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Accurate tibial tunnel position in transtibial pullout repair for medial meniscus posterior root tears delays the progression of medial joint space narrowing

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Abstract

Purpose: This study aimed to evaluate the association between the progression of medial joint space (MJS) narrowing, medial meniscus extrusion (MME) and clinical scores and the tibial tunnel position in pullout repairs for medial meniscus posterior root tears (MMPRTs).

Methods: This retrospective study examined 54 patients. Changes in MJS (ΔMJS), MME (ΔMME) and clinical scores and their relationship with the tibial tunnel position were evaluated using correlation coefficients. The distance from the anatomical to technical attachment position in the tibial tunnel position was measured in the anterior and medial directions, and the direct distance was measured using the Pythagorean theorem.

Results: The mean ΔMJS and ΔMME were 0.6 ± 0.8 and 1.3 ± 1.3 mm, respectively, and the mean anterior, medial and direct distances were 1.4 ± 2.3, 2.2 ± 1.7 and 3.4 ± 1.7 mm, respectively. ΔMJS had a significant positive correlation with the medial ($r = 0.580$, $p < 0.001$) and direct ($r = 0.559$, $p < 0.001$) distances, while ΔMME had a significant positive correlation with direct distance ($r = 0.295$, $p = 0.030$). Several clinical scores were significantly negatively correlated with these distances.

Conclusion: In transtibial pullout repair for MMPRTs, accurate tibial tunnel position delayed the progression of MJS narrowing and MME, leading to improved clinical outcomes. The progression of MJS narrowing was associated with the mediolateral direction of the tibial tunnel position, while the clinical scores were associated with the anteroposterior direction of the tibial tunnel position. These findings indicate the need to orient the tip of the guide in a more posterolateral direction when creating the tibial tunnel.

Level of Evidence: Level IV.

KEYWORDS

clinical score, joint space, meniscus extrusion, posterior root tear, tibial tunnel

Abbreviations: 3D, three-dimensional; BMI, body mass index; CT, computed tomography; FFV, fixed-flexion view; MJS, medial joint space; MM, medial meniscus; MME, medial meniscus extrusion; MMPR, medial meniscus posterior root; MMPRT, medial meniscus posterior root tear; MRI, magnetic resonance imaging; ΔMJS, change in medial joint space; ΔMME, change in medial meniscus extrusion.

INTRODUCTION

The long-term outcomes of nonoperative management of medial meniscus (MM) posterior root (MMPR) tears (MMPRTs) are reported to be poor[18]; however, the mid-term to long-term outcomes of MMPR repair have known to be favourable [2, 5, 17]. Regardless, MMPR repair does not completely prevent the progression of osteoarthritis and medial joint space (MJS) narrowing [2, 8, 14]. While many similar studies have reported on postoperative MM extrusion (MME) progression [19, 23, 29], a previous study reported that MMPR repair slowed the progression of osteoarthritis compared with conservative treatment or meniscectomy in a rabbit model [3]. Factors such as age, weight, quadriceps muscle strength, healing status of the repaired posterior roots and time from symptom onset to surgery have been reported to influence the progression of MJS, MME and osteoarthritis in the postoperative period after MMPR repair [7, 11, 24]. However, recent studies have shown significant progression of MJS narrowing and MME in the first postoperative year but tapering off in the second postoperative year [13, 15].

MMPRTs can result in a 25% increase in medial tibiofemoral joint pressure, comparable to that noted for the joint pressure after meniscectomy [1, 22]. Biomechanical studies have reported that accurate tibial tunnels improve medial tibiofemoral joint pressure during MMPR repair [21, 27]. Clinical studies further emphasize the importance of accurate tibial tunnels in promoting the healing of repaired posterior roots and improving clinical scores [6, 10].

Despite the significance of accurate anatomical tibial tunnels in MMPR repair, their relationship with the postoperative progression of MJS narrowing and MME remains poorly understood. Therefore, this study aimed to evaluate the association between the progression of MJS narrowing, MME and clinical scores and the tibial tunnel position in pullout repairs for MMPRTs. This study addresses a critical concern in pullout repair for MMPRTs—progression of postoperative MJS narrowing and osteoarthritis—by examining the relationship between these progressions and the technical tibial tunnel position. We hypothesized that the creation of an anatomical tibial tunnel is associated with reduced progression of MJS narrowing and MME and improved clinical scores.

