

Surgical Timing and Outcomes in Medial Meniscus Posterior Root Tear Repair

A Systematic Review

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Background: Medial meniscus posterior root tears (MMPRTs) compromise hoop stress transmission and tibiofemoral load distribution, accelerating degenerative changes comparable with total meniscectomy. While early repair has been recommended, many patients present late because of a delayed diagnosis or an insidious onset of symptoms. The effect of delayed surgical management on outcomes remains unclear.

Purpose: To systematically review the literature comparing clinical outcomes, radiological progression, and complication rates of MMPRT repair performed at <3 months, 3 to 6 months, and >6 months after the injury.

Study Design: Systematic review; Level of evidence, 4.

Methods: A systematic search of PubMed, Embase, and Scopus was conducted in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines and registered with PROSPERO. A total of 11 studies (366 patients) reporting isolated transtibial pullout repair with a documented time from injury to surgery were included. Extracted data included patient-reported outcome scores (International Knee Documentation Committee [IKDC], Lysholm), osteoarthritis progression by the Kellgren-Lawrence grade, meniscal extrusion, healing status, and surgical failures or complications.

Results: Across all surgical timing groups, MMPRT repair resulted in significant functional improvements. Patients treated at <3 months demonstrated the greatest gains (IKDC: +39.0; Lysholm: +44), while those undergoing repair at 3 to 6 months also achieved clinically meaningful improvements (IKDC: +26.5 to +31.8; Lysholm: +25.0 to +40.4). Delayed repair >6 months remained beneficial, with increases of +22.9 in the IKDC score and +33.1 to +36.1 in the Lysholm score. Subgroup analyses confirmed statistically significant improvements in both the IKDC and Lysholm scores at all time points. Osteoarthritis progression by the Kellgren-Lawrence grade was reported in 24.2% of patients treated at <3 months, 30.2% to 52.2% at 3 to 6 months, and 4.8% to 10.0% at >6 months. Magnetic resonance imaging showed variable meniscal extrusion changes, with partial to complete healing observed in both the 3- to 6-month group and >6-month group. Failure rates ranged from 5.9% to 20.9% without a consistent association with surgical timing.

Conclusion: Both early and delayed repair (<3 months and >6 months, respectively) yielded significant improvements in outcomes for patients with MMPRTs; however, the early repair group had clinically significant increases in patient-reported outcomes over the delayed repair group. Although data were limited by the number and quality of included studies, this finding suggests that while delayed repair of the meniscus root results in worthwhile improvements for properly selected patients and meets the minimal clinically important difference, early treatment of these tears should be pursued to limit the knee's exposure to altered biomechanics and to provide patients with the best chance at complete healing and lasting improvements.

Registration: CRD420251145118 (PROSPERO)

Keywords: meniscus root tear; surgical timing; clinical outcomes

Medial meniscus posterior root tears (MMPRTs) present a significant clinical and biomechanical challenge because

of the crucial role of the meniscus root in the distribution of hoop stress, load dispersion, and overall knee joint stability. These lesions are biomechanically equivalent to total meniscectomy, as they lead to meniscal extrusion and a substantial increase in tibiofemoral contact pressure, contributing to accelerated joint degeneration and the early onset of osteoarthritis (OA).¹⁴ Therefore, surgical

repair is essential to restore meniscal integrity, re-establish joint biomechanics, and prevent or delay degenerative changes.¹⁰

In recent years, 2 surgical techniques—transtibial pull-out repair and all-inside suture repair—have gained popularity for the treatment of MMPRTs, showing promising results regarding structural healing and symptomatic relief.²⁵ Although surgical repair of MMPRTs is essential for restoring knee biomechanics and for offering patients the best chance of avoiding deleterious changes in their knee, the influence of the interval between injury and surgery on both clinical and radiological outcomes remains incompletely understood. It has been reported that surgical management at ≤ 13 weeks after a meniscal injury may aid in reducing the degree of medial meniscal extrusion (MME), subsequently slowing OA progression over time.¹⁹ Additionally, a recent scoping review of 461 studies concluded that from the 101 studies that mentioned timing from injury to surgery, 6 studies^{5,11,15,18,19,21} reported on early versus delayed repair, with only 2 studies^{11,19} providing a cutoff for surgery that was considered early (<3.5 and <3 months, respectively).⁶ Furthermore, a recent Delphi panel agreed that symptomatic MMPRTs without advanced OA should be repaired early; however, a specific definition of “early” was not reported.²

Although early surgical repair may offer clinical benefit, MMPRTs often develop insidiously over months to years, and patients may present well after the initial onset of the injury, making “timely” repair within weeks to a few months of symptom onset impractical in many cases.⁷ Moreover, the subtle clinical presentation frequently leads to delays in diagnoses, further extending the interval to surgery. Despite this, evidence suggests that meaningful clinical improvements can still be achieved even when repair is performed in a delayed fashion. In fact, several studies have reported favorable outcomes in patients undergoing MMPRT repair at approximately 6 months after the index injury, including significant improvements in clinical function.^{3,17,27} These findings support the concept that while early repair may mitigate meniscal extrusion and joint degeneration, a delayed intervention does not necessarily preclude successful restoration of the medial compartment and can still result in substantial symptomatic relief and clinical gains.

Despite these encouraging findings, high-quality comparative evidence specifically evaluating the timing of MMPRT repair remains scarce. Most available studies are retrospective and exhibit significant variability regarding surgical techniques, inclusion criteria, and outcome parameters. Consequently, definitive conclusions regarding the optimal timing for surgical management cannot yet be established.

To help delineate optimal surgical timing, this study’s purpose was to systematically review the available literature on clinical, radiological, and complication outcomes in patients who underwent MMPRT repair at 3 key time points after a meniscal injury: <3 months, 3 to 6 months, and >6 months. The working hypothesis was that surgical management at >6 months would be associated with inferior clinical and functional outcomes, with an increase in mechanical failure or complication rates.

