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Original Article

Isolated Root Repair Versus Root Repair Combined with Meniscal Centralization for Medial Meniscus Posterior Root Tears with Extrusion: Clinical and Radiographic Outcomes

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ABSTRACT

Objective: Medial meniscus posterior root tears (MMPRTs) disrupt hoop stress transmission and knee biomechanics and are commonly associated with medial meniscus extrusion (MME) and osteoarthritis progression. This study aimed to determine whether adding meniscal centralization to transtibial pull-out posterior root repair improves clinical outcomes and radiographic osteoarthritis severity compared with isolated root repair in patients with MMPRTs.

Materials and Methods: This retrospective comparative study included patients who underwent arthroscopic surgery for MMPRTs and were allocated to either isolated transtibial pull-out root repair or root repair combined with meniscal centralization. Patients with advanced osteoarthritis (Kellgren–Lawrence [K–L] grade ≥3) or varus malalignment >5° were excluded. Clinical outcomes were assessed using the Knee Injury and Osteoarthritis Outcome Score (KOOS), International Knee Documentation Committee (IKDC) subjective score, Lysholm score, and Tegner activity scale. Radiographic evaluation was performed using the K–L grading system on preoperative and postoperative standing radiographs. Between-group comparisons were performed using the independent-samples t-test or Mann–Whitney U test, and within-group comparisons were analyzed using the Wilcoxon signed-rank test.

Results: Twenty patients were included (isolated root repair group, n=10; root repair with meniscal centralization group, n=10). The groups were comparable in age, body mass index, and follow-up duration. Postoperative patient-reported outcome scores were similar between groups for KOOS (78.0±2.6 vs. 79.0±2.1; p=0.356), IKDC (73.2±1.9 vs. 74.0±1.1; p=0.270), Lysholm (89.8±3.1 vs. 90.3±1.8; p=0.666), and Tegner (4.2±0.4 vs. 4.3±0.5; p=0.628). No statistically significant progression in K–L grade was detected within either group, and postoperative K–L grades did not differ significantly between groups.

Conclusion: In patients with MMPRTs without advanced osteoarthritis or marked varus malalignment, the addition of meniscal centralization to posterior root repair did not demonstrate superior short- to mid-term clinical outcomes or radiographic osteoarthritis severity compared with isolated root repair. Larger prospective randomized studies with longer follow-up are needed to better define the indications for meniscal centralization.

Keywords: Medial meniscus posterior root tear, meniscal centralization, transtibial pull-out repair, meniscal extrusion, knee osteoarthritis.

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INTRODUCTION

Medial meniscus posterior root tears (MMPRTs) are characterized by disruption of the meniscal root attachment to the tibial plateau and have a substantial negative impact on knee biomechanics. Loss of root integrity compromises hoop stress transmission, increases tibiofemoral contact pressure and may accelerate the progression of osteoarthritis (OA).[1] Accordingly, MMPRTs are considered biomechanically comparable to a functional total meniscectomy.[2] Once regarded as a vestigial structure, the meniscus is now recognized as essential for joint stability, load transmission, and cartilage protection.[3,4] Nonoperative management has been associated with unfavorable clinical outcomes, rapid OA progression, and higher arthroplasty rates, leading to the development of surgical techniques aimed at restoring native meniscal anatomy and biomechanics.[5,6]

Recently, medial meniscus extrusion (MME) has received increasing attention in association with MMPRTs. MME may result not only from root disruption but also from injury to the meniscotibial attachments, concomitant cartilage degeneration, and lower-limb malalignment.[7] Varus alignment, increased age, and higher body mass index have been linked to greater extrusion and medial compartment overload, suggesting that MME may contribute independently to OA development.[8] Importantly, MME can progress shortly after symptomatic MMPRTs and may persist despite surgical repair, and persistent extrusion has been reported as a strong predictor of OA progression.[9-11]

These observations raise the question of whether isolated root repair is sufficient to restore meniscal position and adequately control extrusion. Meniscal centralization has therefore been proposed as an adjunct to transtibial pull-out repair for repositioning the meniscus closer to its anatomic location. However, the reported effectiveness of centralization remains controversial, with conflicting clinical and radiological findings in the literature.[12,13]

The purpose of this study was to evaluate whether adding meniscal centralization to posterior root repair improves clinical and radiographic outcomes compared with isolated root repair in patients with MMPRT. We hypothesized that adjunctive meniscal centralization would provide superior postoperative patient-reported outcomes and better radiographic preservation.