MATERIALS AND METHODS

This retrospective study was approved by the Ethics Committee of Okayama University (No. 1857) and performed in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients.

This study retrospectively enrolled a total of 57 patients who underwent pullout repair for unilateral MMPRT between June 2020 and June 2021 and had fixed-flexion view (FFV) radiographs obtained preoperatively and at 2 years postoperatively. Of these, three patients with chronic MMPRTs were excluded, and 54 patients were finally examined.

The surgical indications for pullout repair in patients with symptomatic MMPRTs at our institution included femorotibial angle [13] ≤180°, Kellgren–Lawrence grades 0–2 and mild cartilage lesions. No patient was excluded from surgery based on age, body mass index (BMI), time from the onset of symptoms to surgery or activity levels. The surgery was performed by a single experienced surgeon. The time from the onset of symptoms to surgery was determined through detailed interviews regarding painful popping episodes.

Surgical technique and rehabilitation protocol

In all patients, the outside-in pie-crusting technique was used to enlarge the medial knee compartment [12]. Thereafter, two No. 2 Ultrabraid sutures (Smith & Nephew) were passed through the torn end of the posterior root. A tibial tunnel measuring 4.0 mm in diameter was created using a custom-made MMPRT aiming guide (Smith & Nephew) [4]. Tibial fixation was performed using a bioabsorbable screw (Smith & Nephew), with a knee flexion angle of 30° and an initial tension of 10 N applied to the sutures. An additional posterior anchoring technique was performed between December 2020 and March 2021 [31]. All patients had no evidence of meniscal or cartilage lesions requiring additional procedures except for MMPRTs on preoperative MRI scans. However, five patients with asymptomatic incomplete discoid lateral meniscus who underwent additional partial meniscectomy were included.

The leg was postoperatively immobilized using a knee extension splint. The knee joint range of motion was limited to 30° in postoperative Week 1, 60° in postoperative Week 2, 90° in postoperative Week 3 and 120° in postoperative Week 4. The range of motion was unrestricted 3 months postoperatively. Body weight loading was limited to 20 kg in postoperative Week 1, 40 kg in postoperative Week 2 and 60 kg in postoperative Week 3; body weight loading was unrestricted after postoperative Week 4.

FFV radiographs and MJS measurements

A handmade lower extremity fixation device was developed according to previous studies [25], and FFV radiographs were obtained preoperatively and at

2 years postoperatively. The MJS widths (measured at each time point using FFV radiographs) were measured as the distance between the femoral and tibial intersections along a line parallel to the tibial bone axis at the midpoint between the medial eminence and medial tibial margin (Figure 1). MJS measurements were recorded to one decimal place, with a high intra/inter-rater reliability of >0.95 being reported for this measurement method [13, 14].

For MJS widths, the MMPRT and contralateral knees were evaluated. The change in MJS (ΔMJS) was calculated as the preoperative minus postoperative MJS widths. In addition, a difference in ΔMJS was defined as ΔMJS for the MMPRT knee minus ΔMJS for the contralateral knee.

