial slope angle was measured preoperatively on lateral radiographs as the angle between the proximal mid-diaphyseal anatomical line and the line parallel to the tibial plateau.

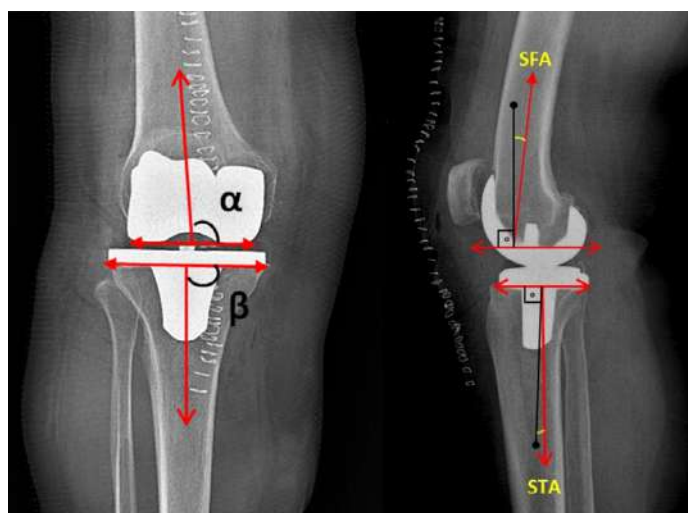


Figure 1. Measurements of the frontal and sagittal femoral and tibial component angles (α , β , SFA, and STA) on short knee radiographs.

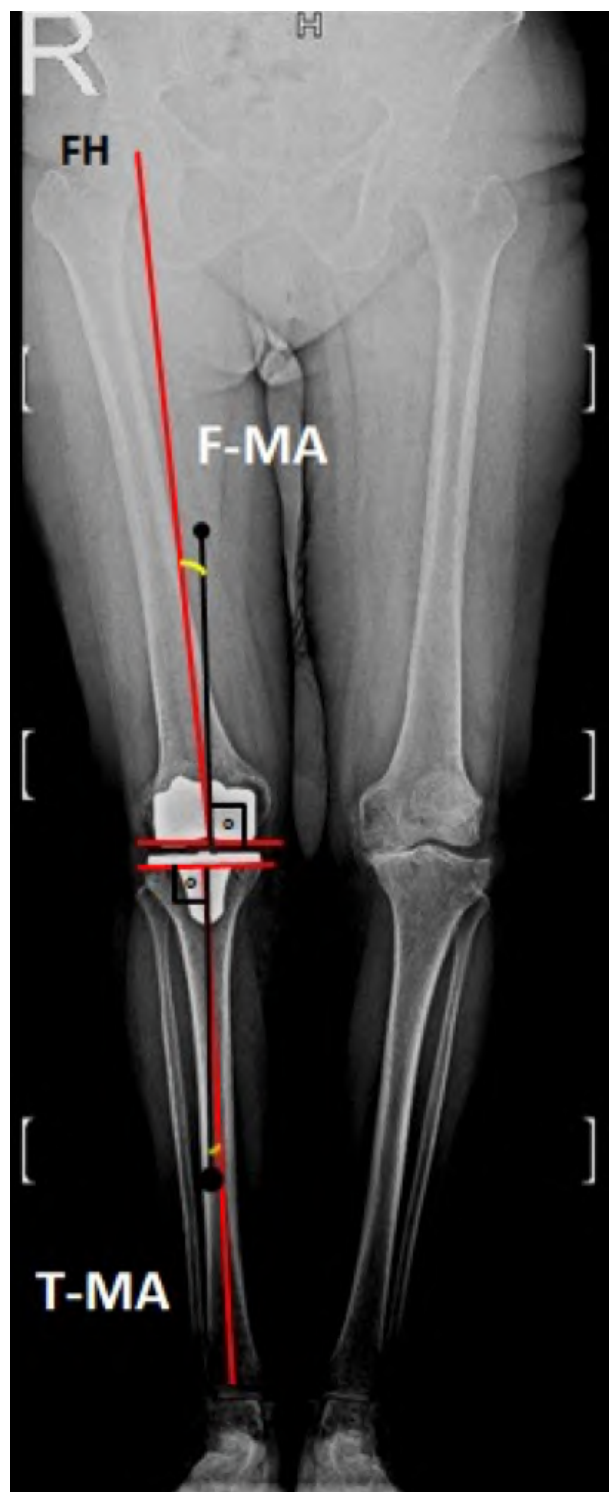


Figure 2. Postoperative measurements of the mechanical axis deviations and component positioning relative to the mechanical axes of the femur and tibia.

F-MA (femoral mechanical axis and femoral component), T-MA (tibial mechanical axis and tibial component).

On the short knee radiographs, the normal component positioning values were as follows: frontal femoral component angle (α angle)= 92° – 98° , frontal tibial component angle (β angle)= 90° , sagittal femoral angle (SFA) $\leq 3^{\circ}$ of flexion, and sagittal tibial angle (STA)= 0° – 7° posterior slope. Angles outside of these values were considered outliers, and the proportion of outliers was compared between the two groups.

Component orientation was further assessed by measuring the inclinations of the femoral and tibial components relative to the ground and by calculating the angles between tangential lines drawn parallel to the femoral and tibial components (tibiofemoral angle, TFA) on postoperative standing long-leg anteroposterior radiographs [1,13,14]. The F angle was defined as the angle between the tangential line drawn parallel to the most prominent parts of the medial and lateral condyles of the femoral component and the line parallel to the ground. Similarly, the T-angle was defined as the angle between the tangential line drawn parallel to the tibial baseplate and the line parallel to the ground (Fig. 3).

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences, version 18 (SPSS Inc., Chicago,

IL, USA). Descriptive statistics were presented as means, standard deviations, and percentages. The normality of distribution was tested using the one-sample Kolmogorov-Smirnov test, and the homogeneity of variances was determined using the Levene test. Independent t-tests were used to compare means, and Fisher's exact test was used to compare proportions. The significance level was set at 0.05.

RESULTS

The mean preoperative mechanical axis deviations were $11.13^{\circ} \pm 4.06^{\circ}$ (range, 2° – 17°) in the mild to moderate varus deformity group and $22.60^{\circ} \pm 2.24^{\circ}$ (range, 20° – 27°) in the severe deformity group. Component positioning measured on the short knee radiographs showed that the frontal, sagittal femoral and tibial component angles (α , β , SFA, STA) were not significantly different between the mild to moderate and severe deformity groups. The outlier ratios of these four angles were comparable between the two groups (Table 2).

As measured on the long-leg radiographs, the postoperative mechanical axis deviations and the angles between the components and the mechanical axes of the femur and tibia did not exhibit statistically significant differences between the groups (Table 3).

The radiographic evaluations of the orientations of the components in relation to the ground revealed that both the femoral and tibial components exhibited a significantly greater lateral inclination in the group with severe deformities (Table 2). The mean inclination of the tibial components was $4.73^{\circ} \pm 2.58^{\circ}$ in group 2, in comparison to $3.07^{\circ} \pm 1.77^{\circ}$ in group 1 ($p=0.005$). The mean inclination angle of the femoral components was $5.24^{\circ} \pm 2.36^{\circ}$ in group 2 and $3.69^{\circ} \pm 1.87^{\circ}$ in group 1 ($p=0.007$). It was observed that the joint line obliquity was greater following the TKAs in the highly deformed knees. The comparison of the angles between the component inclinations (TFA) revealed no statistically significant differences between the two groups (Table 2).

DISCUSSION

Total knee arthroplasty presents a distinctive set of challenges in cases where the knees exhibit severe varus deformities. When the sole perioperative focus is restoring the mechanical axis of the lower extremity, this can result in errors in component placement. In addition to addressing various other parameters, the postoperative artificial knee joint line should ideally be parallel to the ground and perpendicular to the weight-bearing axis [2,15]. Failure in mechanically aligned TKAs has been documented to be higher due to excessive load variations and an increased number of outliers in joint line orientation [1,16].