MATERIALS AND METHODS

Patients and Study Design

This retrospective comparative study was conducted after approval was obtained from the institutional ethics committee (approval no. 2025/288), and written informed consent was obtained from all patients. Patients who underwent arthroscopic surgery between 2022 and 2025 for MMPRTs treated with a transtibial pull-out repair technique were retrospectively reviewed.

All included patients demonstrated MME ≥3 mm on preoperative MRI. In all cases, transtibial pull-out posterior root repair was performed as the primary procedure. After completion of the root repair, the degree of extrusion was reassessed intraoperatively. The meniscal body was reassessed arthroscopically by the senior surgeon using a probe to evaluate its reducibility relative to the edge of the medial tibial plateau. No formal millimeter-based intraoperative measurement or predefined threshold was used. Meniscal centralization was added when the meniscus remained visibly extruded and could not be satisfactorily reduced after root repair alone.

Accordingly, patients were allocated into two groups based on the final procedure performed: isolated posterior root repair and posterior root repair combined with meniscal centralization.

Inclusion criteria were as follows: (1) diagnosis of MMPRT confirmed by MRI and arthroscopic findings, (2) preoperative MME ≥3 mm, (3) treatment with transtibial pull-out root repair with or without additional meniscal centralization, and (4) minimum clinical follow-up of 24 months. Exclusion criteria were advanced osteoarthritis (Kellgren–Lawrence grade ≥3), varus malalignment greater than 5°, previous surgery on the same knee, concomitant ligament injuries or fractures, inflammatory arthritis, and incomplete clinical or radiographic data (Fig. 1).

Surgical Technique

All procedures were performed arthroscopically through standard anterolateral and anteromedial portals. Transtibial pull-out posterior root repair was performed in all patients. The torn root footprint was debrided to expose a bleeding bony surface. Sutures were passed through the posterior root using a standardized suture configuration, and a tibial tunnel was created to allow transtibial passage of the repair sutures. The sutures were then tensioned and secured over the anteromedial tibial cortex to restore the anatomic position of the root. In patients undergoing centralization, an all-suture anchor was inserted onto the medial tibial plateau with the knee in full flexion. The peripheral meniscal rim was then centralized and secured onto the tibial plateau using the anchor sutures, with the aim of reducing persistent meniscal extrusion (Fig. 2).

Postoperative Rehabilitation

All patients followed the same standardized postoperative rehabilitation protocol regardless of whether meniscal centralization was performed. Brace immobilization in full