METHODS

Literature Search

A comprehensive search of the PubMed, Embase, and Scopus databases was performed in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines in July 2025 and was prospectively registered with PROSPERO (CRD420251145118). The following search strategy was utilized: (“medial meniscus posterior root tear” OR “medial meniscal root tear” OR “meniscus root tear” OR “posterior root tear” OR MMPRT) AND (repair OR surgery OR “arthroscopic repair” OR “transtibial pullout” OR “root repair”) AND (“clinical outcome” OR “functional outcome” OR “radiological outcome” OR “Lysholm score” OR IKDC OR KOOS OR “return to sport” OR “osteoarthritis progression” OR healing OR failure OR reoperation). The search was performed by one of the authors (L.D.M.).

Inclusion criteria were studies involving male and female patients of any age group who underwent either isolated transtibial pullout repair or isolated all-inside suture repair for MMPRTs. Additionally, they included a mean time from injury to surgery. Lastly, along with the aforementioned criteria, studies needed to report on patient-reported outcomes (PROs) and to be published between 2000 and June 2025. Exclusion criteria were studies that were cadaveric or translational; involved patients who underwent concomitant ligamentous, soft tissue, or osteotomy procedures; did not report PROs; did not report a mean time from meniscal injury to surgery; or had study designs that were systematic reviews, narrative reviews, conference abstracts, technical notes, letters to editors, or meta-analyses. Also, studies with overlapping cohorts based on the reported years of data collection from the same group of authors (most frequently Kawada et al, Furumatsu et al, Hiranaka et al, and Tamura et al) were excluded because of the risk of bias inherent with using overlapping cohorts for data extraction purposes. However, if it met the other inclusion criteria, the most recently published study from the author group with the largest sample

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size was included. There were 2 authors (L.D.M. and N.T.) who independently screened titles, abstracts, and full texts using the online software program Covidence (Veritas Health Innovation). Any disagreements were resolved with a discussion, leading to a consensus between the 2 authors (L.D.M. and N.T.).

Data Extraction and Quality Assessment

Data extracted from each study included patient information such as sex, age, body mass index (BMI), type of repair technique used, time from meniscal injury to surgery, postoperative rehabilitation plan, preoperative and postoperative PROs including the International Knee Documentation Committee (IKDC) score and Lysholm score, failures, reoperations, and complications. Radiographic and second-look arthroscopic outcomes, such as the Kellgren-Lawrence (KL) grade, MME, and meniscal healing status, were also extracted. An assessment of data quality for each of the nonrandomized prospective and retrospective studies included in this systematic review was performed with the Methodological Index for Non-Randomized Studies (MINORS) criteria.²⁴

Statistical Analysis

All statistical analyses were performed using a meta-analytic approach with Review Manager (RevMan Version 5.4.1; The Cochrane Collaboration). For continuous outcomes, the mean difference (MD) with the corresponding 95% confidence interval (CI) was calculated to compare preoperative and postoperative values. A fixed-effects model was used when studies were sufficiently homogeneous or when only a single study was available for analysis. Statistical heterogeneity among studies was assessed using the chi-square test and quantified with the I^2 statistic. An I^2 value $<50\%$ and a chi-square test with $P > .10$ were considered to indicate low heterogeneity, in which case a fixed-effects model was applied. Subgroup analyses were conducted according to time from injury to surgery (<3 months, 3-6 months, and >6 months). For outcomes that could not be pooled quantitatively because of insufficient data or heterogeneity in reporting, results were synthesized qualitatively. A 2-tailed P value $<.05$ was considered statistically significant.

RESULTS

Literature Search Findings

A total of 1384 studies were identified in the initial search, 749 of which were duplicates and were subsequently excluded. The remaining 635 studies underwent title and abstract screening, and 565 were found to be irrelevant to the study aims and therefore excluded. The remaining 70 studies were assessed for eligibility with a full-text review. After excluding 59 studies for having overlapping cohorts ($n = 10$), not being in the English language ($n = 2$), having

a wrong study design ($n = 1$), including a wrong intervention ($n = 3$), not reporting outcomes ($n = 2$), and not reporting the time from symptom to surgery ($n = 41$), 11 studies were ultimately included for data extraction (Figure 1). Each of the studies included in this systematic review evaluated PROs after isolated MMPRT repair with a reported time from the original injury to surgery.

Study Quality and Risk of Bias

Table 1 summarizes the study quality based on the MINORS criteria for nonrandomized studies. The ideal MINORS score for noncomparative studies is 16, with scores ≤ 8 being the accepted cutoff for poor study quality. Each of the included studies had a score ≥ 9 , indicating a sufficiently low risk of bias.²⁴ The ideal MINORS score for comparative studies is 24, with scores ≥ 18 being the accepted cutoff for high study quality, ≥ 12 and <18 for moderate study quality, and <12 for poor study quality. Of note, no study received points for the prospective calculation of data, unbiased assessment of study endpoints, or prospective calculation of study size. Overall, the risk of bias was low for the included studies in this systematic review.

Study Characteristics

Overall, 2 studies^{9,28} included in this review reported a mean time from injury to surgery <3 months, 6 studies^{12,13,20,22,23,27} reported a mean time between 3 and 6 months, and 3 studies^{3,17,26} reported a mean time >6 months from injury to surgery. The mean BMI ranged from 24.3 ± 2.5 to 31.8 ± 7.2 kg/m². The mean follow-up time ranged from 12.0 ± 8.4 to 110.4 ± 7.2 months. The mean age ranged from 47.2 ± 12.2 to 65.3 ± 7.6 years (Table 1).

Surgical Technique and Postoperative Rehabilitation

All included studies reported using the isolated transtibial pullout technique for MMPRT repair. Postoperative rehabilitation plans varied, although they all reported a time of restricted weightbearing, gradual progression of range of motion, and physical therapy (Table 2).