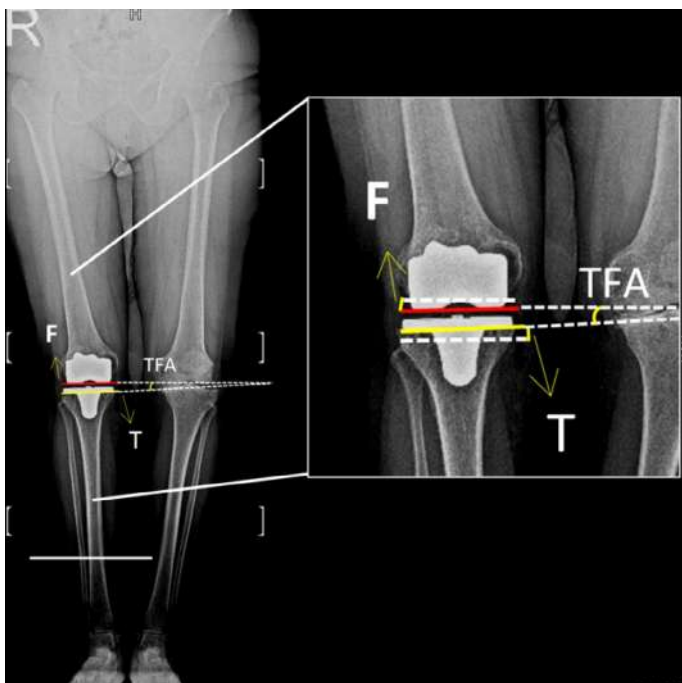


Figure 3. Evaluation of component orientation, including the inclination angles of the femoral and tibial components relative to the floor and the tibiofemoral angle (TFA), measured on postoperative standing long-leg anteroposterior radiographs.

Table 2. Inclination of the femoral and tibial components relative to the ground (mean±standard deviation [SD]). Component positioning angles in the frontal and sagittal planes measured on short knee radiographs (mean±SD), including the proportion of outliers

	Group 1 <20° varus (n=30) (Mean±SD)	Group 2 ≥20° varus (n=30) (Mean±SD)	p*
Inclinations of the femoral and tibial components relative to the floor			
Inclination of the tibial component relative to the floor (T)	3.07°±1.77°	4.73°±2.58°	0.005*
Inclination of the femoral component relative to the floor (F)	3.69°±1.87°	5.24°±2.36°	0.007*
Angle between the inclinations of the tibial and femoral components (TFA)	1.02°±0.79°	1.14°±0.72°	0.546
Component positioning in the frontal and sagittal planes as measured on short knee radiographs (mean±SD)			
Posterior tibial slope (preoperative)	6.64°±2.53°	7.98°±3.25°	0.08
Frontal femoral component angle (α angle)	96.32°±2.80°	96.29°±3.09°	0.969
Frontal tibial component angle (β angle)	90.12°±2.49°	90.78°±2.69°	0.317
Sagittal femoral component angle (SFA)	3.24°±2.64°	4.06°±4.00°	0.353
Sagittal tibial component angle (STA)	3.93°±2.13°	3.30°±3.08°	0.358
Component positioning outliers on short knee radiographs n (%)			
Frontal femoral component angle (α angle)	9 (30)	8 (26.7)	1.000
Frontal tibial component angle (β angle)	26 (86.7)	24 (80)	0.731
Sagittal femoral component angle (SFA)	13 (43.3)	16 (53.3)	0.606
Sagittal tibial component angle (STA)	1 (3.3)	6 (20)	0.103

p*: Independent t-test; p**: Fisher's exact test.

Table 3. Component positioning measured on standing long-leg radiographs, presented in relation to the mechanical axes (Mean±SD)

Angles between	Group 1 <20° varus (n=30)	Group 2 ≥20° varus (n=30)	p
Femoral and tibial mechanical axes	3.93°±2.13°	3.30°±3.08°	0.136
Tibial mechanical axis & tibial component	6.64°±2.53°	7.98°±3.25°	0.779
Femoral mechanical axis & femoral component	92.32°±2.01°	93.19°±3.66°	0.258

The present study demonstrated that, although the components could be accurately implanted in both the frontal and sagittal planes in knees with severe varus deformities (mechanical axis deviation ≥20°), achieving a parallel orientation of the

components with respect to the ground was more challenging compared to knees with milder deformities. The inclination of the components was more oblique in knees with severe deformities than in those with mild deformities. Although postoperative mechanical axis deviations in the severe deformity group were not significantly different from those in the mild to moderate deformity group, restoration was observed to be more optimal in the latter group.

In a successfully implanted, mechanically aligned TKA, even with proper correction of coronal plane alignment, insufficient release of contracted soft tissues can lead to complications in the postoperative outcome. Imbalances in soft tissue may result in discrepancies in the orientation of the knee joint line. The meticulous execution of osteotomies can facilitate the restoration of limb alignment in the coronal plane. However, the presence of minor angular discrepancies, which are often compounded by the imbalance of soft tissues, can considerably impact the outcome [17,18]. As determined by anthropometric studies [2,17], the target inclination of the knee joint line represents the objective in TKA for severely deformed knees.

Nevertheless, attaining this inclination can prove challenging due to the presence of soft tissue contractures.

Another factor that has been linked with postoperative changes in the alignment of the knee joint line is the presence of severe hindfoot deformity. Failure to correct the ankle joint inclination in knees with severe varus deformity following total knee arthroplasty (TKA) can result in an unfavorable alignment of the knee joint, preventing a parallel orientation^[19]. In cases of advanced varus, the pre-existing constitutional varus deformity and joint obliquity are frequently elevated, even in the contralateral, unaffected knee^[20]. Consequently, the anticipated postoperative inclination of the components may be greater than that observed in patients with mild varus deformities. In such cases, it may be more appropriate to target a patient-specific inclination that optimizes functional outcomes rather than striving for values that are expected in the general population or in patients with mild varus deformities.

Nishida et al.^[21] reported excellent functional outcomes in patients with both mild residual varus deformities and neutral alignment following TKA, with mild varus alignment deemed acceptable. Nevertheless, further clinical trials and functional data, particularly in patients with severe varus deformities, are required to reach definitive conclusions.

Recent studies have indicated a growing popularity of navigation-assisted TKA techniques for achieving more precise joint inclination, particularly in terms of minor angular adjustments, compared to conventional mechanically aligned TKAs. Nevertheless, navigation-assisted techniques have also been linked to an increased likelihood of lateral inclination of the knee joint line when compared to kinematically aligned TKA procedures^[1,15,22].

It should be noted that this study is not without limitations. Firstly, the retrospective design may have introduced a degree of selection bias, as patient data were collected from historical records rather than being prospectively gathered. Furthermore, the relatively modest sample size of 60 knees may restrict the applicability of the findings to a broader population. A further limitation is the reliance on static radiographic parameters, which may not fully capture the dynamic aspects of knee function following TKA. Furthermore, the lack of long-term clinical outcomes precludes an evaluation of the true impact of joint line obliquity on implant survival and patient satisfaction. Furthermore, the study did not include a comparison between conventional and navigation-assisted TKA techniques, which could provide additional insights into achieving optimal joint line orientation in patients with severe varus deformities.

CONCLUSION

The findings of this study indicate that severe varus deformities are associated with a greater postoperative inclination of the lateral joint line than that observed in cases of mild to moderate deformities following mechanically-aligned TKA. Despite achieving the desired coronal alignment, these cases presented difficulties in restoring a parallel joint line orientation. This is the inaugural study to compare postoperative knee joint line orientations in patients with severe and mild to moderate varus deformities who underwent mechanically-aligned TKA. Although confounding factors such as preoperative knee joint line inclination and surgical technique (conventional, navigation-assisted, or kinematically aligned) may have influenced the results, the long-term effects of lateral joint line inclination on prosthesis survival remain unknown. Further long-term studies are required to address this issue. It is therefore recommended that particular attention be paid to anatomical parameters and soft tissue contractures during soft tissue release, osteotomy, and instrumentation to achieve optimal outcomes in patients with severe varus deformities.

DECLARATIONS

Ethics Committee Approval: The Ege University Faculty of Medicine Clinical Research Ethics Committee granted approval for this study (Date: 24.06.2014, number: 14-4.2/12).