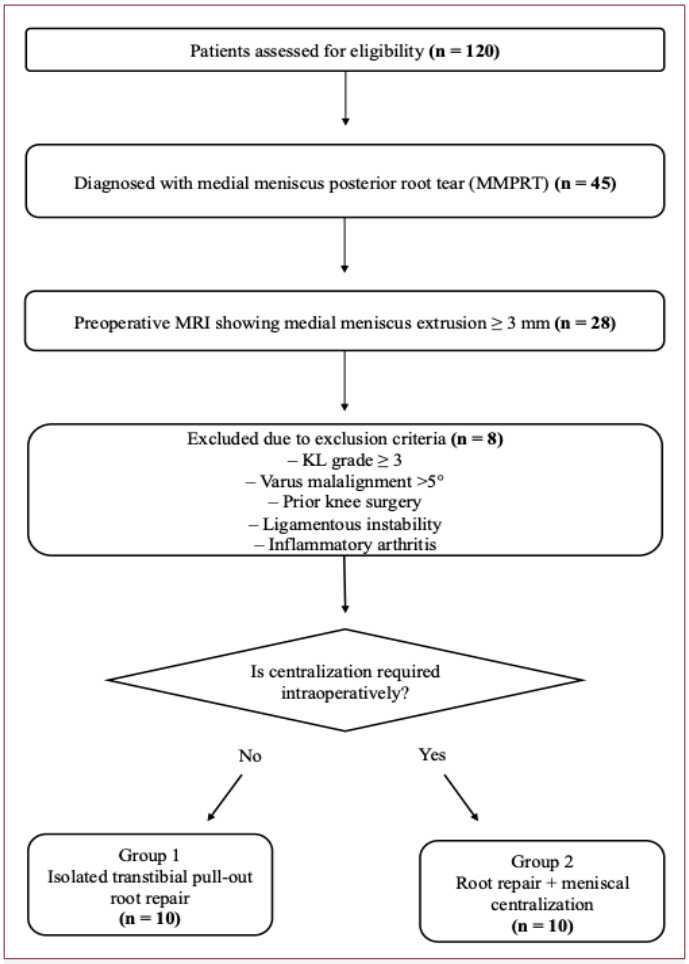

Figure 1. Flowchart demonstrating patient selection and allocation to treatment groups.

extension was maintained for the first four weeks, with toe-touch weight-bearing allowed during this period. Range-of-motion exercises were initiated gradually, and weight-bearing was progressively advanced thereafter according to clinical tolerance.

Outcome Measures

Clinical outcomes were assessed postoperatively using the Knee Injury and Osteoarthritis Outcome Score (KOOS), the International Knee Documentation Committee (IKDC) subjective score, the Lysholm score, and the Tegner activity scale. Radiographic evaluation included preoperative and postoperative weight-bearing standing knee radiographs, and osteoarthritis severity was graded according to the Kellgren–Lawrence classification. Lower-limb alignment was assessed on full-length standing anteroposterior lower-extremity radiographs using the hip-knee-ankle (HKA) angle based on the mechanical axis. Kellgren–Lawrence grading was performed by an experienced orthopaedic surgeon who was not involved in the surgical procedures and was blinded to treatment allocation. Interobserver and intraobserver reliability analyses were not performed.

Statistical Analysis

Statistical analyses were performed using SPSS software (version 26.0; IBM Corp., Armonk, NY, USA). Normality of continuous variables was assessed before analysis. Between-group comparisons were performed using the independent-samples t-test or the Mann–Whitney U test, as appropriate. Within-group comparisons of preoperative and postoperative Kellgren–Lawrence grades were performed using the Wilcoxon signed-rank test. A p-value <0.05 was considered statistically significant. For descriptive interpretation of between-group differences in postoperative patient-reported outcome measures, standardized effect sizes and 95% confidence intervals for mean differences were calculated.

RESULTS

Twenty patients were included and divided into two groups according to the surgical technique: isolated transtibial pull-out root repair (Group 1, n=10) and root repair combined with meniscal centralization (Group 2, n=10). The two groups were comparable in terms of age (54.2±2.0 vs. 55.3±2.0 years; p=0.234), body mass index (25.7±1.4 vs. 24.9±0.9 kg/m^2; p=0.190), and follow-up duration (25.9±1.2 vs. 25.6±1.2 months; p=0.579). Laterality distribution was also similar between the two groups (Table 1).

At final follow-up, patient-reported outcome measures were comparable between the two groups. Mean KOOS scores were

Table 1. Demographic and baseline characteristics of the patients

Variable	Group 1: Isolated root repair (n=10)	Group 2: Root repair + centralization (n=10)	p
Age (years), mean± SD	54.2±2.0	55.3±2.0	0.23
BMI (kg/m^2), mean±SD	25.7±1.4	24.9±0.9	0.19
Follow-up (months), mean±SD	25.9±1.2	25.6±1.2	0.57
Sex (F/M)	6/4	3/7	0.37
Side (Right/Left)	6/4	7/3	0.87

Values are presented as mean±standard deviation or number of patients. A p-value<0.05 was considered statistically significant.

