

Repair versus nonrepair of medial meniscus posterior root tear

A systematic review of patients' selection criteria, including clinical and radiographic outcomes

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Abstract

Background: The general consensus regarding a rational choice among various treatment strategies for medial meniscus posterior root tears (MMPRTs) has yet to be clearly established. The purpose of this systematic review was to analyze patient selection criteria based on index arthrosis, as well as clinical and radiological outcomes after repair or nonrepair treatment in patients with MMPRTs.

Methods: A systematic electronic search was performed with established medical databases. Data from the selected studies which were assessed using the modified Coleman methodology score were analyzed in terms of index arthrosis and degree of lower limb alignment, functional and radiologic outcomes after meniscus repair, partial meniscectomy, and conservative treatment.

Results: In total, 17 studies and 655 patients (665 cases) were enrolled in this study, of which 42% (279 cases) underwent MMPRT repair and 58% (386 cases) were treated using a nonrepair strategy. The mean age and the mean follow-up period were 54.7 years and 32.5 months in the repair group, respectively, and 57.0 years and 49.3 months in the nonrepair group, respectively. Based on the clinical data available in this study, most of the MMPRT repairs were performed in patients with mild arthrosis, mild varus alignment, and mild chondral injury. Although data were limited, the percentage of patients with mild chondral injury was only 40% in the nonrepair group, implying that the nonrepair group may have more advanced arthrosis at the baseline. Based on the available Lysholm score across the studies, good functional outcomes were obtained in the repair group, whereas the results of the nonrepair treatment exhibited fair functional outcomes that were somewhat heterogenous. The radiologic outcomes of the mean 5 years' follow-up study showed that arthritic change could not be prevented by either nonrepair or repair treatment.

Conclusions: In general, MMPRT repair led to significant improvement in clinical outcomes. On the contrary, the nonrepair group also showed symptomatic relief in some selected cases, despite the somewhat heterogenous results. Given the subgroup analysis for the functional results reported in this review, strict patient selection is important to obtain satisfactory clinical outcomes, regardless of the treatment option selected.

Abbreviations: HSS score = Hospital for special Surgery score, IKDC SKF score = International Knee Documentation Committee Subjective Knee Form score, KL grade = Kellgren-Lawrence grade, MMPRT = medial meniscus posterior root tear.

Keywords: medial meniscus, posterior root tear, repair, systematic review

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1. Introduction

Medial meniscus posterior root tears (MMPRTs) have recently been receiving considerable attention in the clinical setting.^[1,2] In the absence of accurate demographic data, studies have reported MMPRT are more prevalent in Asian cultures with a tradition of sitting on the floor, and have suggested that obesity and old age are the major risk factors.^[3,4]

The consequences of a MMPRT can be as undesirable as total meniscectomy in terms of the loss of function of the circumferential fibers and weakening of the ability of the meniscus to withstand hoop stress in the medial compartment of the knee, which could lead to early onset of medial femorotibial arthritis.^[1,2,5,6]

A biomechanical study demonstrated that the peak contact pressure could be restored to normal after a MMPRT repair.^[7-9] Subsequently, the repair of MMPRTs has attracted increasing interest and a variety of arthroscopic repair techniques have been proposed. However, MMPRT repair is a technically demanding and time-consuming operation, with only limited evidence of success.^[1,2,5,10-13]

In general, although the short-term clinical results of repair for MMPRTs have been encouraging,^[14-16] other studies using magnetic resonance imaging (MRI) or second-look arthroscopy have shown increased meniscal extrusion and incomplete or failed healing in several patients.^[17,18] In contrast, meniscectomy for MMPRT has been traditionally used because it is a relatively easier procedure than the repair procedure and symptomatic improvement could be expected by removing the source of mechanical pain, even though it cannot prevent the progression of osteoarthritis.^[3,19,20]

Conservative treatment with supervised exercise therapy has also been reported to be a reasonable treatment option for middle-aged patients with early osteoarthritis.^[21,22]

The purpose of this systematic review was to analyze patient selection criteria based on index arthrosis, as well as clinical and radiological outcomes after repair or nonrepair treatment in patients with medial meniscus posterior root tears. We hypothesized that repair for MMPRTs would result in good functional and radiological outcomes and a nonrepair strategy including meniscectomy and conservative treatment would also show symptomatic improvement for some selected patients.

2. Methods

2.1. Literature search

A systematic electronic search of the PubMed database, Embase, and the Cochrane Library was performed in January 2019 to identify studies that reported the clinical and radiological outcomes of the repair and nonrepair of MMPRTs. The following search terms were used: (“medial meniscus” OR “medial meniscal” OR “posterior horn”) and (“Root” OR “Radial tear” OR “Avulsion”).

The inclusion criteria were as follows: articles written in English about clinical and radiological outcomes of treatment for the MMPRTs; all levels of evidence; and studies on line or in print with no limits of the date of publication. Exclusion criteria were as follows: articles written in a language other than English; review articles; biomechanical studies; nonhuman studies; technical notes; case reports; not relevant MMPRTs; abstract only articles; coprocedure other than the repair of MMPRTs

(ligament reconstruction). No ethical approval was necessary for the present study because all the data were based on previously published studies and anonymized.