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

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

Conflict of Interest: The authors declared that they have no conflicts of interest with regard to this research.

Informed Consent: Informed consents were obtained from all participants prior to their inclusion in the study.

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ABBREVIATIONS

TKA - Total Knee Arthroplasty

AP - Anteroposterior

RA - Rheumatoid Arthritis

OA - Osteoarthritis

SPSS - Statistical Package for the Social Sciences

FMA - Femoral Mechanical Axis

TMA - Tibial Mechanical Axis

SFA - Sagittal Femoral Angle

STA - Sagittal Tibial Angle

TFA - Tibiofemoral Angle

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Original Article

Early Outcomes of Hip Arthroscopy in Tönnis Grade 2 Osteoarthritis Patients

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ABSTRACT

Objective: Femoroacetabular impingement syndrome (FAIS) is a common cause of hip pain and significantly impairs quality of life. Morphological changes between the femur and acetabulum can lead to a range of pathologies, from focal cartilage defects to labral tears, which may ultimately progress to osteoarthritis. Evidence suggests that patients with osteoarthritis classified as Tönnis grades 0 and 1 typically benefit from hip arthroscopy. However, the available literature on the prognosis of patients with Tönnis grades 2 and higher remains limited. The short-term outcomes of hip arthroscopy were evaluated in patients with Tönnis stage 2 osteoarthritis whose symptoms persisted despite undergoing conservative treatment.

Materials and Methods: Patients who underwent hip arthroscopy with the diagnosis of femoroacetabular impingement syndrome at our center between 2020 and 2023 were included in the study. The inclusion criteria were patients diagnosed with femoroacetabular syndrome who had undergone hip arthroscopy and had been followed up for at least one year. Patients with Tönnis grade 0, 1, 3 and patients with bilateral surgery were excluded from the study. Tönnis stage 2 hips were included in the study. The clinical outcomes were assessed both pre-operatively and the last follow-up using the Modified Harris Hip Score (mHHS), the Non-arthritic Hip Score (NAHS), the Hip Disability and Osteoarthritis Score (HOOS), the Hip Outcome Score-Activities of Daily Living (HOS-ADL), the Hip Outcome Score-Sport Score (HOS-SS) and the Visual Analog Score (VAS).

Results: This study comprises a total of 26 patients, 15 males (57.7%) and 11 females (42.3%). The mean age of our patients was 38.3±9.8 years (range 19-56). The mean follow-up time of the patients was 24.5±3.8 months (range 15-37). Our patients exhibited significant improvement in preoperative scores, including mHHS, NAHS, HOS-Sports, HOS-ADL, and HOOS ($p<0.001$). Additionally, the VAS scores decreased markedly from an average of 6.9±0.8 to 2.6±0.7 ($p<0.001$).

Conclusion: This study revealed a significant improvement in early pain relief and functional outcomes in patients with Tönnis stage 2 osteoarthritis who underwent hip arthroscopy for the treatment of femoroacetabular impingement syndrome.

Keywords: Femoroacetabular impingement, hip arthroscopy, osteoarthritis, Tönnis stage



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INTRODUCTION

FAIS (femoroacetabular impingement syndrome) is a common cause of hip pain and leads to impaired quality of life [1,2]. As a result of abnormal contact between the femur and acetabulum, morphologic changes may occur in the femur, acetabulum or both. These changes vary from focal cartilage defects, cartilage detachment, chondro-labral separation to labral tears, eventually leading to osteoarthritis [3–5].

The Tönnis classification is generally used to classify osteoarthritis of the hip joint. It has been shown that patients with osteoarthritis of Tönnis grades 0 and 1 generally benefit from hip arthroscopy [6,7]. The Tönnis grade is reported to be one of the prognostic factors for the progression of osteoarthritis in patients who have undergone hip arthroscopy with a diagnosis of FAIS [8]. There are studies indicating that the prognosis is worse in patients with Tönnis grade 2 and higher and the rate of total hip arthroplasty (THA) is higher [9,10]. There is even concern that these patients may have poor clinical outcomes following hip arthroscopy, which may necessitate THA [11].

There are conflicting results in the literature regarding hip arthroscopy in patients with grade 2 Tönnis [12,13]. Nevertheless, several studies have reported favorable clinical outcomes of hip arthroscopy in patients with Tönnis grade 2 and higher [14,15]. Therefore, we wanted to share our short-term results after hip arthroscopy in patients with Tönnis grade 2 whose symptoms persisted despite conservative treatment.

MATERIALS AND METHODS

Study Design

Patients who underwent hip arthroscopy with the diagnosis of femoroacetabular impingement syndrome at our center between 2020 and 2023 were included in the study. This retrospective study was approved by the local ethics committee (approval no: 2024-638). The inclusion criteria were patients diagnosed with femoroacetabular syndrome who had undergone hip arthroscopy and had been followed up for at least one year. Patients with Tönnis grade 0, 1, 3 and patients with bilateral surgery were excluded from the study. The radiographs of the patients were evaluated by two independent authors, and only those determined to be in Tönnis stage 2 by both authors were included in the study.

During the specified time period, 28 patients with grade 2 Tönnis underwent surgery. Due to incomplete follow-up of two patients, 26 patients were included in the study (Fig. 1).

Surgical Technique & Rehabilitation

The patients were operated on in the supine position and on a traction table by a single experienced surgeon. A soft cylindrical perineal support with a diameter of 20 cm and a height of

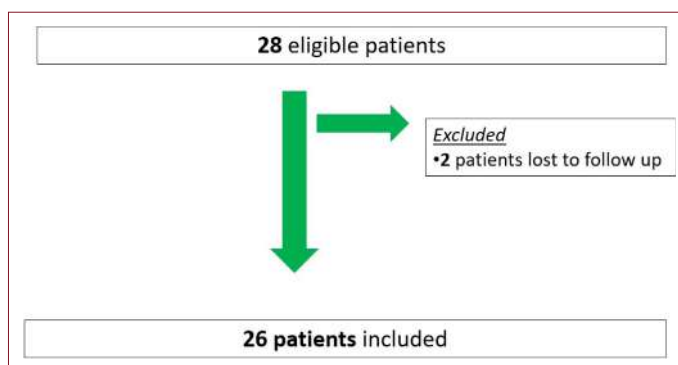


Figure 1. Patients diagram.

35 cm was used to protect the groin area. After appropriate anesthesia, patient preparation was started. Traction was then applied. After providing adequate hip joint space for central compartment pathologies, standard anterolateral, mid-anterior and distal anterolateral accessory portals were created. Initially, existing Pincer lesions were addressed using a superior labral approach. Following sufficient pincer excision, labrum repair was performed using suture anchors through the distal anterolateral accessory portal. Subsequently, traction was released, and the peripheral compartment was visualized. The existing cam lesion was excised under arthroscopic and fluoroscopic guidance. The capsule was then repaired, and the surgery was considered completed.

Postoperative Rehabilitation and Follow-up

All patients were started on standard rehabilitation protocol with partial weight-bearing mobilization followed by isometric exercises. Rehabilitation protocol through phases 1–4 was then applied with minor individual changes according to patient condition.

The clinical outcomes were assessed both pre-operatively and at the last follow-up using the Modified Harris Hip Score (mHHS), the Non-arthritis Hip Score (NAHS), the Hip Disability and Osteoarthritis Score (HOOS), the Hip Outcome Score-Activities of Daily Living (HOS-ADL), the Hip Outcome Score-Sport Score (HOS-SS) and the Visual Analog Score (VAS). Radiographic evaluations were conducted during patient follow-ups (Fig. 2).

Statistical Analysis

SPSS v25.0 (IBM, Chicago, USA) was used for statistical analysis. Continuous variables are shown as mean, standard deviation, median, and minimal to maximal data. Categorical data are shown as numbers and percentages. After distribution analyses, continuous variables were compared preoperatively and postoperatively using the Wilcoxon signed rank test. A value of $p < 0.05$ was considered statistically significant.