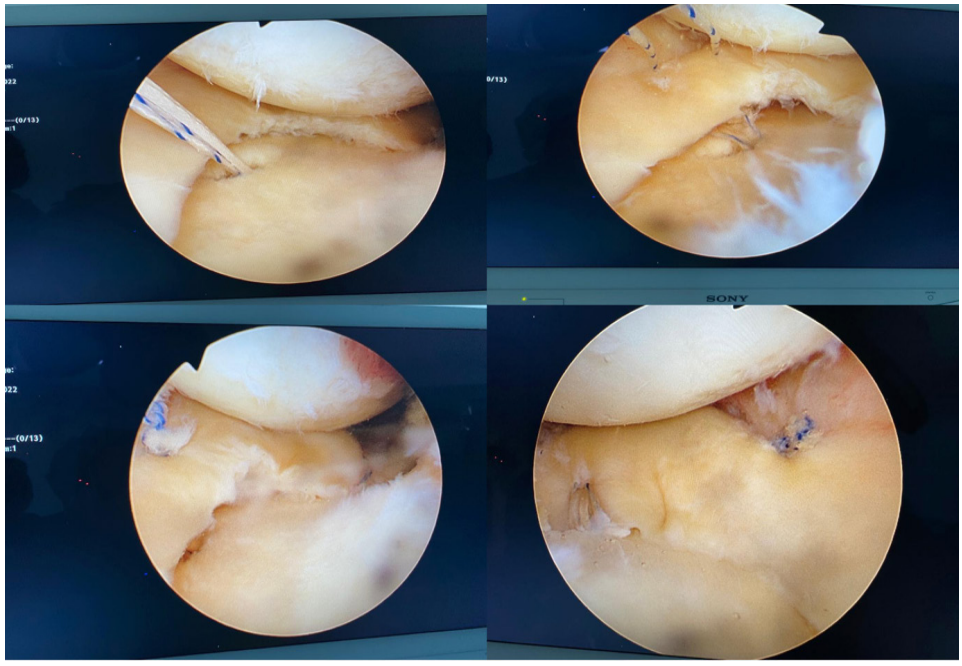

Figure 2. Intraoperative arthroscopic views demonstrating meniscal centralization performed with the all–suture anchor technique. After transtibial pull-out fixation of the medial meniscus posterior root, a single all–suture anchor was inserted into the medial tibial plateau, and peripheral meniscal tissue was centralized toward the anatomic footprint to reduce extrusion.

78.0±2.6 in Group 1 and 79.0±2.1 in Group 2 (p=0.356). Similarly, IKDC (73.2±1.9 vs. 74.0±1.1; p=0.270), Lysholm (89.8±3.1 vs. 90.3±1.8; p=0.666), and Tegner activity scores (4.2±0.4 vs. 4.3±0.5; p=0.628) did not differ significantly between groups (Table 2). Effect size analysis suggested only small between-group differences in the main postoperative patient-reported outcomes.

Table 2. Comparison of postoperative patient-reported outcome measures between the two groups

Outcome score	Group 1: Isolated root repair (n=10)	Group 2: Root repair + centralization (n=10)	p
KOOS total	78.0±2.6	79.0±2.1	0.35
IKDC subjective score	73.2±1.9	74.0±1.1	0.27
Lysholm score	89.8±3.1	90.3±1.8	0.66
Tegner activity level	4.2±0.4	4.3±0.5	0.62

Values are presented as mean±standard deviation. KOOS: Knee injury and Osteoarthritis Outcome Score; IKDC: International Knee Documentation Committee. A p-value<0.05 was considered statistically significant.

Preoperative Kellgren–Lawrence (K–L) grades were comparable between the two groups. Within-group analysis demonstrated no statistically significant progression of K–L grade from preoperative assessment to final follow-up in either group (Wilcoxon signed-rank test, both p=0.317). Postoperative K–L grades were also similar between the groups (Mann–Whitney U test, p=0.734) (Table 3).

Table 3. Distribution of Kellgren–Lawrence grades before and after surgery

	KL 0/1/2	p
Group 1 (Isolated root repair)		
Preoperative	1/4/5	
Postoperative	1/3/6	0.317
Group 2 (Root repair + centralization)		
Preoperative	1/5/4	
Postoperative	1/4/5	0.338
Postoperative between-group comparison		0.734

KL: Kellgren–Lawrence. Values are presented as number of patients. Statistical significance was set at p<0.05.

DISCUSSION

The principal finding of the present study is that, in patients with MMPRTs accompanied by preoperative MME ≥3 mm, posterior root repair combined with meniscal centralization did not result in superior short- to midterm patient-reported outcomes or radiographic osteoarthritis severity compared with isolated posterior root repair. Postoperative KOOS, IKDC, Lysholm, and Tegner scores were comparable between groups, and no statistically significant progression in Kellgren–Lawrence grade was detected during a mean follow-up of 26 months. These findings suggest that any potential biomechanical advantages of centralization may not have translated into detectable short- to mid-term clinical benefit in this cohort; however, this interpretation should be made cautiously in light of the study's methodological limitations.