Patient-Reported Outcomes

Functional outcomes after MMPRT repair were consistently improved across all time intervals from injury to surgery. Patients who underwent surgery at <3 months demonstrated the greatest gains, with Hopkins and Lawrie⁹ reporting a mean improvement of 39.0 points in the IKDC score ($P < .001$) and 44 points in the Lysholm score ($P < .001$). Surgery performed at 3 to 6 months also yielded statistically significant improvements, with mean IKDC score improvements ranging from 26.5 to 31.8 points (all $P < .05$) and mean Lysholm score improvements ranging from 25.0 to 40.4 points (all $P < .05$). In the >6 -month group, improvements remained statistically significant, although

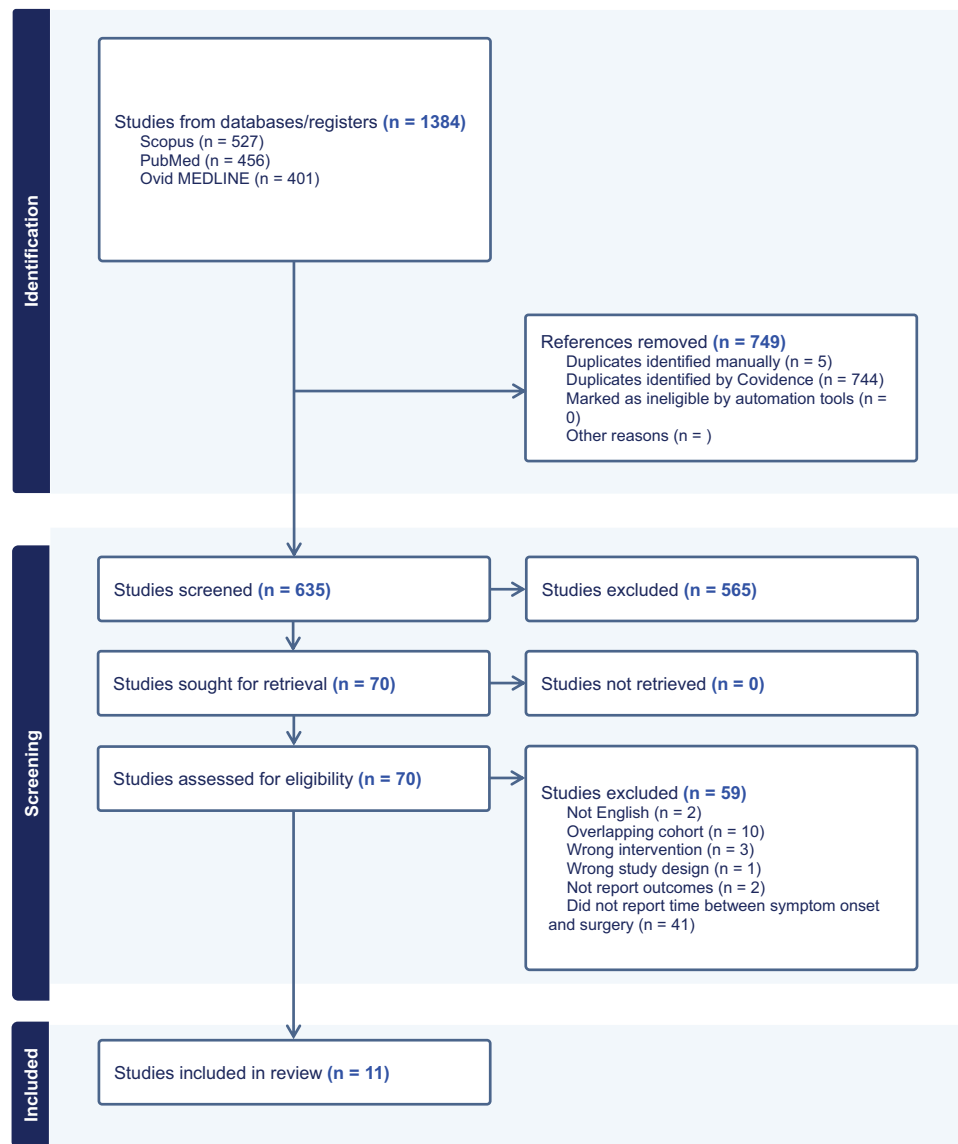


Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of study selection. The numbers of screened, excluded, and included studies are shown.

generally lower than earlier interventions. Thamrongsuksiri et al²⁶ reported a mean IKDC score improvement of 22.9 points ($P < .001$) and a mean Lysholm score improvement of 33.1 points ($P < .001$), while Lee et al¹⁷ demonstrated a 36.1-point increase in the Lysholm score ($P < .001$). Overall, an earlier surgical intervention was associated with greater functional gains, but clinically meaningful improvements were observed across all time frames.

Subgroup analysis stratified by time from injury to surgery demonstrated significant improvements in IKDC scores across all groups (Figure 2). For patients who underwent surgery at <3 months after the injury, the MD between postoperative and preoperative scores was 39.00 (95% CI, 29.82-48.18; $P < .001$), analyzed using a fixed-effects model because only 1 study was available. For patients with surgery performed between 3 and 6 months

after the injury, 5 studies were pooled using a fixed-effects model, demonstrating an MD of 29.59 (95% CI, 26.53-32.65; $P < .001$). Heterogeneity was low and not statistically significant ($\chi^2 = 0.98$; $P = .91$; $I^2 = 0\%$). For patients with surgery delayed at >6 months, analysis was based on a single study, yielding an MD of 22.90 (95% CI, 17.85-27.95; $P < .001$) using a fixed-effects model (Table 3).