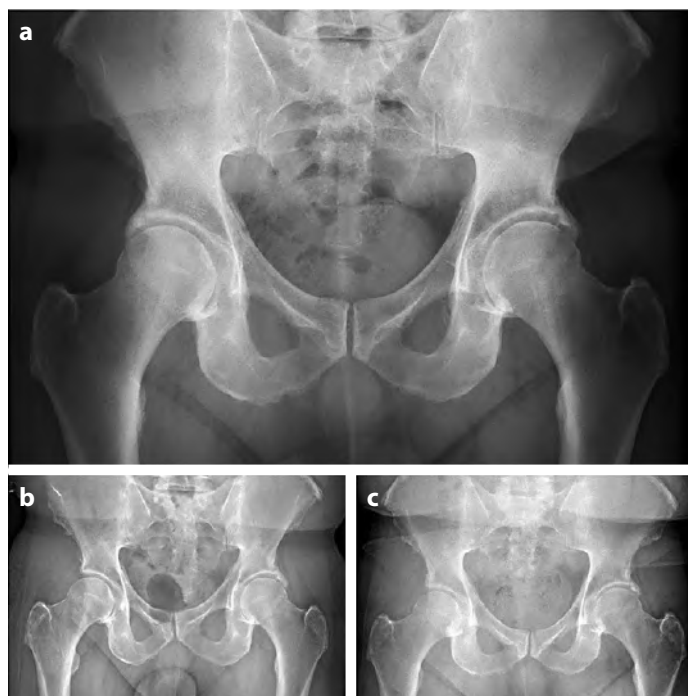


Figure 2. (a) Preoperative radiograph showing a Tönnis grade 2 right hip, (b) Early postoperative radiograph of the patient, (c) Radiograph of the patient 26 months post-surgery.

RESULTS

This study comprises a total of 26 patients, 15 males (57.7%) and 11 females (42.3%). The mean age of our patients was 38.3 ± 9.8 years (range 19–56). The mean follow-up time of the patients was 24.5 ± 3.8 months (range 15–37). 19 of the patients were operated on the right hip (73.1%) and 7 on the left hip (26.9%). The mean BMI of the patients was 25.4 ± 2.5 (Table 1).

While the mean mHHS score of our patients before surgery was 72.4 ± 6.2 , it increased to 77.3 ± 6.0 at the last follow-up ($p < 0.001$). While the average NASH score before surgery was 54.6 ± 13.5 , it increased to 72.9 ± 10.4 at the last follow-up ($p < 0.001$).

While the mean HO-SPORTS score of our patients was 63.7 ± 7.3 before surgery, it increased to 73.7 ± 5.8 at the last follow-up ($p < 0.001$). The mean HO-ADL score was 63.4 ± 4.1 before surgery but increased to 75.6 ± 6.6 at the last follow-up ($p < 0.001$).

While the average HOOS score of our patients before surgery was 62.7 ± 5.8 , it increased to 73.0 ± 6.4 at the last follow-up ($p < 0.001$). The VAS score decreased on average from 6.9 ± 0.8 to 2.6 ± 0.7 ($p < 0.001$) (Table 2).

Table 1. Demographic and follow-up information of the study cohort

	n=26
Age	
Mean $\pm$ SD	38.3 ± 9.8
Median (min–max)	39 (19–56)
Side	
Right	19 (73.1%)
Left	7 (26.9%)
Gender	
Female	11 (42.3%)
Male	15 (57.7%)
BMI	
Mean $\pm$ SD	25.4 ± 2.5
Median (min–max)	26 (20–28)
Follow-up (months)	
Mean $\pm$ SD	24.5 ± 3.8
Median (min–max)	25 (15–37)

SD: Standard deviation; BMI: Body mass index.

Table 2. Comparison of preoperative and final follow-up scores of the study cohort

n=26	Preoperative values Mean $\pm$ SD Median (min–max)	Final follow-up values Mean $\pm$ SD Median (min–max)	p
mHHS	72.4 ± 6.2 76 (50–79)	77.3 ± 6.0 78 (58–88)	<0.001
NAHS	54.6 ± 13.5 60 (22–64)	72.9 ± 10.4 75 (33–82)	<0.001
HOS-SS	63.7 ± 7.3 64 (48–76)	73.7 ± 5.8 74 (58.3–80.6)	<0.001
HOS-ADL	63.4 ± 4.1 62 (51–69.4)	75.6 ± 6.6 73 (65–88)	<0.001
HOOS	62.7 ± 5.8 62 (51–75)	73.0 ± 6.4 71 (62–84.4)	<0.001
VAS	6.9 ± 0.8 7 (5–8)	2.6 ± 0.7 3 (1–4)	<0.001

mHHS: Modified Harris Hip Score; NAHS: Non-arthritis Hip Score; HOS-SS: Hip Outcome Score-Sport Score; HOS-ADL: Hip Outcome Score-Activities of Daily Living; HOOS - Hip Disability and Osteoarthritis Score; VAS: Visual Analog Score.

During the follow-up of our patients, no progression in the Tönnis stage was detected on X-ray imaging.

Four of our patients (15%) exhibited symptoms indicative of pudendal nerve damage; however, all symptoms resolved within a 5-month period. Heterotopic ossification was identified in one of our patients (3%).

DISCUSSION

The most important result of our study is that the early functional results after hip arthroscopy in Tönnis grade 2 hips are significantly improved. The data demonstrated that, during the early period, patients experienced improvements in clinical functional scores and reductions in pain scores.

Studies have shown a correlation between femoroacetabular impingement and early osteoarthritis [16] and many patients with idiopathic osteoarthritis have been found to have FAI on previous radiographs. A study by Ecker et al. [17] emphasized that the risk of developing osteoarthritis in the future is high in hips with pathomorphological findings (cam, pincer). Viswanath and Khanduja [18] found that the cam/pincer lesion progresses to osteoarthritis as a result of damage to the chondrolabral junction. They even found a correlation between FAI and alpha angle above 60° [18]. Patients exhibiting morphological abnormalities on anteroposterior (AP) radiographs, particularly the presence of a posterior wall sign and a decreased medial proximal femoral angle, demonstrate a significantly higher likelihood of osteoarthritic progression [19].

While the relationship between femoroacetabular impingement syndrome and osteoarthritis has become clearer in the literature, the benefit of hip arthroscopy in patients with hip osteoarthritis remains controversial [3,20]. In a systematic review conducted by Domb et al. [21] based on 13 articles, they found that patients with osteoarthritis at Tönnis stage 2 and above were significantly more likely to undergo total hip arthroplasty compared to patients without osteoarthritis. The cumulative risk of reoperation after hip arthroscopy for FAI, including revision surgery or conversion to THA, was 5.5% when including patients with stage 2 and above Tönnis hip osteoarthritis [22]. Moon et al. [23] showed in their study that patients who had undergone arthroscopy for FAI with labral tear had improved functional scores and no decrease in joint space after at least two years of follow-up. In our results, we observed a significant improvement in postoperative functional scores without the need for total hip arthroplasty during the follow-up period. We believe that these contradictions can be clarified in the literature with larger patient groups and longer follow-up periods.

In the study by Moon et al. [23], mHHS increased from 74.8±13.2 preoperatively to 93±8.1 at the last follow-up, with a decrease in mHHS observed in five patients (5.6%). They found that WOMAC scores were 75±12.7 before surgery but increased to 89.4±8.4 at the last follow-up after surgery [23]. In a study conducted by Byrd et al. [14] on athlete patients, mHHS scores and return-to-sport rates were lower in Tönnis 2 patients than in Tönnis stage 0-1 patients, but they found no statistically significant difference. Lee et al. [24] reported that after hip arthroscopy in patients with early-stage osteoarthritis, mHHS scores decreased from 61.2 to 79.5, HOS-ADL scores decreased from 60.6 to 81.8, and VAS scores decreased from 6.3 to 3.2, and they found a significant improvement. Lee et al. [24] reported that after hip arthroscopy in patients with early-stage osteoarthritis, mHHS scores increased from 61.2 to 79.5, HOS-ADL scores increased from 60.6 to 81.8, and VAS scores decreased from 6.3 to 3.2, and they found a significant improvement. We also observed a significant increase in our patients' functional scores and a significant decrease in VAS scores.