In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, 2 authors independently reviewed the title and abstract of all articles to evaluate the fitness of search-returned articles for the defined inclusion and exclusion criteria. The relevance of the studies extracted based on the title and abstract was screened by the full text review. The same 2 authors independently recorded data from each study using a predefined data extraction form. If data of the same patients were used for multiple studies, we chose the data from only 1 study.

2.2. Quality assessment

The methodologic quality of the included studies was analyzed using the modified Coleman Methodology Score.^[23] This score assesses the methodology of clinical studies by using 10 specific quantitative and qualitative criteria: study size; mean follow-up; number of surgical procedures; type of study; diagnostic certainty; description of surgical procedure; postoperative rehabilitation; outcome measures; outcome assessment; and selection process. The final score ranges from 0 to 100, with a score of 100 indicating the highest study quality.

2.3. Data Abstraction

Data from the selected studies that met the inclusion criteria were obtained by 2 of the authors. The data extracted included the year of publication, study design, patients' index arthrosis, and degree of lower limb alignment, treatment strategy including partial meniscectomy, conservative treatment and specific repair technique, number of cases, mean age (years), mean follow-up period (months), functional outcomes (mean Lysholm score, mean International Knee Documentation Committee Subjective Knee Form (IKDC SKF) score and mean Hospital for special Surgery (HSS) score, and progress of osteoarthritis (Kellgren-Lawrence [KL]) grade.

3. Results

3.1. Literature search

The number of initially identified articles by electronic search was 557. A flow chart regarding the screening of the articles is shown in Figure 1. Of the 557 identified articles, a total of 17 studies met the inclusion criteria.^[1-3,15,17-22,24-30] The general characteristics of the included studies are shown in Table 1. Of the 17 studies included, 5 were Level III evidence^[1,24,26-28] and 12 were Level IV.^[2,3,15,17-22,25,29,30] Of the Level III evidence comparative studies, 1 compared partial meniscectomy with pull-out suture repair^[26] and 1 compared conservative treatment with pull-out suture repair.^[27] Another 2 studies reported the outcomes of the subgroup analysis after MMPRT repair.^[1,28] The remaining 1 study compared the clinical and radiological outcomes between groups with partial meniscectomy and conservative treatment.^[24] Of the Level IV case series studies, 6 reported the outcomes of the MMPRTs repair,^[2,15,17,18,29,30] 3 reported the outcomes of conservative treatment for MMPRTs,^[21,22,25] and the remaining 3 reported outcomes of partial meniscectomy for MMPRTs.^[3,19,20]

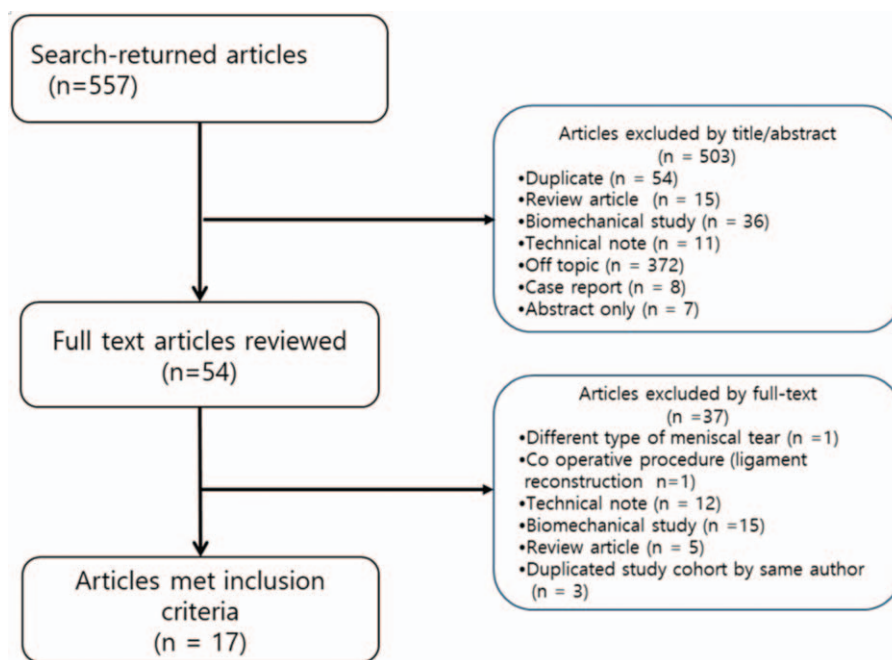


Figure 1. Flowchart of articles during selection process in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines.

Table 1

General characteristics of the studies.