Subgroup analysis stratified by time from injury to surgery also demonstrated significant improvements in Lysholm scores across all groups (Figure 3). For patients who underwent surgery at <3 months after the injury, the MD between postoperative and preoperative scores was 44.00 (95% CI, 34.51-53.49; $P < .001$), analyzed using a fixed-effects model because only 1 study was available. For patients with surgery performed between 3 and 6 months after the injury, 6 studies were pooled using

TABLE 1
Study Characteristics^a

First Author (Year)	Study Design (LOE)	MINORS Score	No. of Patients	Age, ^b y	Follow-up, ^b mo	BMI, ^b kg/m ²	Time From Injury to Surgery, ^b mo
Time from injury to surgery <3 mo							
Hopkins ⁹ (2021)	Retrospective case series (4)	12	33	56.8 ± 9.7	39.4 ± 15.2	30.5 ± 5.3	2.8 ± 13.1
Zhang ²⁸ (2023)	Retrospective case series (4)	14	33	65.3 ± 7.6	13.0 ± 1.1	24.3 ± 2.5	0.8 ± 1.1
Time from injury to surgery of 3-6 mo							
Kaplan ¹² (2022)	Retrospective case series (4)	12	10	48.4 ± 12.0	65.5 ± 8.3	29.5 ± 4.5	3.4 ± 12.6
Kawada ¹³ (2024)	Retrospective case series (4)	13	63	64.8 ± 7.6	36.0	25.9 ± 4.1	3.3 ± 21.7
Moore ²⁰ (2024)	Retrospective case series (4)	14	17	47.2 ± 12.2	110.4 ± 7.2	30.1 ± 5.8	3.7 ± 15.6
Okazaki ²² (2025)	Retrospective case series (4)	12	43	63.1 ± 7.4	70.8 ± 9.6	26.5 ± 4.1	3.0 ± 2.4
Schlumberger ²³ (2024)	Retrospective case series (4)	10	62	49.6 ± 9.8	27.6 ± 8.4	31.8 ± 7.2	3.6 ± 5.6
Yanagisawa ²⁷ (2020)	Retrospective comparative (3)	17	23	61.5 ± 8.5	12.0 ± 8.4	25.2 ± 3.6	4.0 ± 3.2
Time from injury to surgery >6 mo							
Dzidzishvili ³ (2022)	Retrospective comparative (3)	18	30	52.2 ± 27.3	27.3 ± 4.5	28.5 ± 15.6	8.1 ± 7.3
Lee ¹⁷ (2009)	Retrospective case series (4)	10	20	51.2 ± 20.3	31.8 ± 18.0	NR	23.4 ± 55.4
			(21 knees)				
Thamrongsuksiri ²⁶ (2024)	Retrospective case series (4)	12	32	57.0 ± 8.9	24.0	27.7 ± 4.9	7.0 ± 3.8

^aEach included study had a sufficiently low risk of bias. BMI, body mass index; LOE, level of evidence; MINORS, Methodological Index for Non-Randomized Studies; NR, not reported.

^bData are presented as mean ± SD.

a random-effects model, demonstrating an MD of 31.20 (95% CI, 26.38-36.02; $P < .001$). Heterogeneity was high and statistically significant ($\chi^2 = 20.41$; $P = .001$; $I^2 = 76\%$). For patients with surgery delayed at >6 months, 3 studies were pooled using a fixed-effects model, demonstrating an MD of 33.34 (95% CI, 26.50-40.18; $P < .001$). Heterogeneity was low and not statistically significant ($\chi^2 = 0.05$; $P = .82$; $I^2 = 0\%$) (Table 4).

Magnetic Resonance Imaging (MRI) Outcomes

Postoperative MRI demonstrated variable findings in terms of meniscal extrusion and healing. In the <3-month group, Zhang et al²⁸ reported a nonsignificant increase in extrusion from 2.7 ± 0.6 mm preoperatively to 3.4 ± 0.8 mm postoperatively (+ 0.7 mm). In the >6-month group, Dzidzishvili et al³ found that 12 of 30 patients (40%) demonstrated increased meniscal extrusion, while Thamrongsuksiri et al²⁶ observed a statistically significant reduction in extrusion from 4.1 ± 0.8 mm to 3.6 ± 0.9 mm (−0.5 mm; $P = .002$) (Table 5). With respect to MRI-based healing, Kaplan et al¹² reported in the 3- to 6-month group that 30% achieved complete healing and 70% partial healing, with no retears. In contrast, Thamrongsuksiri et al²⁶ in the >6-month group reported 53.1% complete healing, 37.5% partial healing, and 9.4% retears.

OA Progression

There were 8 studies^{3,9,13,17,22,26,27,28} included in this review that reported on OA with the KL grade. Of these,

7 studies^{3,9,13,17,22,27,28} reported the outcomes based on the number of patients with each KL grade; all studies noted a progression of OA based on the KL grade (Table 6). Thamrongsuksiri et al²⁶ reported a mean KL grade preoperatively and postoperatively, which was 1.7 ± 0.5 and 1.8 ± 0.4, respectively.

Complications, Reoperations, and Failures

The study by Thamrongsuksiri et al²⁶ was the only one to report complications, which were defined as adverse events not requiring further surgery; they reported zero complications. Reoperations, defined as subsequent surgical procedures not because of the previous MMPRT repair procedure, were reported by 4 studies.^{3,20,22,26} Rates of conversion to total knee arthroplasty ranged from 5.9% to 10%. The rates of manipulation under anesthesia and lysis of adhesions ranged from 2.3% to 5.9%. Failure, defined as requiring a subsequent meniscal procedure on the index meniscus, was reported by 4 studies,^{20,22,23,26} and this rate ranged from 5.9% to 20.9%. The 4 failures reported by Okazaki et al²² were caused by a retear of the MMPRT in which 2 underwent revision repair and the other 2 underwent partial meniscectomy. Schlumberger et al²³ reported 13 failures in which 10 were caused by a retear, 2 because of meniscal degradation with varus alignment, and 1 for a loose meniscal suture; 10 of these failures were treated with revision repair, and 3 were treated non-operatively, and the mean time from the index procedure to the revision procedure was 8.4 ± 3.6 months. Moore et al²⁰ reported 1 failure due to a meniscal retear that was treated with partial meniscectomy at 2 years