Accurate patient selection and the management of patient expectations play a pivotal role in determining the success of arthroscopy in individuals with Tönnis grade 2 hip osteoarthritis. Evidence suggests that the success of femoroacetabular impingement (FAI) surgery is influenced more significantly by appropriate patient selection and expectation management than by technical aspects of the procedure [25]. Although our early patient outcomes appear favorable, the use of advanced preoperative imaging to precisely evaluate the extent of cartilage damage, combined with surgical decision-making tailored to patient expectations, may hold greater significance in achieving optimal results.

The main limitation of our study is that it is a retrospective study that includes only a small number of patients. Another important limitation is that it only reports the results of the Tönnis 2 patient group as a single group, without comparing it to any other group. However, we believe that the inclusion of functional scores reported by both patients and surgeons, which are currently used in the literature, will enrich the study. We believe that our study will pave the way for future investigations with larger and more diverse patient groups.

CONCLUSION

This study showed significant improvement in early pain and function in patients who underwent hip arthroscopy for femoroacetabular impingement syndrome and Tönnis stage 2 osteoarthritis. This study is expected to illuminate future research that involves comparing larger and more diverse patient groups.

DECLARATIONS

Ethics Committee Approval: The Ankara Etlik City Hospital Scientific Research Assessment and Ethics Committee granted approval for this study (Date: 17.07.2024, number: 2024-638).

Author Contributions: Idea/Concept – YE, KS; Design – YE, KS; Control/Supervision – AS, EV; Data Collection and/or Processing – EI, AAU; Analysis and/or Interpretation – EV; Literature review – YE, KS; Writing – YE, SG; Critical Review – EV.

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

Conflict of Interest: The authors declared they have no conflict of interest with regard to the results of this study.

Informed Consent: Informed consents were obtained from all participants prior to their inclusion in the study.

Use of AI for Writing Assistance: Artificial intelligence-supported technologies were not used in the study.

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ABBREVIATIONS

FAI - Femoroacetabular impingement

FAIS - Femoroacetabular impingement syndrome

mHHS - Modified Harris Hip Score

NAHS - Non-arthritis Hip Score

HOOS - Hip Disability and Osteoarthritis Score

HOS-ADL - Hip Outcome Score-Activities of Daily Living

HOS-SS - Hip Outcome Score-Sport Score

VAS - Visual Analog Score

THA - Total hip arthroplasty

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Original Article

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

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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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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 $\pm$ 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 $\pm$ SD)	8.2 ± 0.5	8.2 ± 0.5	8.1 ± 0.6	0.546
Follow-up duration (months $\pm$ 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 $\pm$ 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 technique; 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

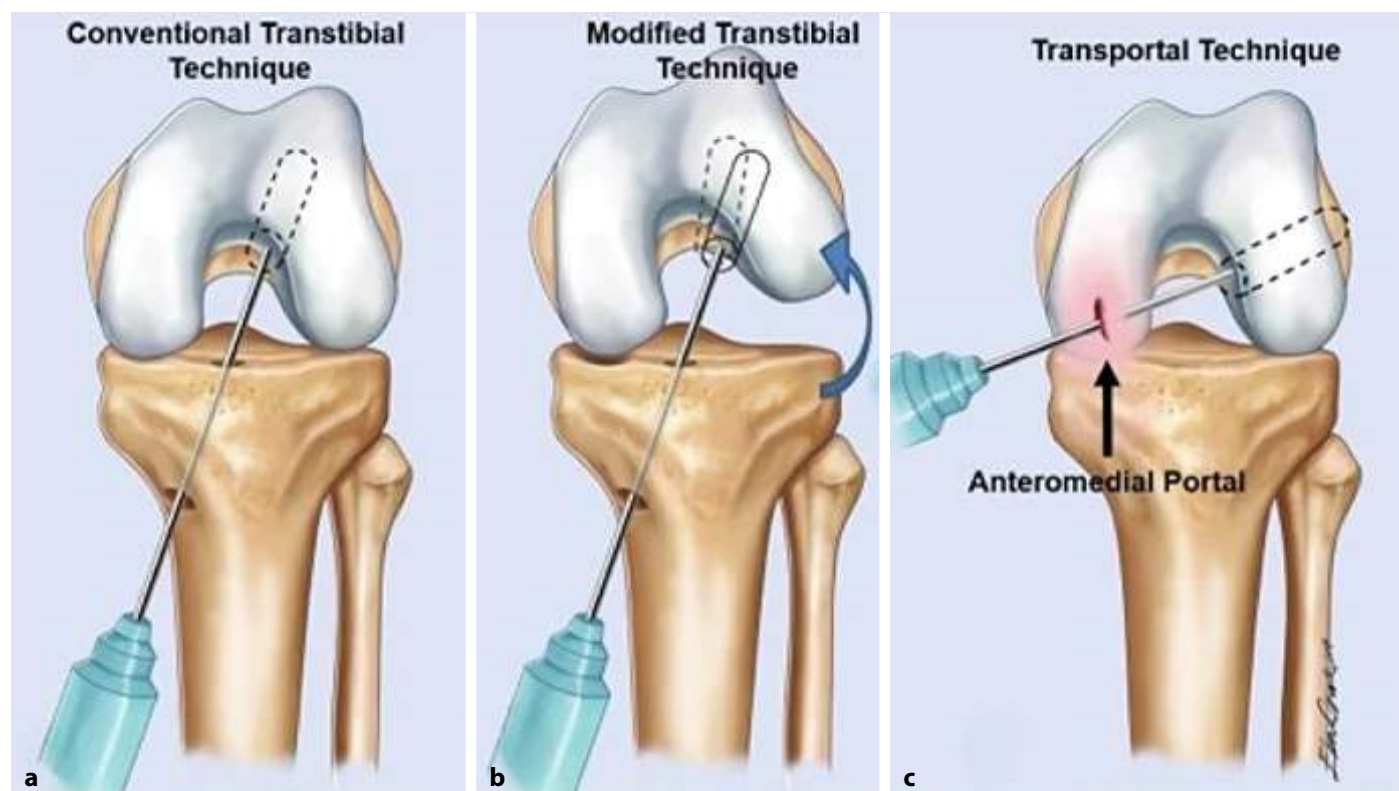


Figure 1. Illustration of femoral drilling techniques. **(a)** Conventional Transtibial, **(b)** Modified transtibial, **(c)** Transportal technique. Note the change in intraarticular femoral aperture in each technique.

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 technique. Metin girmek için buraya tıklayın veya dokununuz. 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 technique. Metin girmek için buraya tıklayın veya dokununuz. 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).

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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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Case Report

Sinding-Larsen-Johansson Syndrome in a 9-Year-Old Tennis Player: A Case ReportEmre Mucahit Kartal,¹ Hakan Cetin,² Koray Kaya Kilic³¹Department of Orthopedics and Traumatology, Antalya City Hospital, Antalya, Türkiye²Department of Orthopedics and Traumatology, Mehmet Akif Inan Training and Research Hospital, Sanliurfa, Türkiye³Department of Radiology, University of Health Sciences, Antalya Training and Research Hospital, Antalya, Türkiye**ABSTRACT**

Sinding-Larsen-Johansson syndrome (SLJS) is a rare cause of anterior knee pain in young athletes and is often underdiagnosed due to low clinical suspicion and poorly recognized features. A 9-year-old female tennis player presented with anterior knee pain; radiographs showed patellar fragmentation, and MRI confirmed edema at the patellar tendon insertion. Conservative management with rest resulted in the complete resolution of symptoms and return to sport. This case highlights the clinical and radiological features of SLJS in a 9-year-old athlete, emphasizing the importance of MRI in confirming the diagnosis and facilitating timely management.

Keywords: Adolescent athlete, overuse injury, patellar apophysitis, pediatric knee pain, Sinding-Larsen-Johansson Syndrome

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INTRODUCTION

Sinding-Larsen-Johansson Syndrome (SLJS) is a relatively uncommon but clinically significant cause of anterior knee pain in active adolescents. This condition, first described independently by Sinding-Larsen and Johansson in 1921, is a traction apophysitis affecting the proximal attachment of the patellar tendon to the inferior pole of the patella [1,2]. It is part of the spectrum of overuse injuries common during adolescence, characterized by rapid growth and increased participation in sports and physical activities. SLJS is often compared to Osgood-Schlatter disease, another apophysitis affecting the extensor mechanism of the knee, but differs in its anatomical location and clinical presentation [3]. While the pain in Osgood-Schlatter disease is more localized to the tibial

tubercle, SLJS pain predominantly focuses on the inferior pole of the patella.