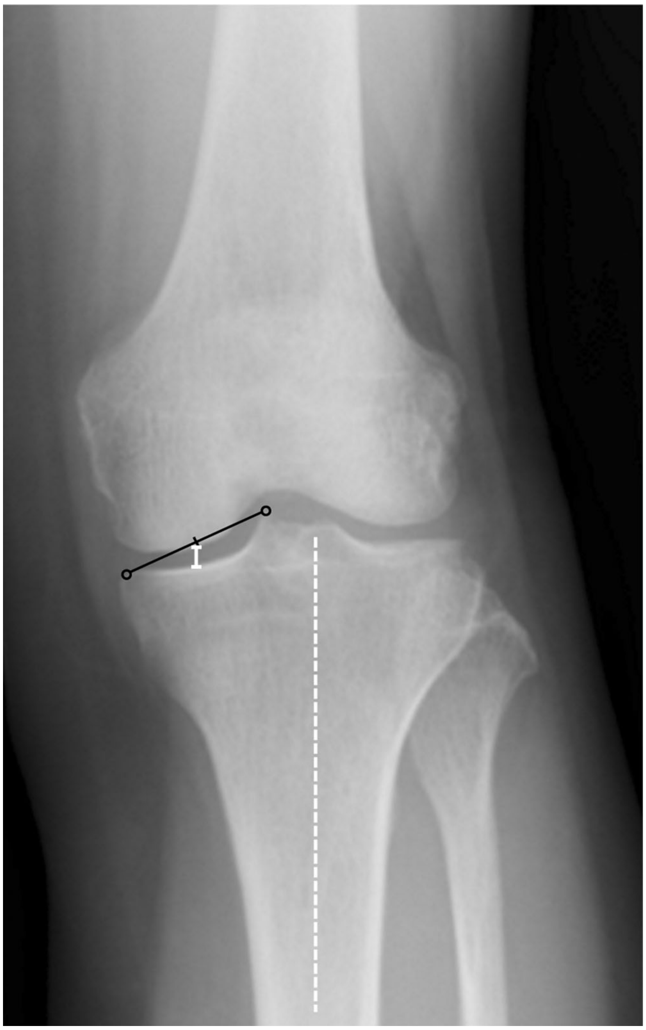

FIGURE 1 Measurement of the MJS width using FFV radiography. The MJS width was defined as the distance between the intersection of the femur and tibia (white line) parallel to the tibial bone axis (white dashed line) at the midpoint between the medial tibial eminence and medial margin of the tibia (black circles). FFV, fixed-flexion view; MJS, medial joint space.

Three-dimensional computed tomography evaluation

Computed tomography (CT) was performed in all patients at 1 week postoperatively. A three-dimensional (3D) model of the tibia was constructed using a 3D volume-rendering technique (AZE Virtual Place software; AZE Ltd.). Tibial internal/external rotation for the measurement of the anatomical attachment and technical attachment positions was defined such that the posterior borders of the medial and lateral tibial plateaus were horizontal (Figure 2). The anatomical attachment position of the MMPR was defined as the midpoint of a regular circle within the three borders of the anterior margin of the tibial attachment of the posterior cruciate ligament, lateral margin of the medial tibial plateau and posterior margin of the medial tibial eminence. The technical attachment position of the MMPR was defined as the midpoint of the tibial tunnel. The distance from the anatomical attachment to the technical attachment position was measured in the anterior and medial directions. The direct distance was measured using the Pythagorean theorem: $(\text{direct distance})^2 = (\text{anterior distance})^2 + (\text{medial distance})^2$.

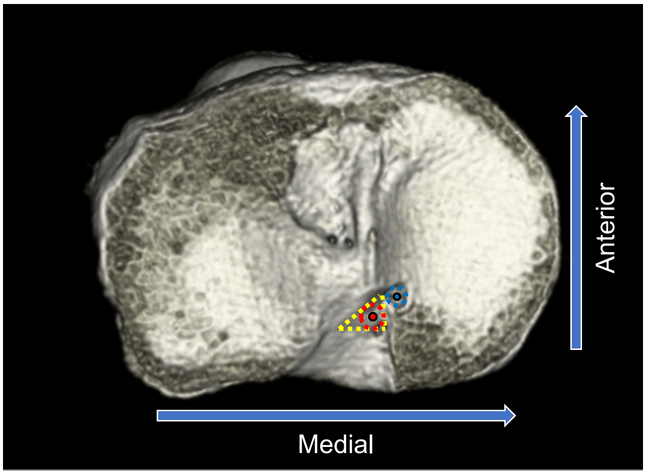

FIGURE 2 Measurement of the anatomical attachment and technical attachment positions. Three-dimensional CT-based tibial surfaces were used to confirm the positions of the anatomical and technical attachments of the MMPR. The anatomical attachment of the MMPR was the midpoint (red point) of a regular circle (red dotted line) in a triangle (yellow dotted line) consisting of the anterior margin of the PCL attachment, lateral margin of the medial tibial plateau and posterior margin of the medial tibial eminence. The technical attachment is the midpoint (blue point) of the created tibial tunnel (blue dotted line). The anterior and medial distances from the anatomical to technical attachments were measured. CT, computed tomography; MMPR, medial meniscus posterior root; PCL, posterior cruciate ligament.