Study	Study design	Level of evidence	mCMS (No. of each group)	No. of patients	Mean age,	Mean follow-up, mo	Repair technique
Meniscus repair							
Lee et al ^[15] 2009	Case series	IV	67	21	51.2 (23–58)	31.8 (24–48)	Pull-out suture (simple stitch)
Kim et al ^[1] 2011	Prospective comparative study (pull-out vs suture anchor)	III	80	45 (22/23)	53.2 (pull-out) 52.8 (suture anchor)	25.9 (pull-out) 24.8 (suture anchor)	Pull-out suture (vertical mattress) vs. Suture anchor
Seo et al ^[18] 2011	Case series	IV	60	11	55.4 (49–62)	13.4 (10–22)	Pull-out suture (simple stitch)
Nha et al ^[30] 2011	Case series	IV	62	31	53.4 (23–70)	38 (27–60)	Double vertical suture
Moon et al ^[17] 2012	Case series	IV	70	51	59 (45–72)	33 (24–44)	Pull-out suture (simple stitch)
Jung et al ^[2] 2012	Case series	IV	65	13	53.2 (47–60)	30.8 (24–40)	Suture anchor
Lee et al ^{[26]*} 2014	Comparative study (MAS vs SS)	III	75	50 (25/25)	55.7 ± 10.6 (MAS) 56.5 ± 6.1 (SS)	24.1 ± 5.4 (MAS) 25.9 ± 6.1 (SS)	Modified Allen stitch vs. Simple stitch
Cho et al ^[29] 2014	Case series	IV	62	20	50.3	7.1	Pull-out suture (simple stitch)
Ahn et al ^[27] 2015	Comparative study (repair vs conservative)	III	60	25	55.56 ± 7.54	17.43 ± 4.07	Pull-out suture (vertical mattress)
Chung et al ^[26] 2015	Comparative study (repair vs meniscectomy)	III	76	37	55.5 ± 7.1	72	Pull-out suture (simple stitch)
Meniscectomy							
Bin et al ^[20] 2004	Case series	IV	60	96	56.3 (31–77)	28.3 (12–52)	
Ozkoc et al ^[3] 2008	Case series	IV	72	70	55.8 (38–72)	56.7 (8–123)	
Han et al ^[19] 2010	Case series	IV	66	46	59 (48–85)	78 (60–103)	
Chung et al ^[26] 2015	Comparative study	III	76	20	55 ± 14 (M)	67.5 (M)	
Krych et al ^[24] 2018 [†]	Retrospective comparative study (M vs C)	III	60	52 (26/26)	54.7 ± 9.0 (M) 55.8 ± 7.9 (C)	66.0 ± 22.8 (M) ND (C)	
Conservative							
Lim et al ^[21] 2010	Case series	IV	66	30	59 (51–65)	36 (24–51)	
Neogi et al ^[22] 2013	Case series	IV	66	33	55.8 (50–62)	35 (26–49)	
Ahn et al ^[27] 2015	Comparative study	III	60	13	62.30 ± 7.17	18.40 ± 4.64	
Krych et al ^[25] 2017	Case series	IV	72	52	58 ± 10	62 ± 30	

C = conservative, M = meniscectomy, MAS = modified Mason Allen Stitch, mCMS = modified Comemann Methodology Score, SS = simple stitch.

* Simple stitch group^[29] was included in a larger series^[26] which was included in this systematic review. The data from only Mason Allen Stitch group were used for evaluation of mean score across the studies in this systematic review.

† Control group^[24] (conservative treatment group) was included in a larger series,^[25] which is included in this systematic review. The data from only meniscectomy group were used for evaluation of mean score across the studies in this systematic review.

3.2. Quality Assessment

The mean modified Coleman Methodology Score was 67 (range 60–68). The corresponding values for each study are shown in Table 1. In the section A, the average score for the study size was 5.6; the average score for the mean follow-up, number of procedure, type of the study, diagnostic certainty, surgery description and rehabilitation description were 4.2, 10, 0.6, 5, 5, 4.7, respectively. In the section B, the average score for the outcome criteria, the procedure for outcome and the selection process were 10, 6.9, 15, respectively.

3.3. Data Abstraction

3.3.1. General. In total, 655 patients (665 cases) were enrolled in this systematic review. Of these, 272 patients (279 cases) (42% of total cases in this review) underwent MMPRT repair in 10 of the reviewed studies.^[1,2,15,17,18,26–30] The remaining 383 patients (386 cases) (58%) were treated using the nonrepair strategy in 9 of the reviewed studies (partial meniscectomy or conservative treatment).^[1,3,19–22,24,25,27] The mean age and the mean follow-up period of the cases in which the patients underwent MMPRT repair across all studies were 54.7 years and 32.5 months, respectively. The mean age and the mean follow-up period in the cases in which patients underwent nonrepair treatment across all studies were 57.0 years and 49.3 months, respectively. Of the nonrepair of MMPRT cases, the mean age and follow-up period were 56.4 years and 51.7 months in the meniscectomy group (in 258 cases), respectively, and those in the conservative treatment group (in 128 cases) were 58.1 years and 44.5 months, respectively.