SLJS is a rare condition with distinct prevalence rates in the general adolescent population and young athletes. In a population-based study involving adolescents aged 12-15 years, SLJS was identified in 0.8% of participants who underwent MRI imaging, underscoring its rarity in a non-athletic, general cohort [4]. In contrast, sports populations, particularly those engaged in high-impact activities such as soccer, show a higher incidence due to the repetitive stress on the extensor mechanism of the knee. A study of young soccer players revealed that SLJS was present in 10 out of 106 athletes (9.4%) who underwent radiographic or ultrasonic evaluations for knee pain, highlighting its



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increased prevalence in physically active adolescents [5]. Materne et al. [6] further supported this by reporting on a four-year prospective study involving 551 youth soccer players, during which 307 physeal injuries were identified, comprising 14% of all recorded injuries. Among these, apophyseal injuries accounted for 85% (258 cases), with SLJS representing 16 cases or 6% of the total injuries observed.

Given the rarity of SLJS, there is often a low index of suspicion among clinicians, and its clinical and radiological features are not well-recognized, leading to potential underdiagnosis or misdiagnosis and delays in appropriate management. This case report contributes to the growing literature on SLJS by highlighting its characteristic clinical presentation, imaging findings, and successful conservative management in a young female tennis player. The unique aspects of this case include the patient's early age, the use of magnetic resonance imaging (MRI) to confirm findings, and the role of complete rest in achieving symptom resolution and a return to sports. By documenting these features, this report aims to improve awareness and understanding of SLJS among healthcare professionals, particularly in pediatric and sports medicine, and to facilitate the early and accurate diagnosis of this condition in young athletes presenting with anterior knee pain.

CASE REPORT

A 9-year-old female tennis player presented with anterior knee pain, persisting for several weeks. The pain had a gradual onset, with no history of acute trauma or significant past medical issues. It was exacerbated by physical activity, particularly during tennis training, and partially subsided with rest, only to recur after subsequent training sessions. On physical examination, the patient demonstrated a complete and pain-free range of motion in the affected knee. Ligamentous stability tests were normal, indicating no instability. Tenderness was elicited at the patellar tendon and its junction with the inferior pole of the patella upon palpation. Neurovascular examination and muscle strength testing were normal.

Plain radiographs of the knee revealed fragmentation at the distal pole of the patella, consistent with SLJS (Fig. 1). Initial management included recommendations to reduce training intensity and frequency and rest from sports activities. Despite adherence to this conservative approach, the patient continued to experience pain after four weeks. Further evaluation with MRI revealed edema at the inferior pole of the patella, corroborating the diagnosis of SLJS (Fig. 2). Based on these findings, the management plan was revised to include complete rest from sports activities. The patient reported a complete resolution of her knee pain at the three-month follow-up. She subsequently resumed tennis training under a structured and gradual return-to-sport program. The tennis

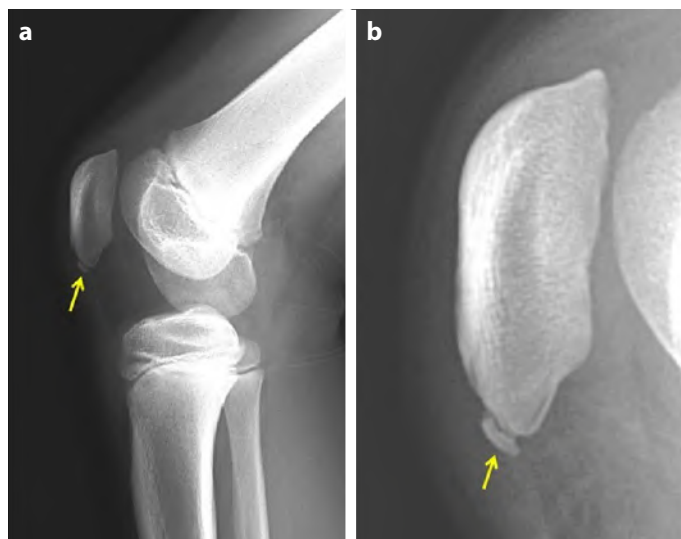


Figure 1. (a) Lateral knee radiograph showing fragmentation at the inferior pole of the patella (yellow arrow), characteristic of SLJS. (b) Magnified view of the inferior patellar pole highlighting the fragmented and irregular appearance (yellow arrow), consistent with apophyseal injury.

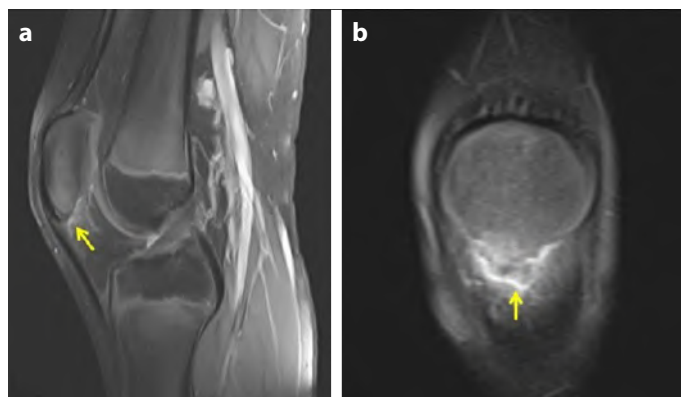


Figure 2. (a) Sagittal T2-weighted MRI showing edema and signal changes at the inferior pole of the patella (yellow arrow), consistent with inflammation due to traction apophysitis. (b) Axial T2-weighted MRI highlighting increased signal intensity at the patellar tendon attachment site (yellow arrow), confirming the diagnosis of SLJS.

training program was initiated with one session per week for a period of one month, subsequently transitioning to two sessions per week. At the six-month follow-up, she had returned to her usual level of activity without any recurrence of symptoms, demonstrating successful recovery with conservative management.

DISCUSSION

This case highlights the clinical, diagnostic, and management aspects of SLJS in a pediatric athlete, reinforcing the key points reported in the literature. The 9-year-old tennis player presented with activity-related anterior knee pain and tenderness at the inferior pole of the patella, symptoms consistent with previous descriptions of SLJS [7]. Radiographic imaging revealed patellar fragmentation, a hallmark finding which guided the initial diagnosis and conservative management. This aligns with reports emphasizing the utility of plain radiographs in diagnosing SLJS [3,8].

Conservative management, including rest and activity modification, is typically adequate for SLJS, as most cases respond well to reduced physical load [3,8]. However, persistent symptoms in this patient necessitated further investigation with MRI to rule out other causes of anterior knee pain seen in adolescents such as osteochondral lesions and patellofemoral instability. The MRI findings, showing bone marrow edema at the inferior pole of the patella, provided additional confirmation of the diagnosis and ruled out alternative conditions such as patellar sleeve avulsion fractures, which require different management strategies [9,10]. This case underscores the value of advanced imaging in cases where symptoms do not resolve as expected.

The etiology of SLJS involves repetitive mechanical stress and microtrauma at the osteotendinous junction, compounded by the rapid skeletal growth seen during adolescence. This period of musculoskeletal development increases vulnerability to conditions like SLJS, particularly in young athletes engaged in sports that involve jumping, sprinting, or frequent directional changes [11]. The biomechanical stresses associated with these activities contribute to the development of apophyseal injuries, with SLJS representing a specific manifestation at the inferior pole of the patella.

The management approach in this case was consistent with existing guidelines, focusing on activity modification, rest, and symptom relief through icing and nonsteroidal anti-inflammatory drugs (NSAIDs). The use of physical therapy to improve flexibility and strengthen the quadriceps and hamstrings aligns with best practices for managing SLJS [4,12]. The gradual return-to-sport protocol ensured the patient resumed athletic activity without symptom recurrence, highlighting the importance of structured rehabilitation. Preventative measures are essential in reducing the risk of SLJS in young athletes. These include regular stretching, warm-up exercises, and strengthening programs targeting the quadriceps and hamstrings. Monitoring training loads and incorporating adequate rest periods, especially during growth spurts, are also critical in minimizing stress on the patellar tendon. Early recognition of symptoms and timely

intervention remain vital in preventing progression and facilitating recovery [11].