MME has been increasingly recognized as a key pathomechanical factor associated with altered tibiofemoral contact mechanics and osteoarthritis progression. Debieux et al.[14] demonstrated that extrusion exceeding 4 mm reduces medial compartment contact area and increases contact pressures, while also highlighting the stabilizing role of peripheral meniscotibial structures. In clinical settings, extrusion has been associated with cartilage damage, varus alignment, osteophyte formation, higher Kellgren–Lawrence grades, and an increased risk of progression to arthroplasty. These observations have supported the rationale for adjunctive procedures to correct extrusion, including meniscal centralization.

Several studies have reported that centralization can reduce extrusion and may improve structural outcomes. Choi et al.[15] showed that transtibial pull-out repair yields substantial mid-term improvements in functional outcomes, while knees with decreased extrusion demonstrated less joint-space narrowing and a lower rate of Kellgren–Lawrence progression. Similarly, Zhou et al.[16] reported comparable short-term functional improvements between isolated repair and repair with centralization but noted greater extrusion reduction and a more favorable distribution of postoperative Kellgren–Lawrence grades in the centralization group. In contrast, our findings indicate that, in a cohort without advanced osteoarthritis or marked varus malalignment, adding centralization did not confer a measurable advantage in patient-reported outcomes or radiographic grading during early follow-up. This is particularly relevant because previous studies have suggested that centralization may improve extrusion-related structural parameters even when short-term patient-reported outcomes remain comparable between treatment groups.

From a clinical standpoint, these results suggest that isolated posterior root repair may provide satisfactory short- to mid-term outcomes in appropriately selected patients, and that meniscal centralization may not be necessary as a routine adjunct for all MMPRT cases. However, it remains possible that centralization may be beneficial in specific subgroups, such as patients with marked extrusion, compromised peripheral meniscotibial stabilizers, or a higher risk of persistent extrusion and structural deterioration. Longer-term follow-up is required to determine whether subtle structural benefits of centralization translate into clinically meaningful differences in osteoarthritis progression and survivorship.[17-20]

This study has several limitations. First, the sample size was small, which may have limited the statistical power to detect small but clinically relevant between-group differences; therefore, the absence of statistically significant differences should not be interpreted as evidence of equivalence. Second, the retrospective design and nonrandomized treatment allocation may have introduced selection bias, as meniscal centralization was selectively performed in knees with persistent residual extrusion after root repair. Consequently, the centralization group may have included more challenging cases and may also have had more severe baseline extrusion, although quantitative comparison of preoperative extrusion severity between the groups was not available. Third, routine postoperative MRI was not performed; therefore, residual extrusion and the structural effect of centralization could not be quantitatively assessed during follow-up. Finally, the mean follow-up duration of approximately 26 months may have been insufficient to reliably evaluate radiographic osteoarthritis progression.

CONCLUSION

In patients with medial MMPRTs without advanced osteoarthritis or marked varus malalignment, posterior root repair combined with meniscal centralization did not demonstrate superior short- to mid-term patient-reported outcomes or radiographic osteoarthritis severity compared with isolated posterior root repair. These findings suggest that meniscal centralization may not be required as a routine adjunct in all MMPRT cases, and that its use should be individualized based on patient- and knee-specific factors. Further prospective randomized studies with larger cohorts and longer follow-up are warranted to clarify optimal indications for meniscal centralization.

DECLARATIONS

Ethics Committee Approval: The Karadeniz Technical University, Faculty of Medicine Scientific Research Ethics Committee approved this study. (Date: 17/12/2025, Number: 2025/288).

Informed Consent: Written informed consent was obtained from all patients.

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

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Peer-review: Externally peer-reviewed.

ABBREVIATIONS

BMI: Body Mass Index

CI: Confidence Interval

HKA: Hip-Knee-Ankle angle

IKDC: International Knee Documentation Committee

K–L: Kellgren–Lawrence

KOOS: Knee Injury and Osteoarthritis Outcome Score

MME: Medial Meniscus Extrusion

MMPRT: Medial Meniscus Posterior Root Tear

MRI: Magnetic Resonance Imaging

OA: Osteoarthritis

PROs: Patient-Reported Outcomes

SD: Standard Deviation

SPSS: Statistical Package for the Social Sciences

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