3.3.2. Comparative studies between non-repair and repair of MMPRTs. Two studies directly compared the clinical outcomes between groups with repair and nonrepair of MMPRT.^[26,27] Among these studies, 1 compared clinical outcomes between groups of conservative treatment and pull-out suture repair with a mean of 17.4 months follow-up^[27]. Another study compared the outcomes of partial meniscectomy with pull-out suture repair with a minimum of 5 years' follow-up.^[26]

3.3.3. Studies for repair only. Six case series^[2,15,17,18,29,30] and 2 comparative studies^[1,28] reported the outcomes of MMPRT repair. Of the comparative studies, 1 prospectively compared the clinical outcomes between pull-out and suture anchor repair,^[1] whereas another compared the outcomes between a modified Mason Allen stitch and a simple stitch.^[28] For this study, we only chose data for the Mason Allen stitch group because data of simple stitch groups were included in another study which is included in this systematic review.^[26] In terms of the repair technique, in all studies except 4, the pull-out with simple stitch technique was used: 1 study used pull-out with the Mason Allen stitch technique,^[28] 2 studies used suture anchor technique,^[1,3] and the remaining study used a double vertical suture with open technique.^[30]

3.3.4. Studies for non-repair only. The outcomes of meniscectomy for MMPRT were reported in 3 studies,^[3,19,20] whereas in another 3 studies, outcomes of conservative treatment were also reported.^[21,22,25] One study reported outcomes after meniscectomy compared with those after conservative treatment with a minimum 2-year follow-up.^[24]

3.4. Patient selection criteria based on index arthrosis

3.4.1. Repair group. In terms of index arthrosis in the MMPRT repair group, the KL grade was used for 9 of the 10 studies (228

cases, 82% of repair group).^[1,2,15,18,26–30] Of these, 91% of the MMPRT repair treatments were performed in patients with KL grade 2 or <2 (208/228 cases). Cartilage status in the medial femoral condyle confirmed by MRI or arthroscopy was reported in 9 of the 10 studies (266 cases, 95% of repair group).^[1,15,17,18,26–30] Of these 9 studies, 79% (210/266 cases) were graded as II or less than II.

Baseline degree or indication of lower limb alignment was reported in 8 of the 10 studies (227 cases, 81.3% of repair group).^[1,2,17,18,26–29] Of the 8 studies, the number of the patients according to the degree of varus alignment was available in 7 (202 cases, 74% of repair group).^[1,2,17,18,26,28,29] Among these 202 cases, repair was indicated for the patients with mild varus malalignment: (1) <3 or 5 degree; weight bearing line crossing of >25% of the tibial width; and severe malalignment was excluded) in 164 of the 202 cases (81%). However, among these 164 cases, 5 had >3 or 5 degree varus alignment and concurrent high tibial osteotomy was performed.^[2,18] The initial patient selection criteria regarding meniscus extrusion was reported in 5 studies of the 10 studies (152 cases, 54% of repair group).^[1,17,18,27,29] Of these 5 studies, 3 (121/152 cases, 80%) reported that the mean index meniscal extrusion was 3.73 mm. In the other 2 studies (31/152 cases, 20%), repair was indicated in the patients with less than 3 or 4.5 mm of meniscal extrusion, respectively.^[18,29]

3.4.2. Nonrepair group. The number of the patients according to the KL grade was available in 7 studies (238 cases, 62% of nonrepair group).^[1,3,19,21,22,24,27] Among these 7 studies (238 cases), nonrepair treatment (partial meniscectomy) was indicated for the patients with KL grade 3 or <3 in 2 studies (96/238 cases, 40%).^[3,24] Of the remaining 5 studies (142 cases), 135 patients (57%/238 cases in 7 studies)^[19,21,22,26,27] could be categorized into a mild arthrosis group (equal or less than KL grade 2). Cartilage status in medial femoral condyle confirmed by MRI or arthroscopy was reported in 5 of the 10 studies (245 cases, 63% of nonrepair group).^[3,19,20,26,27] Of these 5 studies, 40% (97/242 cases) were graded as II or less than II.

Patient selection criteria regarding lower limb alignment was reported in 5 of 9 studies (192 cases, 61% of nonrepair group).^[20–22,26,27] Of these 5 studies, 179 of 192 cases (93%) in 4 studies^[20–22,26] showed mild varus alignment: <5 m; 30% medial tibial condyle deviation of mechanical axis; and severe malalignment was excluded). In the remaining 1 study, only mean varus alignment was available (3.4); however, categorization of the patients according to lower limb alignment was not provided.^[27] Patient selection criteria regarding meniscus extrusion were reported in 3 of 9 studies (63 cases, 16% of nonrepair group).^[21,25,27] Of these 3 studies, the mean meniscus extrusion was 3.65 mm in 1 study^[27] and another study reported that 57% of the cases showed meniscus extrusion of >3 mm.^[21] The remaining 1 study^[25] reported that 79% of the cases had meniscus extrusion with no specific amount provided.