TABLE 2
Postoperative Rehabilitation Protocols^a

First Author (Year)	WB	ROM	Physical Therapy	Return to Sport
Time from injury to surgery <3 mo				
Hopkins ⁹ (2021)	Non-WB for 6 wk; gradual progression after 6 wk	Hinged knee brace set to 0°-90° for 6 wk; no deep knee flexion for 6 mo	Starting at 6 wk	NR
Zhang ²⁸ (2023)	Non-WB for 2 wk; gradual progression to full WB at 6 wk	Knee immobilizer for 2 wk; 0°-90° after 2 wk and then full ROM at 6 wk; no deep flexion for 12 wk	Focusing on ROM at 0-4 wk; lunges and leg presses at 6 wk	12 wk
Time from injury to surgery of 3-6 mo				
Kaplan ¹² (2022)	Non-WB for 6 wk; gradual progression to full WB at 6 wk	Hinged knee brace locked in extension for 4 wk; full ROM from 4-6 wk	Focusing on ROM at 0-4 wk; lunges and leg presses at 6 wk	16 wk
Kawada ¹³ (2024)	Non-WB for 1 wk; progressive WB from 1 wk	No ROM for 1 wk and then progressive ROM from 1 wk; knee flexion limited to 120° for 3 mo	NR	NR
Moore ²⁰ (2024)	Non-WB for 6 wk; full WB at 6 wk	Hinged knee brace locked in extension for 6 wk; full ROM at 6 wk	NR	16 wk
Okazaki ²² (2025)	Non-WB for 2 wk; partial WB from 2-4 wk; full WB at 5 or 6 wk	Knee immobilizer for 2 wk; progressive ROM from 2 wk	NR	NR
Schlumberger ²³ (2024)	Partial WB immediately after surgery; full WB at 6 wk	Knee immobilizer for 6 wk; full ROM at 6 wk	ROM activities until full ROM achieved at 3 d	NR
Yanagisawa ²⁷ (2020)	Non-WB for 4 wk; full WB at 6 wk	Knee immobilizer for 4 wk	NR	NR
Time from injury to surgery >6 mo				
Dzidzishvili ³ (2022)	Non-WB for 4 wk	0°-90° for 4 wk; 0°-110° for 6-12 wk	Quadriceps strengthening immediately	NR
Lee ¹⁷ (2009)	Non-WB for 6 wk; partial WB at 6 wk; full WB at 8 wk	Long leg cast in extension for 2 wk; passive ROM of 0°-90° from 2-4 wk; full ROM after 4 wk	Quadriceps strengthening immediately; squatting at 6 mo	24 mo
Thamrongsuksiri ²⁶ (2024)	Toe-touch WB for 2 wk; gradual WB from 2-6 wk	0°-30° for first 2 wk; progression to 0°-90° after 2 wk; full ROM at 6 wk	Quadriceps strengthening immediately	12-16 wk

^aNR, not reported; ROM, range of motion; WB, weightbearing.

postoperatively. Thamrongsuksiri et al²⁶ reported 3 failures due to a meniscal retear that were treated nonoperatively.

DISCUSSION

The main finding of this study was that delayed surgical management (>6 months) of MMPRTs resulted in significant improvements in PROs, similar to the reported improvements from studies with earlier surgical management (<3 months and 3-6 months) of MMPRTs. Additionally, there were high rates of OA progression across all studies (4.8%-52.2%), with the highest rate of OA progression reported by the 3- to 6-month repair group (30.2%-

52.2%). Finally, failure rates were similar, regardless of surgical timing.

The clinical outcomes of this study were equivocal compared with the reported minimal clinically important difference (MCID) and patient acceptable symptom state (PASS) for arthroscopic meniscal procedures. The MCID and PASS for the IKDC score established by Figueroa et al⁴ specifically in isolated arthroscopic MMPRT repair were 10.2 and 67.8, respectively, while the MCID for the Lysholm score was 10¹ in other arthroscopic meniscal procedures; the PASS for these PRO measures in arthroscopic meniscal procedures has not been reported. Within the data reported from this review, all 7 studies^{9,12,13,20,22,23,26} that reported IKDC scores met the MCID; however, only 3 studies^{12,20,22} met the PASS, and all these studies were from the 3- to 6-month surgery group. Moreover, the 10