Magnetic resonance imaging assessments

Magnetic resonance imaging (MRI) was performed in all patients preoperatively and at 1 year postoperatively. MME was defined as the distance from the medial margin of the tibia, excluding osteophytes, to the medial margin of the MM in the slice where the medial eminence of the tibia was the highest. The change in MME (ΔMME) was calculated as the postoperative MME minus the preoperative MME.

The healing status of the repaired posterior roots was assessed using MRI at 1 year postoperatively and classified based on a previous study as follows: complete healing (continuity was confirmed in all three MRI views: sagittal, coronal and axial), partial healing (loss of continuity in any one view) and repeated tears (no continuity in any view) [16].

Clinical scores

Clinical outcomes were assessed in all patients preoperatively and at 2 years postoperatively based on components such as the Knee Injury and Osteoarthritis Outcome Score, International Knee Documentation Committee score, Lysholm score, Tegner activity score and pain visual analogue scale score.

Statistical analysis

Statistical analysis was performed using EZR software (Saitama Medical Center). Normality of distribution was assessed using the Kolmogorov–Smirnov test, which revealed a parametric distribution for patient characteristics, technical attachment position, MJS, MME, ΔMJS and ΔMME and a nonparametric distribution for clinical scores. Comparisons of the preoperative and postoperative MJS and MME were performed using the paired t-test. Comparisons of the preoperative and postoperative clinical scores were performed using Wilcoxon's signed-rank test. Pearson's correlation coefficient was used to determine the correlation between the technical attachment position with the ΔMJS for MMPRT knee, difference in ΔMJS and ΔMME. Spearman's rank correlation coefficient was used to establish the correlation between the technical attachment position and the clinical scores.

Furthermore, we divided the anatomical group (direct distance ≤3 mm) and the nonanatomical group (direct distance >3 mm) into two groups and compared patient characteristics, ΔMJS for MMPRT knee, difference in ΔMJS and ΔMME using the unpaired *t* test. In addition, we categorized the two groups with or without the additional posterior anchoring technique of pullout repair and compared patient characteristics, ΔMJS for MMPRT knee, difference in ΔMJS and ΔMME using the unpaired t-test.

The direct distance was measured two times, 6 weeks apart, to assess intraobserver reliability. A post hoc analysis of the actual power in Pearson's correlation coefficient between ΔMJS and direct distance (G*Power, University of Düsseldorf) was performed. The intraobserver reliability of the direct distance measurements was 0.926. The actual power in Pearson's correlation coefficient for ΔMJS and direct distance was 99.8%, with an effect size of 0.56, α error of 0.05 and sample size of 54.

RESULTS

The patient characteristics in this study are shown in Table 1. The healing status of MMPR at 1 year postoperatively was 52/54 (96.3%) for complete healing and 2/54 (3.7%) for partial healing. Notably, re-tear was not reported in any patient.

Significant progression of MJS for MMPRT knee and MME was observed from preoperative to postoperative periods ($p < 0.001$; Table 2). The mean ΔMJS for MMPRT and contralateral knees was 0.6 ± 0.8 and 0.2 ± 0.7 mm, respectively. The mean difference in ΔMJS was 0.4 ± 0.9 mm, and the mean ΔMME was 1.3 ± 1.3 mm. Compared with the preoperative scores, all clinical scores improved significantly at 2 years postoperatively ($p < 0.001$; Table 3).

The mean anterior, medial and direct distances were 1.4 ± 2.3, 2.2 ± 1.7 and 3.4 ± 1.7 mm, respectively (Figure 3). Correlation coefficients for technical attachment positions with ΔMJS for MMPRT knee, difference in ΔMJS, ΔMME and clinical scores are shown in Table 4. Scatter plots and approximate curves for

TABLE 1 Patient characteristics.

Characteristics	Value	Range
Patients	54	
Age, years	64.2 ± 10.1	44–83
Sex, male/female	11/43	
Body mass index, kg/m^2	26.2 ± 4.8	18.3–45.9
MMPRT side, left/right	23/31	
Time from the onset of symptoms to surgery, days	74.9 ± 65.3	9–348
MMPRTs classification, 1/2/3/4/5	8/44/0/2/0	
Preoperative femorotibial angle, °	178.5 ± 1.5	173.5–180.0
Surgical technique, TCS/TCS + PA	36/18	

Note: Values are presented as the means ± standard deviation or numbers.