Table 2 shows the details of the patient selection criteria based on index arthrosis.

3.5. Functional outcomes

The Lysholm score was used as the functional knee scoring system for 15 of the total 17 studies.^[1–3,15,17–22,24–30] The IKDC SKF score was used for 7 of these 17 studies.^[1,24–28,30] The HSS score was used to assess the knee function in 4 studies.^[1,15,18,29]

Table 2
Patient selection criteria.

Study	Patients selection criteria based on baseline arthrosis characteristics		
	KL grade	Cartilage status (medial femoral condyle)	Varus alignment
Meniscus repair			
Lee et al ^[15] 2009	≤ 3 3/5/9/4/0 (0/1/2/3/4)	≤III (grade III: 9)	ND
Kim et al ^[1] 2011	≤2	≤III (grade III: 6)	Excluded malignment
Seo et al ^[7] 2010	≤2	≤II	Varus alignment <3 degree
Nha et al ^[30] 2011	≤2	≤II	
Moon et al ^[17] 2012	ND	I/II/III/IV (0/1/7/10/4)	33 cases: varus alignment <5 18 cases: varus alignment >5
Jung et al ^[2] 2012	≤2	ND	Varus alignment <3 degree
Lee et al ^[28] 2014	≤3 0/10/13/2/0 (0/1/2/3/ 4 in MAS group)	≤III 2/19/4/0 (I/II/III/IV)	Asymmetric varus alignment <3 degree
Cho et al ^[29] 2014	≤2	≤II	Wt. bearing line crossing >25% of tibial width
Ahn et al ^[27] 2015	11/14 (1,2/3,4)	16/9 (I, II/III, IV)	Median varus alinment: 4.62 degree
Chung et al ^[26] 2015	≤2	≤III (grade III: 14)	Varus alignment <5 degree
Meniscectomy			
Bin et al ^[20] 2004	ND	0/II/III/IV (5/11/11/23/46)	Excluded varus malalignment
Ozkoc et al ^[9] 2008	≤2	II/III/IV (28.5/28.5/42.8%)	ND
Han et al ^[19] 2010	≤20	All but 4 (IV) ≤III	ND
Chung et al ^[26] 2015	≤20	≤III (grade III: 8)	Varus alignment <5 degree
Krych et al ^[24] 2018	≤2	ND	ND
Conservative			
Lim et al ^[21] 2010	≤2	ND	No varus
Neogi et al ^[22] 2013	≤2	ND	≤30% medial tibial condyle deviation of MA
Ahn et al ^[27] 2015	6/7 (1,2/3,4)	4/9 (I, II/III, IV)	Median varus alignment: 3.44 degree
Krych et al ^[25] 2017	Median 1.5	ND	ND

KL = Kellgren Lawrence, ND = not described.

Based on 2 studies that compared clinical outcomes between groups with repair and non-repair of MMPRT,^[26,27] the MMPRT repair group showed significantly better final Lysholm and IKDC scores than the nonrepair group.

3.5.1. Lysholm score. The mean Lysholm score for the patients who underwent repair of MMPRTs across all studies improved from preoperative 54.7 to postoperative 85.6 in 279 cases (100% of the repair group, 10 of the 10 studies).^[1,2,15,17,18,26-30] Of the 308 cases (80% of nonrepair group, 7/9 studies) in the nonrepair group,^[3,19-22,26,27] 295 cases (96%) exhibited a significantly improved score at final follow-up compared to the initial score (from mean 47.7 to 74.6). On the contrary, a slightly decreased score was reported in 13 cases (4%) at final follow-up after conservative treatment compared to initial data (from mean 52.6 to mean 51.1).^[27] Among the 295 cases in the nonrepair group that showed a significantly better final Lysholm score, 232 cases (79%) were in the partial meniscectomy group^[3,19,20,26] and 63 cases (21%) were in the conservative treatment group.^[21,22]

3.5.2. IKDC SKF score. The mean IKDC SKF score in the studies on the repair of MMPRTs was available in 163 of 279 cases (58% of repair group) in 5 studies,^[1,26-28,30] which improved from 50.1 to 80.1. The mean IKDC SKF scores in the nonrepair group were available in 33 of 386 cases (9% of nonrepair group) in 2 studies, and these also improved from 40.6 to 56.8.

3.5.3. HSS score. The mean HSS score was available in 97 of 279 cases (35%, in 5 studies) regarding MMPRT repair and improved from 52.8 to 90.2.

Table 3 shows the results of the functional outcome scores for each study.