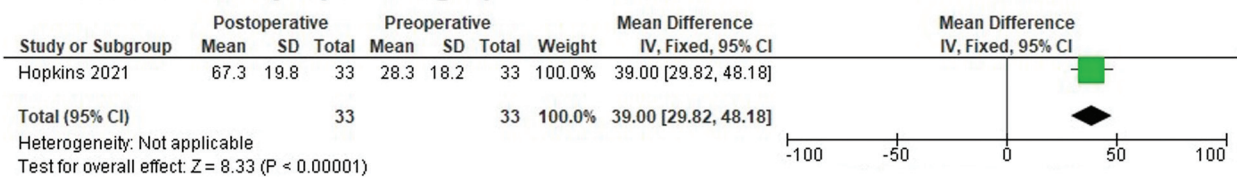
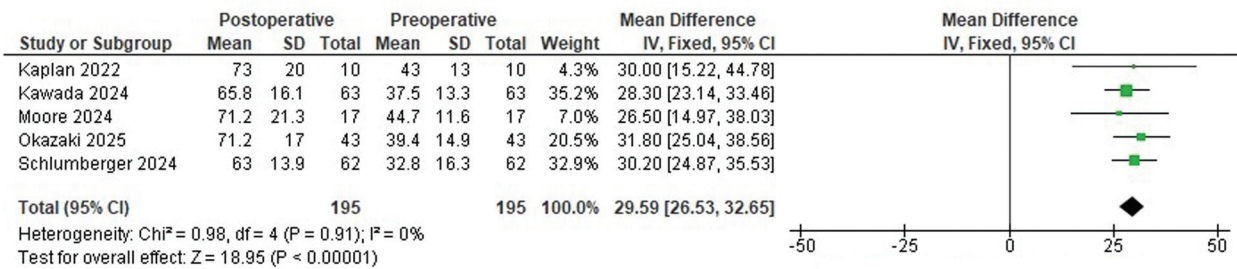
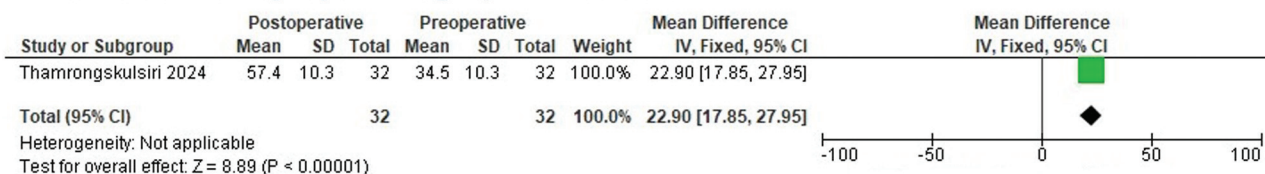
A Time from injury to surgery < 3 months**B Time from injury to surgery 3-6 months****C Time from injury to surgery > 6 months**

Figure 2. Forest plots of preoperative and postoperative International Knee Documentation Committee (IKDC) scores stratified by time from injury to surgery: (A) <3 months, (B) 3-6 months, and (C) >6 months.

TABLE 3
IKDC Scores^a

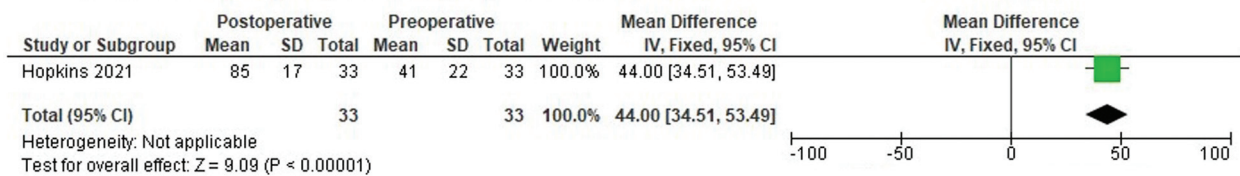
First Author (Year)	Preoperative	Postoperative	Mean Change	P Value
Time from injury to surgery <3 mo				
Hopkins ⁹ (2021)	28.3 ± 18.2	67.3 ± 19.8	+ 39.0	<.001
Time from injury to surgery of 3-6 mo				
Kaplan ¹² (2022)	43 ± 13	73 ± 20	+ 30	.004
Kawada ¹³ (2024)	37.5 ± 13.3	65.8 ± 16.1	+ 28.3	<.05
Moore ²⁰ (2024)	44.7 ± 11.6	71.2 ± 21.3	+ 26.5	.001
Okazaki ²² (2025)	39.4 ± 14.9	71.2 ± 17.0	+ 31.8	<.001
Schlumberger ²³ (2024)	32.8 ± 16.3	63.0 ± 13.9	+ 30.2	<.001
Time from injury to surgery >6 mo				
Thamrongsuksiri ²⁶ (2024)	34.5 ± 10.3	57.4 ± 10.3	+ 22.9	<.001

^aData are presented as mean ± SD unless otherwise indicated. IKDC, International Knee Documentation Committee.

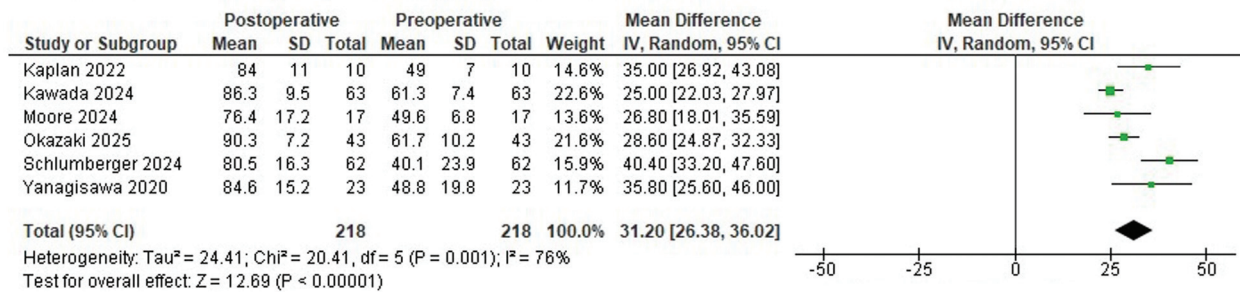
studies^{3,9,12,13,17,20,22,23,26,27} that reported both preoperative and postoperative Lysholm scores met the MCID. Although earlier surgical management of MMPRTs has been favored, as reported by the recent Delphi panel on MMPRTs,² the results of this review support positive clinical outcomes with more delayed treatment, as evidenced by the comparable mean changes in Lysholm and IKDC scores between the 3- to 6-month group (IKDC: +26.5 to +31.8; Lysholm: +25.0 to +40.4) and >6-month group

(IKDC: +22.9; Lysholm: +33.1 to +36.1). Moreover, the insidious and often subtle clinical presentation of MMPRTs frequently delays surgical management by several months.⁷ Consequently, the findings of this review are consistent with the natural history of the condition, underscoring the clinical relevance of the positive outcomes observed. Across all studies reporting PROs, Moore et al²⁰ cited lower mean changes in Lysholm and IKDC scores at final follow-up compared with the rest of the