Abbreviations: MMPRT, medial meniscus posterior root tear; PA, posterior anchoring; TCS, two-cinch stitches.

TABLE 2 Comparison of MJS for MMPRT and contralateral knees and MME pre-operatively and post-operatively.

Characteristics	Preoperative	Postoperative	*p* Value
MJS for MMPRT knee, mm	4.4 ± 0.9	3.9 ± 0.9	<0.001*
MJS for contralateral knee, mm	4.7 ± 1.0	4.5 ± 1.0	n.s.
MME, mm	3.4 ± 0.8	4.7 ± 1.6	<0.001*

Note: Values are presented as means ± standard deviations. Statistical relationship was determined using paired *t* test.

Abbreviations: MJS, medial joint space; MME, medial meniscus extrusion; MMPRT, medial meniscus posterior root tear.

*$p < 0.05$.

TABLE 3 Comparison of clinical scores pre-operatively and 2 years post-operatively.

Type of score	Preoperative	Postoperative	*p* Value
KOOS			
Pain	59.6 ± 17.6	88.4 ± 7.8	<0.001*
Symptoms	62.2 ± 21.5	85.2 ± 8.5	<0.001*
ADL	69.4 ± 16.9	90.5 ± 6.8	<0.001*
Sport/Rec	28.2 ± 24.9	58.4 ± 26.4	<0.001*
QOL	37.3 ± 21.8	68.4 ± 16.4	<0.001*
Lysholm score	60.1 ± 13.5	88.6 ± 5.5	<0.001*
Tegner activity score [range]	2 [0–4]	3 [2–5]	<0.001*
IKDC score	39.3 ± 16.8	71.5 ± 10.3	<0.001*
Pain VAS score	41.4 ± 24.5	10.1 ± 10.6	<0.001*

Note: Values are presented as means ± standard deviations. Tegner activity scores are presented as medians. Statistical relationship was determined using Wilcoxon's signed-rank test.

Abbreviations: ADL, activities of daily living; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; QOL, quality of life; Sport/Rec, sports and recreational function; VAS, visual analogue scale.

*$p < 0.05$.

technical attachment positions and the ΔMJS for MMPRT knee are shown in Figure 4.

A comparison of the anatomical and nonanatomical groups is shown in Table 5. Notably, comparison of groups with or without the additional posterior anchoring technique of pullout repair revealed no significant differences between the two groups.

DISCUSSION

The most important finding of this study is that an accurate tibial tunnel in transtibial pullout repair for MMPRTs leads to decreased progression of MJS narrowing and MME, as well as better clinical outcomes. Moreover, the progression of MJS narrowing was associated with the medial tibial tunnel position.

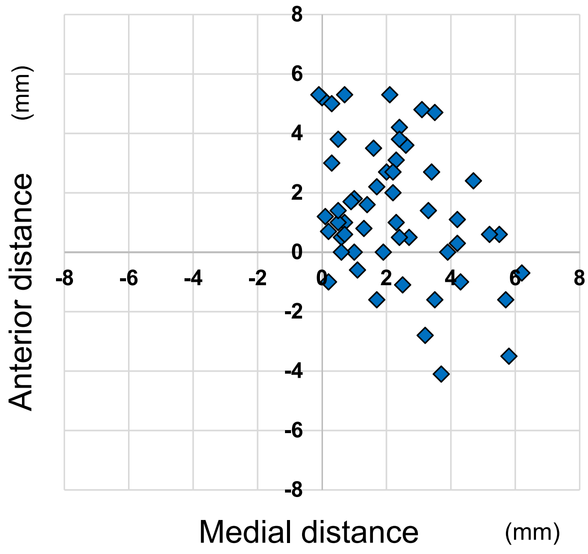

FIGURE 3 Position of technical attachments centred on anatomical attachments. Position of technical attachments in relation to anatomical attachments at the centre (0). In most cases, the technical attachment was created anteromedial to the anatomical attachment (77.8%).

Accurate tibial tunnels are important for healing and improving clinical scores of repaired posterior roots [6, 10]; however, their association with the progression of MJS narrowing and MME is unclear. This study showed that the anatomical tibial tunnel position is also important for reducing the progression of MJS narrowing and MME.