3.6. Progression of arthrosis

The progression of the KL grade based on the weight-bearing radiograph images was evaluated in 436 cases and in 11 studies of the total 17 studies^[1,3,15,19,21,22,24-26,28,30] (61% of total cases: 159 cases in the repair group^[1,15,26,28,30] and 277 cases in the nonrepair group^[3,19,21,22,24-26]). In addition, the progression of degeneration in the articular cartilage of the femoral condyle was determined by MRI scan or arthroscopy in only 4 studies and 98 cases (15% of total cases).^[1,17,18,28] Of these 4 studies, the progression of cartilage degeneration based on pre- and postoperative MRI or arthroscopy was noted in 16 of the 98 cases (16%). Four studies reported outcomes of the MMPRT repair. The outcomes after non-repair of MMPRT based on MRI or arthroscopy was unavailable.

One study compared radiologic outcomes between groups with repair and meniscectomy for MMPRT,^[26] suggesting that MMPRT repair resulted in significantly less progression of KL grade compared to the meniscectomy group.

Table 3
Functional outcome.

Study	Mean Lysholm score		Mean HSS score		Mean IKDC SKF score	
	Pre	Post	Pre	Post	Pre	Post
Menisceus repair						
Lee et al ^[15] 2009	57 (42–78)	93.1 (85–100)*	61.1 (52–74)	93.8 (85–100)*	ND	ND
Kim et al ^[1] 2011	54.3 ± 4.1 (Pull-out) 55.4 ± 4.1 (anchor)	92.5 ± 5.5* (Pull-out) 93.2 ± 1.2 (anchor)	55.3 ± 5.1 (Pull-out) 54.7 ± 5.1 (anchor)	91.7 ± 3.4* (Pull-out) 93.8 ± 2.2* (anchor)	57.3 ± 4.1 (Pull-out) 58.5 ± 2.1 (anchor)	91.8 ± 4.6* (Pull-out) 93.4 ± 3.2* (anchor)
Seo et al ^[7] 2010	56.1 (41–71)	83 (69–91)*	64.1 (50–76)	87.4 (77–95)*	ND	ND
Nha et al ^[9] 2011	68 (61–79)	89 (83–97)*	ND	ND	66 (60–77)	88 (81–96)*
Moon et al ^[17] 2012	48.3 ± 13.7	83.2 ± 16.1*	ND	ND	ND	ND
Jung et al ^[2] 2012	69.1 (53–91)	90.3 (75–100)*	ND	ND	ND	ND
Lee et al ^[28] 2014	57.4 ± 7 (MAS)	87.6 ± 6* (MAS)	ND]	ND	44.1 ± 5.5 (MAS) 43.5 ± 9.3 (SS)	78.4 ± 7.3* (MAS) 77.7 ± 7.5* (SS)
Cho et al ^[29] 2014	56.1 ± 8.3 (SS)	85.4 ± 3.6* (SS)	33.5 (25–46)	82.2 (63–95)*	ND	ND
Ahn et al ^[27] 2015	34.7 (31–40)	75.6 (51–89)*	ND	ND	37.30 ± 14.63	59.18 ± 22.89*
Chung et al ^[26] 2015	57.32 ± 15.56	73.44 ± 21.58*	ND	ND	40.1 ± 7.9	73.7 ± 11.1*
Chung et al ^[24] 2018 [†]	52.3 ± 9.1	84.3 ± 12.1*	ND	ND	ND	ND
Meniscectomy						
Bin et al ^[20] 2004	68 (40–91)	83.4 (60–100)*	ND	ND	ND	ND
Ozkoc et al ^[3] 2008	53 (24–95)	67 (20–100)*	ND	ND	ND	ND
Han et al ^[19] 2010	72 (62–78)	77 (70–98)*	ND	ND	ND	ND
Chung et al ^[26] 2015	51.0 ± 7.3	62.8 ± 24.9*	ND	ND	37.9 ± 6.8	49.3 ± 23.5*
Kych et al ^[24] 2018 [†]	ND	ND	ND	ND	ND	67.8 ± 19.8 (12/26 in meniscectomy group) 57.8 ± 23.4 (17/26 in conservative group)
Conservative						
Lim et al ^[21] 2010	67 (40–78)	80 (72–96)*	ND	ND	ND	ND
Neogi et al ^[22] 2013	56 (32–73) SD ± 8	73 (40–91) ± 7*	ND	ND	ND	ND
Ahn et al ^[27] 2015	51.62 ± 23.09	51.15 ± 422.67	ND	ND	44.73 ± 12.75	45.85 ± 14.00
Kych et al ^[24] 2017 [†]	ND	ND	ND	ND	ND	61.2 ± 21 (36/52)

HSS = Hospital for Special Surgery, IKDC SKF = International Knee Documentation Committee Subjective Knee Form, MAS = modified Mason Allen Stitch, Pre: preoperative, Post: postoperative, SS = simple stitch.

* Denotes statistical significance ($P < .05$) compared with preoperatively.

† This IKDC score was evaluated for the patients who did not undergo arthroplasty.^[24,25] And preoperative IKDC score was not available in these studies.^[24,25] Hence these data were excluded in mean IKDC score across the study.