Although this report is limited by its single-case nature and the absence of long-term follow-up data, it adds to the understanding of SLJS, particularly in pediatric athletes, by illustrating the importance of clinical and radiological findings in early diagnosis, the role of advanced imaging in persistent cases, and the benefits of conservative management. Future research could explore long-term outcomes and risk factors for chronic symptoms in patients with SLJS [4,7,11].

DECLARATIONS

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ABBREVIATIONS

SLJS - Sinding-Larsen-Johansson Syndrome

MRI - Magnetic Resonance Imaging

ROM - Range of Motion

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Case Report

Proximal Migration of the Femoral Fixation Anchor After Medial Patellofemoral Ligament Reconstruction in a Skeletally Immature Patient: A Case Report

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ABSTRACT

The success of medial patellofemoral ligament (MPFL) reconstruction is highly dependent on the accurate placement of the graft on the femoral attachment. Fixation of the graft on the femoral side can be challenging in skeletally immature patients due to the close proximity of the MPFL footprint and the distal femoral physis, which remains open during skeletal growth. Fixation of the graft to the proximal metaphysis may lead to proximal migration of the femoral fixation materials or tunnel during skeletal growth. In this unique case, a 12-year-old patient who underwent MPFL reconstruction experienced re-dislocation at the age of 15, necessitating revision of MPFL reconstruction. Despite the proximal migration of the femoral fixation anchor due to skeletal growth, the graft material remained in its original location. This finding is significant as it suggests that the MPFL graft can demonstrate tight healing with soft tissues and the periosteum at the attachment site, maintaining its position despite the migration of the tunnel or fixation materials within the bone.

Keywords: Anchor migration, femoral fixation, medial patellofemoral ligament, medial patellofemoral ligament reconstruction, skeletally immature patients



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INTRODUCTION

Patellofemoral dislocation is a prevalent disorder in skeletally immature individuals, often resulting from underlying risk factors such as trochlear dysplasia, patella alta, increased Q angle, excessive tibial tubercle lateralization, and ligamentous laxity. Conservative treatment is typically preferred for initial patellar dislocations, but a significant proportion of patients experience recurrent dislocation or persistent patellofemoral instability, necessitating surgical intervention. The medial patellofemoral ligament (MPFL) plays a crucial role as the primary medial stabilizer of the patella, contributing to 60% of the resistance

against lateral dislocation ^[1,2]. Consequently, MPFL reconstruction (MPFLR) has become a cornerstone in the management of recurrent patellofemoral instability. However, achieving optimal outcomes in MPFLR is contingent on the precise anatomical placement of the graft, particularly at the femoral attachment site. Misplacement of the femoral attachment can disrupt ligament isometry, leading to complications such as patellofemoral arthrosis and stiffness and often associated with inferior clinical outcomes ^[3,4].

In skeletally immature patients, the proximity of the MPFL attachment site to the distal



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femoral physis poses additional challenges. The femoral physis remains open during growth, and the MPFL anatomic footprint is located approximately 7 mm distal to the physis, making it susceptible to injury during the surgery [5]. As children grow, the tunnels and fixation materials used in MPFLR may migrate, potentially compromising the stability and function of the reconstruction. This case report presents a unique instance of proximal migration of a metallic suture anchor used for femoral fixation during MPFL reconstruction in a skeletally immature patient. The current literature contains a limited number of case reports on implant migration in MPFLR [6,7]. The report highlights the implications of skeletal growth on the stability of fixation materials and discusses the management and outcomes of this uncommon phenomenon.

CASE REPORT

A 12-year-old boy presented to the emergency department (ED) with a second occurrence of patellar dislocation, accompanied by pain and swelling in his left knee. He had his first patellar dislocation a year earlier, which was treated conservatively. On physical examination, there was effusion within the knee joint, and the medial side of the patella was tender upon palpation. The patellar apprehension test was positive, and the range of motion was limited and painful. Direct knee radiographs and magnetic resonance imaging (MRI) revealed Dejour Type C trochlear dysplasia, hemarthrosis, and a ruptured medial patellofemoral ligament (MPFL) without osteochondral fracture. Patellar height (Caton-Deschamps index: 0.83) was normal, and the tibial tuberosity-trochlear groove (TT-TG) distance was 20.5 mm. Given the recurrent dislocation and anatomical findings, surgical treatment was decided, focusing solely on MPFL reconstruction due to open epiphyses.

The initial surgery involved single-bundle MPFL reconstruction using a gracilis tendon autograft, with fixation achieved by two 5 mm metal anchors at the patellar and femoral attachment sites. Approximately 28 months after the initial surgery, the patient experienced another episode of patellar dislocation and was admitted to the ED. The parents initially refused revision surgery, preferring conservative follow-up. Eleven months later, the patient experienced yet another patellar dislocation. The family eventually agreed to proceed with revision surgery.

Both CT and MRI examinations showed re-rupture of the graft (Fig. 1). The TT-TG distance had increased to 25.4 mm, but patellar height remained normal (Caton-Deschamps index: 0.88). During follow-up, progressive proximal migration of the metal anchor used for femoral fixation was clearly observed (Fig. 2). Under general anesthesia and a thigh tourniquet, a second MPFL reconstruction was performed using a semitendinosus tendon autograft. Patellar fixation was again

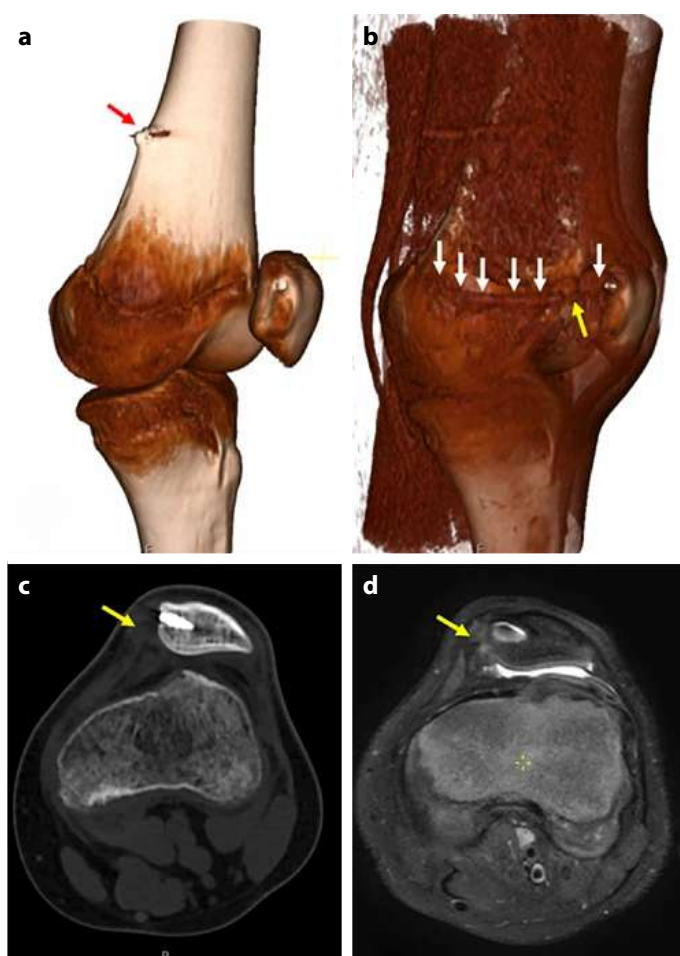


Figure 1. (a) 3D CT examination of the knee showing the metal anchor (red arrow) approximately 8 cm proximal to the distal femoral epiphysis. (b) 3D CT rendering showing the graft (white arrows) and the site of graft failure (yellow arrow). (c) Axial CT scan and (d) Proton density weighted (PDW) MRI examination showed graft failure at the patellar attachment.

achieved with a 5 mm metal anchor, while femoral fixation utilized a bioabsorbable interference screw. To correct the Q angle and restore the TT-TG distance, a Fulkerson osteotomy was also performed, secured with two 4.5 mm cannulated headless screws. The decision to perform a tibial tubercle osteotomy (TTO) in our skeletally immature patient was based on an assessment of bone age using radiographic criteria. We ensured that the growth plates were sufficiently developed to reduce the risk of growth disturbances. Furthermore, given the severity of patellar instability and the failure of prior MPFLR, TTO was deemed necessary to provide stability and prevent progressive joint damage. During surgery, the previous graft was found at the original femoral attachment site (Fig. 3). The



Figure 2. Consecutive follow-up direct radiographs of the anteroposterior knee radiographs showing the gradual proximal migration of the metal anchor through 46 months.