A biomechanical study on tibial tunnel position reported that even with an accurate anatomic tibial tunnel position, there is decreased meniscal hoop function, increased MME and increased cartilage contact area in the medial compartment [27]. Further, they reported that the anterior position of the tibial tunnel can more effectively restore the meniscal hoop function and contact area in the medial compartment; however, suture cutout and strong tension on the repaired posterior roots can be problematic [27]. The relationship between suture cutouts and clinical scores has been previously reported in clinical studies [30]. In the present study, the tibial tunnel position in the anteroposterior direction did not significantly correlate with the progression of MJS narrowing or MME. However, more anteriorly positioned tibial tunnels tended to be significantly worse in some clinical scores. While a more anterior position of the tibial tunnel may have restored meniscal hoop function and contact area in the medial compartment, it may have led to worse clinical scores due to suture cutout or increased loading at the repaired posterior roots.

TABLE 4 Correlations between the ΔMJS, ΔMME and clinical scores and the position of technical attachments.

	Anterior distance		Medial distance		Direct distance	
	Correlation coefficient	*p* Value	Correlation coefficient	*p* Value	Correlation coefficient	*p* Value
Radiograph						
ΔMJS for MMPRT knee	$r = 0.057$	n.s.	$r = 0.580$	$p < 0.001$*	$r = 0.559$	$p < 0.001$*
Difference in ΔMJS	$r = 0.193$	n.s.	$r = 0.285$	$p = 0.036$*	$r = 0.322$	$p = 0.017$*
MRI						
ΔMME	$r = -0.045$	n.s.	$r = 0.259$	n.s.	$r = 0.295$	$p = 0.030$*
Clinical scores						
KOOS-pain	$r = -0.073$	n.s.	$r = -0.034$	n.s.	$r = -0.183$	n.s.
KOOS-symptoms	$r = -0.218$	n.s.	$r = -0.054$	n.s.	$r = -0.193$	n.s.
KOOS-ADL	$r = -0.324$	$p = 0.020$*	$r = 0.065$	n.s.	$r = -0.212$	n.s.
KOOS-Sport/Rec	$r = -0.346$	$p = 0.013$*	$r = -0.044$	n.s.	$r = -0.201$	n.s.
KOOS-QOL	$r = -0.020$	n.s.	$r = -0.275$	n.s.	$r = -0.296$	$p = 0.035$*
Lysholm score	$r = -0.279$	$p = 0.047$*	$r = 0.013$	n.s.	$r = -0.279$	$p = 0.048$*
Tegner activity score	$r = -0.111$	n.s.	$r = -0.119$	n.s.	$r = -0.204$	n.s.
IKDC score	$r = -0.284$	$p = 0.044$*	$r = -0.163$	n.s.	$r = -0.310$	$p = 0.027$*
Pain VAS score	$r = 0.092$	n.s.	$r = 0.173$	n.s.	$r = 0.212$	n.s.

Note: Statistical relationships were determined using Pearson's correlation coefficient for ΔMJS for MMPRT knee, difference in ΔMJS and ΔMME and Spearman's rank correlation coefficient for the clinical scores. Difference in ΔMJS was defined as ΔMJS for the MMPRT knee minus ΔMJS for the contralateral knee.

Abbreviations: ADL, activities of daily living; IKDC, International Knee Documentation Committee; KOOS, Knee Injury and Osteoarthritis Outcome Score; MJS, change in medial joint space; MME, change in medial meniscal extrusion; MMPRT, medial meniscus posterior root tear; MRI, magnetic resonance imaging; QOL, quality of life; Sport/Rec, sports and recreational function; VAS, visual analogue scale; ΔMJS, change in medial joint space; ΔMME, change in medial meniscus extrusion.

*$p < 0.05$.

A biomechanical study on the mediolateral direction of the tibial tunnel reported that a greater medial tibial tunnel position resulted in decreased meniscal hoop function and increased contact pressure in the medial compartment [26]. Additionally, the more medial the tibial tunnel, the smaller the correction of MME immediately after pullout repair. In our present study, the progression of MJS narrowing was significantly positively correlated with the medial tunnel position; this result seems to be consistent owing to the decreased meniscal hoop function, increased cartilage loading and poor correction of MME.