Table 4**Progression of arthrosis.**

Study	Progression of KL grade
Meniscus repair	
Lee et al ^[15] 2009	Progression in 1/21 (5%) (no <i>P</i> value provided)
Kim et al ^[1] 2011	No significant progression in both groups (pull-out and suture anchor group)
Nha et al ^[30] 2011	Progression in 1/25 (4%) (no <i>P</i> value provided)
Lee et al ^[28] 2014	Significantly worsening in SS group (<i>P</i> = .008) Progression (%): 8% (MAS) vs 28% (SS) (n.s)
Chung et al ^[26] 2015	Significantly worsening in both group (all <i>P</i> < .001), but significantly less in repair group than Meniscectomy group. progression (%): 68% (R) vs 100% (M) (<i>P</i> = .005)
Meniscectomy	
Ozkoc et al ^[3] 2008	Significantly worsening: from average 2 (0–3) to average 3 (2–4) (<i>P</i> < .001)
Han et al ^[19] 2010	Progression in 16/46 (35%) (no <i>P</i> value provided)
Chung et al ^[26] 2015	Significantly worsening (<i>P</i> < .001).
Krych et al ^[24] 2018	Significantly worsening in M group: from median KL (1) to KL (2) (<i>P</i> < .001) Worsening in C group: From median KL 1 to KL 3 (no <i>P</i> value provided) Progression to arthroplasty (%): 54.0% (M) vs 34.6% (C) (n.s)
Conservative	
Lim et al ^[21] 2010	Two of 10 patients with KL 2 progressed to KL 3 at last f/u (No <i>P</i> value provided)
Neogi et al ^[22] 2013	Significantly worsening: From median KL1 to KL2 (<i>P</i> = .0021)
Krych et al ^[25] 2017	Significantly worsening: From mean KL 1.5 to KL 2.4 (<i>P</i> < .001) Progression to arthroplasty (%): 31%

C = conservative, KL = Kellgren Lawrence, M = meniscectomy, MAS = modified Mason Allen Stitch, SS = simple stitch, n.s = not significant.

3.6.1. Repair group. For the KL grade progression in the repair group, the percentage of KL grade progression in the study group was available in 114 cases (41% of repair group).^[15,26,28,30] Of these 114 cases, 29 (25%) exhibited KL grade progression by at least 1 degree with a mean follow-up of 45.4 months.

We observed that after a minimum 2-year follow-up of MMPRT repair, no significant worsening or minimal progression (<8% of the patients, no *P* value provided)^[15,28,30] was observed. However, with a minimum 5-year follow-up, 68% of the repair group showed KL grade progression and KL grade at final follow-up were significantly poorer than the index arthrosis (*P* < .001).^[26]

3.6.2. Nonrepair group. For the KL grade progression in the nonrepair group, 96 cases and 3 studies (25% of nonrepair group) were available that provided the percentage of KL grade progression.^[19,21,26] Of these 96 cases, the overall percentage of patients who exhibited progression of KL grade was 40% (38 cases) with a mean follow-up period of 62.7 months. Of these 3 studies, 2 reported the outcomes of meniscectomy (55% showed KL grade progression),^[19,26] and the remaining 1 study reported the outcomes of conservative treatment (7% showed KL grade progression).^[21]

In addition, statistically significant worsening of KL grade compared with the baseline was reported in 5 studies.^[3,22,24–26] Of these 5 studies, 2 were concerned with meniscectomy,^[3,26] and the remaining 3 studies were concerned with conservative treatment.^[22,24,25] The radiologic outcomes in terms of KL grade progression are summarized in Table 4.

4. Discussion

Based on the available Lysholm score across the studies in this systematic review, good to fair functional outcomes were obtained after both repair and nonrepair treatment. The final

mean Lysholm score after repair treatment was 85.6 points, which is considered a good result. Even though the results were somewhat heterogenous, the nonrepair group also showed fair results (mean Lysholm score of 74.6).

We observed that patient selection is important to obtain functional improvement after treatment, regardless of the treatment method. Hence, the results in this systematic review need to be carefully interpreted using subgroup analysis according to patient selection criteria.

Based on the clinical data available in this study, most MMPRT repairs were performed in patients with mild arthrosis (KL grade ≤2, 91% in 9 studies among a total of 10 studies), mild varus alignment (81% in 7 studies among the total 10 studies), and a chondral injury grade ≤grade 2 (79% in 9 among the total 10 studies).^[1,2,15,17,18,26–30] The case numbers available for patient selection criteria were limited in the nonrepair group. The percentage of patients with mild arthrosis (KL grade ≤2) was 57% in 7 among a total 9 studies.^[19,21,22,26,27] Interestingly, the percentage of patients with mild chondral injury was only 40% in 4 studies among the total 9 studies,^[3,20,26,27] implying that the nonrepair group may have more advanced arthrosis at the baseline because meniscectomy or conservative treatment was usually performed in patients with irreparable torn meniscal end.^[21,22,26,27,31]

Severe cartilage degeneration (outerbridge III and IV) as well as severe varus malalignment was considered to be a poor prognostic factor after treatment, regardless of the treatment method.^[14,17,19,27]

