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Degenerative medial meniscus posterior root tear and non-root tear do not show differences in joint survival and clinical outcome after partial meniscectomy

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Abstract

Purpose No comparative studies of outcomes between degenerative medial meniscus posterior root tear (MM PRT) and non-root tear (NRT) have been conducted. This study aimed to compare joint survival and clinical outcome between MM PRT and MM NRT after partial meniscectomy with proper control of confounding factors.

Methods One hundred and ten patients each in MM PRT and MM NRT groups who underwent arthroscopic partial meniscectomy were retrospectively evaluated through propensity score matching. Joint survival was assessed on the basis of surgical and radiographic failures. Clinical outcomes were assessed using the Lysholm score.

Results The confounding variables were well balanced between the groups, with standardized mean differences of < 0.2 after propensity score matching. Failures occurred in 30 (27.3%) and 35 patients (31.8%) in the MM PRT group and MM NRT group, respectively. The estimated mean survival times were 12.5 years (95% confidence interval [CI] 11.5–13.5) and 11.7 years (10.7–12.7), respectively. There were no significant differences in the overall survival rate and Lysholm score between the two groups (n.s.).

Conclusion In middle-aged patients with degenerative MM PRT, joint survival and clinical outcome showed comparable results with those with MM NRT after partial meniscectomy. Arthroscopic partial meniscectomy is one of the effective treatments for MM PRT with consideration of various patient factors.

Level of evidence III.

Keywords Degenerative medial meniscus root tear · Arthroscopic partial meniscectomy · Joint survivorship · Clinical outcome

Introduction

Middle-aged patients with degenerative medial meniscus (MM) tear often experience mechanical symptoms such as painful clicking, catching, pain on squatting, and giving way. These symptoms make it difficult for affected persons to perform daily activities, which leads to a low quality of life. Arthroscopic partial meniscectomy (APM) is an effective surgical treatment for patients with symptomatic meniscal tears who do not respond to conservative management [8, 19, 27, 38]. APM has some benefits for relieving symptoms and helping patients return to daily activities [13, 15, 28]. However, the meniscus is an important structure for axial load distribution and shock absorption in the knee joint [18]. Therefore, although removal of the meniscal fragment in case of a symptomatic tear can improve clinical symptoms, the surgeon should consider

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that meniscectomy can lead to arthritic changes such as joint space narrowing, formation of osteophytes, and femoral and tibial bony changes [20, 44, 46].

MM posterior root tear (MM PRT) in itself is considered similar to the state of total meniscectomy. A complete detachment of the posterior root causes disruption of circumferential meniscal fibers. Thus, the MM cannot provide the hoop stress mechanism, which is an important function for distributing axial loads. Thereby, MM PRT can cause meniscal extrusion and contribute to the rapid progression of arthritic change [1, 31, 32, 42]. A biomechanical study also showed that MM PRT resulted in increasing peak contact pressure in the knee joint as compared with the intact knee, and no significant difference in peak contact pressure was observed between MM PRT and the state of total medial meniscectomy [3]. Although acute medial meniscus root tear in young patients should be repaired for restoration of knee biomechanics, most MM PRTs observed in middle-aged patients were degenerative tears in clinical practice and had preexisting medial knee osteoarthritis [24, 29, 40, 41, 45]. Therefore, the best degenerative MM PRT treatment is still controversial. Some studies reported poor clinical results regardless of the treatment (partial meniscectomy or conservative treatment) for MM PRT [11, 35, 36, 48].

For these reasons, MM PRT was generally considered to have a worse prognosis than MM non-root tear (MM NRT). As mentioned earlier, MM PRT clearly affected the progression of osteoarthritis and disruption of joint biomechanics. Even though mechanical symptoms could be improved after partial meniscectomy in both MM PRT and MM NRT during a short postoperative period, we thought that APM for degenerative MM PRT would have worse clinical courses of joint survival and clinical outcomes than those for degenerative MM NRT. However, the lack of proper control of confounding factors made comparison of the outcomes after APM between MM PRT and MM NRT more difficult. If various confounding factors are properly controlled, determining the effect of tear morphology on long-term outcomes in case of degenerative MM tears after partial meniscectomy, especially by comparing MM PRT and MM NRT, would be helpful. To our knowledge, no previous comparative studies of the effect of partial meniscectomy on long-term joint survival according to the type of degenerative MM tear have been conducted.

The purpose of this study was to compare the joint survival and clinical outcome between degenerative MM PRT and MM NRT with partial meniscectomy after the proper control of confounding factors. It was hypothesized that degenerative MM PRT would show worse results than degenerative MM NRT in terms of joint survival and clinical outcome after arthroscopic partial meniscectomy.