A Time from injury to surgery < 3 months



B Time from injury to surgery 3-6 months



C Time from injury to surgery > 6 months

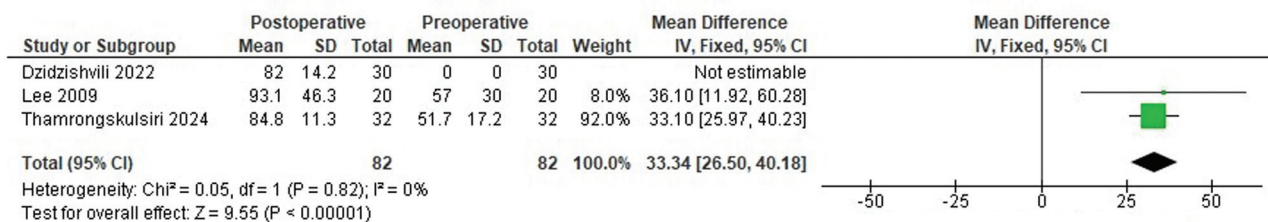


Figure 3. Forest plots of preoperative and postoperative Lysholm scores stratified by time from injury to surgery: (A) <3 months, (B) 3-6 months, and (C) >6 months.

TABLE 4
Lysholm Scores^a

First Author (Year)	Preoperative	Postoperative	Mean Change	P Value
Time from injury to surgery <3 mo				
Hopkins ⁹ (2021)	41 ± 22	85 ± 17	+ 44	<.001
Time from injury to surgery of 3-6 mo				
Kaplan ¹² (2022)	49 ± 7	84 ± 11	+ 35	<.001
Kawada ¹³ (2024)	61.3 ± 7.4	86.3 ± 9.5	+ 25.0	<.05
Moore ²⁰ (2024)	49.6 ± 6.8	76.4 ± 17.2	+ 26.8	<.001
Okazaki ²² (2025)	61.7 ± 10.2	90.3 ± 7.2	+ 28.6	<.001
Schlumberger ²³ (2024)	40.1 ± 23.9	80.5 ± 16.3	+ 40.4	<.001
Yanagisawa ²⁷ (2020)	48.8 ± 19.8	84.6 ± 15.2	+ 35.8	.001
Time from injury to surgery >6 mo				
Dzidzishvili ³ (2022)	NR	82.0 ± 14.2	NA	NA
Lee ¹⁷ (2009)	57.0 ± 30.0	93.1 ± 46.3	+ 36.1	<.001
Thamrongsuksiri ²⁶ (2024)	51.7 ± 17.2	84.8 ± 11.3	+ 33.1	<.001

^aData are presented as mean ± SD unless otherwise indicated. NA, not applicable; NR, not reported.

studies; however, this study had the longest follow-up time (110.4 ± 7.2 months). Moore et al²⁰ also reported PROs at 24 and 60 months postoperatively, with mean IKDC scores of 75.6 ± 14.9 and 82.5 ± 16.6 , respectively, and mean

Lysholm scores of 72.1 ± 18.3 and 80.3 ± 12.6 , respectively, which are more comparable with the other reported scores at similar follow-up times. Moreover, there was a significant difference in reported IKDC scores between the

TABLE 5
Postoperative Meniscal Extrusion on MRI^a

First Author (Year)	Preoperative, mm	Postoperative, mm	Mean Change, mm	P Value
Time from injury to surgery <3 mo				
Zhang ²⁸ (2023)	2.7 ± 0.6	3.4 ± 0.8	+ 0.7	NS
Time from injury to surgery >6 mo				
Dzidzishvili ³ (2022)	NR	12/30 with increased extrusion	NA	NA
Thamrongsuksiri ²⁶ (2024)	4.1 ± 0.8	3.6 ± 0.9	-0.5	.002

^aData are presented as mean ± SD unless otherwise indicated. MRI, magnetic resonance imaging; NA, not applicable; NR, not reported; NS, not significant.

TABLE 6
Kellgren-Lawrence Grades^a

First Author (Year)	Preoperative, 0/1/2/3/4	Postoperative, 0/1/2/3/4	Change, 0/1/2/3/4	Rate of Change, n (%)
Time from injury to surgery <3 mo				
Hopkins ⁹ (2021)	3/13/9/6/0	2/6/13/10/0	-1/-7/+ 4/+ 4/0	8/31 (24.2)
Zhang ²⁸ (2023)	0/11/22/0/0	NR	NA	NA
Time from injury to surgery of 3-6 mo				
Kawada ¹³ (2024)	0/32/31/0/0	0/13/41/9/0	0/-19/+ 10/+ 9/0	19/63 (30.2)
Okazaki ²² (2025)	0/15/28/0/0	0/2/19/22/0	0/-13/-9/+ 22/0	22/43 (51.2)
Yanagisawa ²⁷ (2020)	8/15/0/0/0	6/5/12/0/0	-2/-10/+ 12/0/0	12/23 (52.2)
Time from injury to surgery >6 mo				
Dzidzishvili ³ (2022)	0/5/19/6/0	0/4/17/7/2	0/-1/-2/+ 1/+ 2	3/30 (10.0)
Lee ¹⁷ (2009)	3/5/9/4/0	3/5/8/5/0	0/0/-1/+ 1/0	1/21 (4.8)

^aData are presented as No. unless otherwise indicated. NA, not applicable; NR, not reported.