In the present study, the MJS width for the contralateral knee was used to account for the effect of progressive physiological osteoarthritis in the patients. The difference in ΔMJS was calculated as the MJS narrowing of the MMPRT knee minus the effect of this physiological osteoarthritis. The difference in ΔMJS was significantly correlated with the medial and direct distances of the tibial tunnel position, as was the ΔMJS for the MMPRT knee. Therefore, the tibial tunnel position was significantly correlated with the progression of MJS narrowing, even after accounting for the effects of this physiologic osteoarthritis, with the medial tunnel position being particularly important.

Most previous studies on pullout repair for MMPRTs used guides such as those used for anterior cruciate ligament reconstruction rather than guides specifically designed for MMPRTs [20, 28]. In our present study, the original MMPRT guide was used to obtain the direct distance from the anatomical and technical attachment positions within 3 mm in 23/54 (42.6%) and 5 mm in 41/54 (75.9%) patients. Meanwhile, 42/54 (77.8%) patients had a tibial tunnel created in the anteromedial area. These findings indicate that surgeons should be more conscious of creating a tibial tunnel on the posterolateral aspect, even when using a guide specifically designed for MMPRTs, unlike practices observed in the past.

Johannsen et al. reported that the anatomic attachment area of the MMPR is $30.4 \pm 2.9\,mm^2$ and approximately 6 mm in diameter for the tibial tunnel [9]. Based on this study, a comparison between anatomical and nonanatomical groups was conducted using a cutoff value of 3 mm for the direct distance of the technical tibial tunnel position. The results revealed that the anatomical group

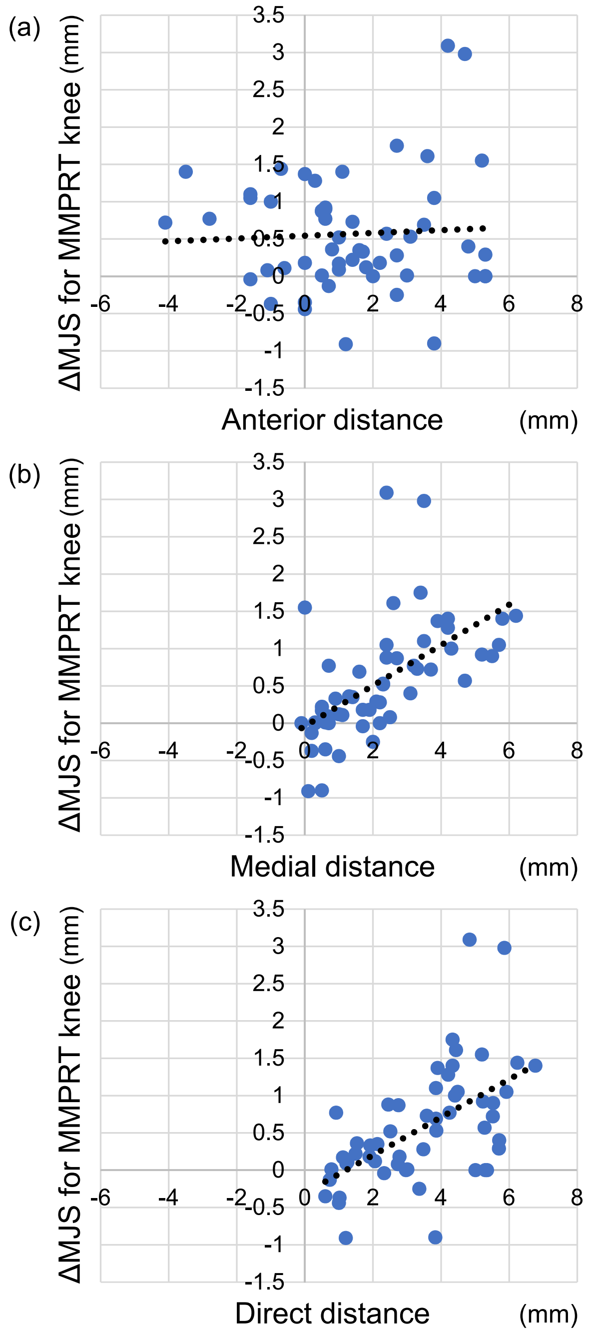

FIGURE 4 Scatter plots and approximate curves for technical attachment positions and ΔMJS for MMPRT knee. The ΔMJS for MMPRT knee did not significantly correlate with anterior distance ($r = 0.054$, n. s.; a) but significantly correlated with medial distance ($r = 0.584$, $p < 0.001$; b) and direct distance ($r = 0.560$, $p < 0.001$; c). ΔMJS, change in medial joint space; MMPRT, medial meniscus posterior root tear.