With regard to clinical outcomes of conservative treatment for MMPRTs, we observed a conflict in the clinical outcomes between 2 studies (Lim et al^[21] and Neogi et al^[22]) that reported relatively satisfactory outcomes and another 2 studies (Ahn et al^[27] and Krych et al^[25]) that exhibited high failure rate or no functional improvement. We believe this disparity may derive from the difference in the inclusion criteria. Lim et al^[21] and

Neogi et al^[22] only included patients with no varus malalignment and relatively early osteoarthritis (KL grade <2). On the contrary, Krych et al^[25] included patients with moderate and severe osteoarthritis (KL grade 3 or 4). In Ahn et al's study,^[27] a considerable number of patients had severe arthrosis and severe chondral injury (54% had KL grade 3 or 4 arthrosis and 69% had severe chondral injury [outerbridge III or IV]).

As mentioned above, broad consensus has been shown that a higher degree of baseline osteoarthritis may have a negative effect on the final clinical outcomes. In fact, Krych et al^[24,25] suggested a higher baseline KL grade (≥ 2) was a risk factor for conversion to arthroplasty.

With regard to clinical outcomes after meniscectomy, most of the studies (4 of a total of 5 studies) reported functional improvement with 2 to 6 years of follow-up.^[3,19,20,26] However, 2 studies^[19,24] concluded unfavorable results due to a low percentage of pain improvement (56%), low patient satisfaction (67%), and high failure rate (77%, conversion to arthroplasty or severely abnormal IKDC score of <75.4 points). However, these 2 studies did not describe the baseline lower limb alignment which may affect the clinical outcomes.

With regard to progression of arthrosis, it is difficult to draw a solid conclusion because radiologic results were infrequently reported. However, follow-up studies with a mean of 5 years showed that arthritic change could not be prevented by nonrepair or even repair treatment.^[24–26] Chung et al^[26] reported a significant KL grade progression (68%) at a minimum of 5 years' follow-up after the repair of MMPRTs. They also suggested grade 3 chondral lesions were a poor prognostic factor in terms of KL grade progression.^[31] Krych et al reported that medial KL grade progressed significantly from 1.5 ± 0.7 at the baseline to 2.4 ± 1.0 at the 4.3-year mean follow-up after conservative treatment.^[25] They also reported that significantly more patients had KL grade 2 arthritis or higher at final follow-up (78%) compared to the baseline (51%). One study compared the clinical and radiological outcomes of patients treated with meniscectomy to a matched group treated nonoperatively.^[24] No significant difference was reported in terms of the final KL grade, suggesting that partial meniscectomy for complete MMPRTs could not prevent arthritic progression.

To summarize, satisfactory clinical outcomes would be expected in patients with no or mild varus limb malalignment, mild chondral damage, and no or early radiological arthrosis after MMPRT repair or nonrepair treatment options. If the patients showed willingness to undergo surgical repair for MMPRTs, if they followed rehabilitation protocol, and if their torn meniscal end was sufficiently healthy to withstand suture loading, root repair would be recommended based on the better clinical outcomes than the nonrepair treatment group reported in this review. However, the meniscectomy or conservative treatment options could still be considered in some selected patients with good prognostic factors and who are not suitable for root repair due to the poor quality of their meniscal tissue or being inactive or not willing to undergo surgical treatment.

This systematic review has several limitations. First, this review only presented 2 direct comparative studies. One compared clinical outcomes between groups of conservative treatment and repair. Another study compared the outcomes of partial meniscectomy with repair. The other studies consist of heterogeneous case series or comparative studies describing subgroup analysis. Hence, it is unable to combine results from different studies that compared same techniques. Furthermore,

all studies included in this review were not randomized. Due to this small sample size, as well as the outcome parameter heterogeneity, it is not possible to evaluate overall meaningful statistical analysis across the clinical and radiological outcomes of the studies. Second, the quality of all the studies included only indicated levels III and IV evidence, implying that many of the studies included have potential selection bias which may affect the clinical and radiological outcomes. Third, due to the lack of long-term follow-up studies, it is not possible to evaluate long-term prognosis after repair or nonrepair of MMPRTs. The mean follow-up period across all the included studies was 42.2 months, whereby only short- and mid-term results were available in this review. The progression of arthrosis, change of symptoms, and functional knee score may be negatively influenced by the long-standing biomechanical alteration of the knee joint. Fourth, none of the patients' inclusion criteria was uniform, which biased the results of the studies. However, regardless of the treatment options including repair or nonrepair of MMPRTs, we observed broad consensus across the studies included that showed good prognostic factors.

5. Conclusions

In general, MMPRT repair led to significant improvement in clinical outcomes, based on the clinical outcomes across the study. However, the nonrepair group also showed symptomatic relief in some selected cases, despite the somewhat heterogeneous results. Given the subgroup analysis for the functional results reported in this review, strict patient selection is important to obtain satisfactory clinical outcomes, regardless of the selected treatment option.

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