Figure 3. Intraoperative appearance of the initial graft during the revision MPFLR surgery. The graft was dissected over the MPFL femoral footprint.

postoperative period was uneventful. At the final follow-up, 18 months after the final surgery, the patient's knee range of motion was normal, the apprehension test was negative, and patellar mobility was normal. The Kujala score was 95 points, indicating a successful outcome.

DISCUSSION

The most important finding of this case was that although the metallic anchor within the bone migrated proximally, the graft remained in its anatomical position. The imaging studies and the dissection during the surgery confirmed this finding. Graft healing occurs at the periosteal level over the bone surface. Thus, soft tissue healing between the graft, retinaculum, and the periosteum appears to prevent graft migration. In this case, the anchor was likely placed proximal to the physis during the initial surgery. Additionally, the failure of the first MPFL reconstruction was likely influenced by the patient's advanced Dejour Type C trochlear dysplasia, which predisposes to instability, and the incorrect placement of the MPFL femoral attachment site. Since the metal anchor is positioned within the bone, it is believed that the anchor migrated superiorly due to skeletal growth.

Within the current literature, only two prior case reports have documented the proximal migration of metallic suture anchors during MPFL reconstruction. Kupczik et al.^[6] described two cases where metal anchors used for femoral fixation in skeletally immature patients migrated proximally, resulting in graft failure and recurrence of patellar instability. They emphasized the need to account for skeletal growth when determining the femoral fixation site in pediatric patients. They proposed that the proximal migration of the femoral fixation materials and the graft due to growth resulted in failure. In contrast, Aoki et al.^[7] reported a case of metaphyseal screw migration in an 11-year-old patient following MPFLR. Despite the screw migrating proximally, the MPFL graft remained at its original insertion site near the medial epicondyle. This case

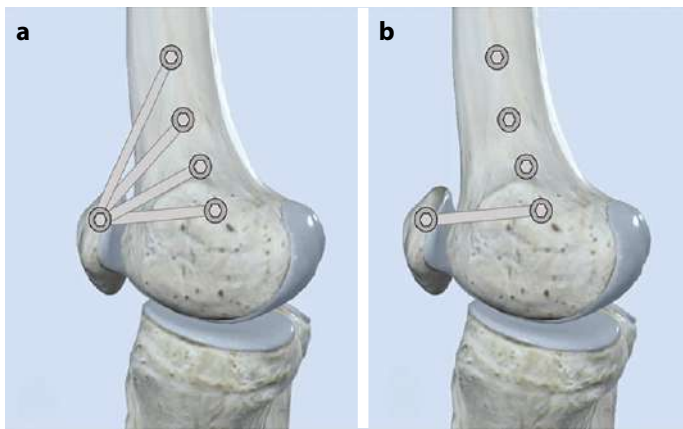


Figure 4. (a) Metal anchor and associated graft migration and failure scenario proposed by Kupczik et al. ^[6] **(b)** Anchor migration and graft status proposed by Aoki et al. The findings in this case support this suggestion.

suggests that while fixation materials may migrate due to skeletal growth, the graft itself remains stable, potentially due to soft tissue and periosteal healing. This observation aligns with the findings in this study, where the graft stayed in place despite the migration of the anchor (Fig. 4).

Other than two case studies that report proximal migration of fixation materials, two other studies investigated femoral tunnel enlargement and migration following MPFLR. Kita et al. ^[8] conducted a study using 3D computed tomography to evaluate morphological changes in the femoral tunnel after MPFLR with a hamstring tendon graft for recurrent patellar dislocation. They found that the femoral tunnel aperture showed significant anterior migration at a one-year follow-up, although the greatest distance in the distal-proximal direction was negligible (approximately 2 mm). The mean age of the patients was 24, but the age range included individuals as young as 14, some of whom might not have completed skeletal growth. This study suggests that while femoral tunnel changes can occur, they are generally minimal in the distal-proximal direction, particularly in skeletally immature patients. Ewald et al. ^[9] studied femoral tunnel widening and migration post-MPFLR in a large cohort. They found that tunnel changes, such as widening and migration of the tunnel center, were related to the initial malpositioning of the tunnel and correlated with poorer clinical and functional outcomes. Specifically, they noted that malpositioned tunnels often migrated anterop proximally, anteriorly, or anterodistally. In both of these studies, the tunnel migration did not exceed 4 mm in any direction. In contrast, the anchor was migrated approximately 8 cm superiorly in our case.

A recent meta-analysis summarizing data from six studies reported that in 82 cases, the medial patellofemoral ligament (MPFL) attachment site was, on average, located 7 mm distal to the femoral physis ^[5]. The MPFL attaches to the saddle sulcus, situated between the adductor tubercle and the medial epicondyle. It is crucial to acknowledge that anatomical variations can occur in this region. An examination of 1,094 knees indicated that these variations can influence the MPFL attachment site ^[10]. Despite these variations, in skeletally immature patients, the MPFL femoral tunnel should be placed distal to the femoral epiphysis to prevent superior migration of the tunnel or fixation anchor, which could compromise the graft's isometry. While the findings of this study show the graft in the expected anatomical location, we did not quantify minor positional changes. Generally, tendons and ligaments attach to bones and maintain their anatomical locations during growth. For instance, despite the distal attachment of the medial collateral ligament to the proximal tibial physis, it does not migrate distally with growth. Similarly, it can be assumed that the graft will not migrate proximally. Although the anatomical MPFL attachment site is located distal to the femoral physis, the fixation was placed proximal to the physis in our case. This placement error highlights the challenge of using intraoperative fluoroscopy, which can sometimes lead to inaccurate positioning. This misplacement underscores the importance of using both lateral and AP fluoroscopic views intraoperatively to ensure accurate positioning and avoid errors associated with relying solely on lateral images.

Among alternative surgical approaches, methods that do not require a femoral tunnel have also been proposed. In particular, techniques such as adductor sling reconstruction and adductor transfer reconstruction may eliminate the need for femoral fixation while preserving the growth plate. However, in the study by Black et al. ^[11], the adductor sling and adductor transfer techniques were significantly more anisometric from 40 to 110 degree of knee flexion. In this case, grafts became tighter in flexion, resulting in potential loss of motion, pain, graft stretching, and failure.

In conclusion, the findings of this study demonstrate that metallic anchors can migrate proximally with skeletal growth while the graft remains stable, likely due to periosteal-level healing. Although this case specifically involved a metallic anchor, similar anchor migration may occur with other materials, such as Polyether Ether Ketone (PEEK), given their susceptibility to growth-related forces. Differences in material properties, such as elasticity and bone integration, could affect the degree of migration and clinical outcomes. Therefore, careful consideration of anchor placement and material selection is crucial in skeletally immature patients, and further research is needed to explore the behavior of various anchor types and optimize surgical strategies.

DECLARATIONS

Ethical Approval: Not applicable.

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

Conflict of Interest: The authors declared no conflict of interest.

Informed Consent: Informed consent was provided by the parents of the patient.

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ABBREVIATIONS

ED - Emergency Department

MPFL - Medial Patellofemoral Ligament

MPFLR - Medial Patellofemoral Ligament Reconstruction

MRI - Magnetic Resonance Imaging

PEEK - Polyether Ether Ketone

TTO - Tibial Tubercle Osteotomy

TT-TG - Tibial Tuberosity-Trochlear Groove

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