showed significantly less progression of MJS narrowing than did the nonanatomical group; in addition, no significant progression of MJS narrowing was observed at 2 years postoperatively. Therefore, the tibial tunnel position within 3 mm from the anatomic attachment of the MMPR is a value that should be targeted.

TABLE 5 Comparison of the anatomical and nonanatomical groups.

	Anatomical group (≤3 mm)	Nonanatomical group (>3 mm)	*p* Value
Patients, *n*	23	31	
Patient characteristics			
Age, years	66.9 ± 9.2	62.3 ± 10.2	n.s.
Body mass index, kg/m^2	25.4 ± 3.8	26.8 ± 5.4	n.s.
The time from onset of symptoms to surgery, days	69.4 ± 50.6	79.0 ± 74.2	n.s.
Radiograph			
ΔMJS for MMPRT knee, mm	0.1 ± 0.4	0.9 ± 0.8	<0.001*
Difference in ΔMJS, mm	0.1 ± 0.7	0.7 ± 0.9	0.013*
MRI			
ΔMME, mm	0.9 ± 0.9	1.6 ± 1.4	0.049*

Note: Values are presented as means ± standard deviation. Statistical relationship was determined using the unpaired *t* test. Difference in ΔMJS was defined as ΔMJS for MMPRT knee minus ΔMJS for the contralateral knee.

Abbreviations: MMPRT, medial meniscus posterior root tear; MRI, magnetic resonance imaging; ΔMJS, change in medial joint space; ΔMME, change in medial meniscus extrusion.

*$p < 0.05$.

This study has several limitations. First, the study was a case series; therefore, we did not perform a comparative study with a control group. However, this study used the MJS width for the contralateral knee to account for the effects of physiologic knee osteoarthritis progression. Second, the study was retrospective. Third, the follow-up period was only 2 years. More long-term evaluation is needed to assess osteoarthritis progression in the postoperative period. Fourth, MRI was performed in a non-weight-bearing position. Fifth, radiography and MRI were not available for immediate postoperative evaluation; thus, the correction of MME could not be evaluated immediately after the pullout repair surgery. Sixth, we were unable to evaluate the presence of a suture cutout at 2 years postoperatively; therefore, the actual relationship between the anterior position of the tibial tunnel and suture cutout is unknown. Seventh, our study patients were middle-aged individuals, with an average age of 64.2 years, all of whom may have developed MMPRTs due to meniscal degeneration. Thus, their degree of meniscal degeneration may have affected the progression of MJS narrowing and MME. Eighth, there was a case that included an additional posterior anchoring technique of pullout repair for MMPRTs and a partial meniscectomy for the incomplete discoid lateral meniscus. In the future, the use of ultrasonography or other methods may help resolve some of these limitations.

CONCLUSIONS

This study demonstrated that accurate tibial tunnel position in transtibial pullout repair for MMPRTs delayed the progression of MJS narrowing and MME, resulting in a more favourable clinical outcome. The progression of MJS narrowing was associated with the mediolateral direction of the tibial tunnel position, while the clinical scores were associated with the anteroposterior direction of the tibial tunnel position. The study findings highlight the need to aim the tip of the guide in a more posterolateral direction when creating the tibial tunnel.

AUTHOR CONTRIBUTIONS

Koki Kawada and Takayuki Furumatsu conceived this study. Koki Kawada and Takayuki Furumatsu performed the documentation, data collection and analysis. All the authors commented on the first draft of the manuscript and approved the final draft.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

This study was conducted in accordance with the principles of the Declaration of Helsinki. The study was approved by the Ethics Committee of the Okayama University (No. 1857). Informed consent was obtained from all individual participants included in the study. Written informed consent was obtained from all patients.

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