<3-month and >6-month groups, as evidenced by the lack of overlap in the 95% CIs in Figure 2. Additionally, there was a 16-point difference in the mean change in IKDC scores between the <3-month and >6-month groups, indicating that not only was there a statistically significant difference in IKDC scores based on the lack of 95% CI overlap but also a clinically significant difference considering the aforementioned MCID of 10.2 for the IKDC score. Similarly, the <3-month repair group had a trend of superior mean changes in the Lysholm score at final follow-up compared with the 3- to 6-month and >6-month groups. Overall, the results of this review support the positive outcomes of MMPRT repair at surgical times >6 months after an injury, although earlier repair appears to produce superior clinical outcomes comparatively. However, these results are difficult to generalize because of the limited number of studies identified by our review.

Additionally, there were high rates of OA progression (4.8%-52.2%) reported by the included studies, with the highest rate reported by the 3- to 6-month group, although surgical timing was likely not as significant of a contributor to this observed result overall as the age and baseline cartilage status of these patients. Moon et al¹⁹ reported a significant difference in MME between patients who underwent transtibial pullout repair for MMPRTs at 2.5 ± 1.6 months and those at 5.0 ± 3.8 months; however, they noted a significant increase in OA progression that was not significantly different between the 2 groups. In

this review, a delayed time from injury to surgery does not appear to increase the risk of OA progression, as evidenced by the overall lowest percentage of patients with OA progression in the >6-month group based on KL grades (4.8%-10.0%). However, these results are difficult to interpret because of the limited number of studies in the >6-month group and the wide range of follow-up times (24.0 to 31.8 ± 18.0 months) that may be too short to fully assess the risk of OA development, as evidenced by studies on a similar topic.¹⁶ In contrast, Yanagisawa et al²⁷ and Okazaki et al²² from the 3- to 6-month group cited the greatest percentage of patients with OA progression (52.2% and 51.2%, respectively), although they did report some of the greatest mean ages (61.5 ± 8.5 and 63.1 ± 7.4 years, respectively), which may have influenced the baseline cartilage status and subsequent OA progression observed. These studies did not assess MME; therefore, a further investigation of its effects on OA progression was not feasible in this review. Moreover, the reduction in MME was minimally reported by the included studies; therefore, the observed trend that there was similar MME reduction between early and delayed MMPRT repair must be considered within the limitations of this study. Furthermore, >6 months may be too early for a chronic root presentation in which the torn root scars to the medial joint capsule, subsequently creating extrusion that is more difficult to treat without meniscotibial ligament repair and a centralization technique.⁵ Only 1 study²⁶ reported a significant reduction

in MME, signifying that regardless of repair timing, there is a significant risk of meniscal extrusion and subsequent OA progression with isolated MMPRT repair, which therefore should be considered when treating MMPRTs.

Finally, the rates of adverse events were similar across the groups, highlighting that the timing of repair may not have a significant effect on surgical success after MMPRTs. Schlumberger et al²³ reported the greatest failure rate (20.9%) compared with the other included studies. They also cited the largest mean BMI ($31.8 \pm 7.2 \text{ kg/m}^2$) and allowed weightbearing immediately after surgery, which have both been cited as risk factors for failure after MMPRT repair.^{8,14,29} Regarding meniscal healing based on postoperative MRI, only 2 studies^{12,26} reported on these outcomes. There was a lower incidence of complete healing in the 3- to 6-month group compared with the >6-month group (30% vs 53.1%, respectively); however, there was a 0% retear rate reported by the 1 study¹² in the 3- to 6-month group compared with 9.4% in the >6-month group. These results must be interpreted with caution because of the inherent biases with MRI interpretation and the overall low number of studies reporting on these findings.

This systematic review presents many opportunities for further research on this topic. There have not been, to our knowledge, any comparative studies that assessed outcomes based on surgical timing after MMPRTs. This would facilitate further understanding of the effect that surgical timing has on clinical and radiological outcomes after these procedures and guide preoperative surgical planning.

Limitations

Several limitations are inherent to this systematic review. Most included studies used retrospective case series designs with small sample sizes, introducing potential selection and reporting biases. While the methodological quality was moderate to high based on MINORS criteria, the lack of prospective randomized trials limits the strength of the conclusions. Importantly, none of the included studies provided a direct comparison between the timing of surgery after an injury, precluding definitive conclusions regarding the superiority or equivalence of early surgical repair. The duration of follow-up in the included studies was limited to short term to midterm, which may not be adequate to assess long-term outcomes such as sustained meniscal healing or OA progression.

There was considerable heterogeneity across studies in surgical techniques, rehabilitation protocols, and definitions and methods used to assess radiological outcomes such as MME and OA progression. Moreover, confounding factors such as lower limb alignment, chondral status, and patient compliance with rehabilitation protocols were not consistently reported, which limits the ability to adjust for potential modifiers of clinical and radiological outcomes, especially to differentiate those with varus alignment, which has a high risk of leading to poorer postoperative outcomes. Additionally, all included studies utilized the transtibial pullout technique; therefore, the

results of this review cannot be generalized to alternative MMPRT repair methods. Furthermore, studies did not report objective measures of adherence to the prescribed rehabilitation regimen, which may affect the validity of the outcome under the intended postoperative protocol. Also, the underrepresentation of patients with high BMIs and varus alignment reduces the generalizability of findings to higher risk populations. In addition, the lack of centralization procedures in the included cohorts may have contributed to the observed increase in postoperative MME and OA progression, highlighting a potential limitation of isolated root repair when not accompanied by extrusion-limiting techniques. Collectively, these limitations underscore the need for high-quality, prospective comparative trials with standardized outcome definitions to further elucidate the optimal surgical timing of MMPRT repair.

CONCLUSION

Both early and delayed repair (<3 months and >6 months, respectively) yielded significant improvements in outcomes for patients with MMPRTs; however, the early repair group had clinically significant increases in PROs over the delayed repair group. Although data were limited by the number and quality of included studies, this finding suggests that while delayed repair of the meniscus root results in worthwhile improvements for properly selected patients and meets the MCID, early treatment of these tears should be pursued to limit the knee's exposure to altered biomechanics and to provide patients with the best chance at complete healing and lasting improvements.

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