Materials and methods

Patients who underwent APM for degenerative MM tears between January 1999 and July 2012 were retrospectively evaluated using prospectively collected data. Patients with degenerative MM tear identified on preoperative magnetic resonance imaging, and persistent or aggravating mechanical symptoms for at least 3 months despite conservative treatment (non-steroidal anti-inflammatory drugs and muscle strengthening exercise) were indicated for partial meniscectomy. The contraindications for partial meniscectomy were evidence of varus thrust gait on physical examination, advanced medial osteoarthritis such as joint space obliteration or Kellgren–Lawrence grade 4 osteoarthritic change on standing radiography, and diffuse full-thickness cartilage wear of the medial compartment on preoperative magnetic resonance imaging. The inclusion criteria for the study were as follows: (1) age of > 40 years, (2) follow-up period of > 4 years, and (3) sole operation for degenerative MM tear. The exclusion criteria were as follows: (1) history of prior knee surgery (meniscus, cartilage, or ligament operation) on the affected knee; (2) traumatic tear of the medial meniscus with a recent history of knee trauma; (3) complex tear accompanied by both posterior root tear and non-root tear; (4) concurrent lateral meniscus tear; and (5) additional operative procedures such as chondroplasty, microfracture, and osteochondral autograft transplantation. A total of 453 patients who met the criteria were finally included in the study.

The 453 patients were divided into two groups according to the type of meniscus tear, which was confirmed with arthroscopic examination. The arthroscopic findings were recorded in a preformatted electronic document system [39]. Those with degenerative MM PRT with detached posterior root or a complete radial tear within 9 mm from the posterior bony root attachment were defined as the "MM PRT group" [37]. Those with other types of degenerative MM tear with intact posterior root attachment, such as a longitudinal-vertical, horizontal, radial, vertical flap, horizontal flap, or complex tear pattern, according to the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine classification of meniscal tears, were defined as the "MM NRT group" [4]. Thus, 288 patients were divided into the MM PRT group; and 165, into the MM NRT group.

To control for potential confounding variables, we matched the patients from the MM PRT and MM NRT groups through propensity score matching. This statistical method allowed us to perform a retrospective study with minimizing the interferences of covariates that mimicked the characteristics of randomized controlled trials [7]. We calculated propensity scores using logistic regression

analysis and considered the following variables: age, sex, body mass index (BMI), anatomical axis on a standing anteroposterior (AP) radiograph, cartilage status of the medial compartment (Outerbridge grade of the medial femoral condyle and medial tibia plateau), and follow-up period. Each patient in the MM PRT group was matched to a patient in the MM NRT group by matching the closest propensity score at a 1:1 ratio. Thus, 110 patients in each group were included in the study.

Although the mechanical axis measured on whole-leg standing radiographs reflected the accurate alignment of the knee, not all the patients underwent whole-leg standing radiography before surgery. Therefore, we measured the anatomical axis of the knee on 14 × 17-in AP standing radiographs as covariate for alignment [49]. The digital caliper tool available in the Picture Archiving and Communication System was used to measure the axis. The tool could measure the angle with a precision of 1°. The evaluation of the medial compartmental cartilage (medial femoral condyle and medial tibia plateau) was confirmed using the Outerbridge grading system by a single senior surgeon during arthroscopic examination. Postoperative radiographs and clinical scores were determined annually. Joint survival after partial medial meniscectomy was assessed on the basis of surgical and radiographic failures. Surgical failures were defined as any requirement for reoperations, including arthroscopic revision surgery for the MM (subtotal or total meniscectomy), realignment osteotomy, and total knee arthroplasty. Radiographic failure was defined as developing Kellgren–Lawrence grade 4 osteoarthritis on follow-up standing AP radiographs. The Kellgren–Lawrence grade was assessed by two senior orthopedic surgeons through a discussion. The clinical outcome was assessed and compared using Lysholm scores preoperatively and at the latest postoperative follow-up. The intra-observer and inter-observer reliability for measurements were analyzed. The intra-class correlation coefficient was 0.930, and the inter-observer correlation coefficient was 0.875 for the measurement of anatomical axis. The kappa value of the intra-observer agreement was 0.834, and that of the inter-observer agreement was 0.808 for the Kellgren–Lawrence grade. Therefore, the measurements by one rater were used for the statistical analyses.

All operations were performed by a single senior orthopedic surgeon. The goal of the operation for a meniscus tear was to sufficiently remove the torn meniscal fragment to resolve mechanical symptoms. Moreover, we attempted to leave an intact meniscus tissue as much as possible. Remnant meniscal tissue was trimmed to a semilunar shape. The remaining meniscal width was measured using a probe, and the resection left a meniscal width of > 3 mm with an intact peripheral rim was defined as partial meniscectomy. The remnant meniscus was evaluated by probing for a possible impingement that could cause mechanical symptoms. The patients were allowed to perform full range of motion and quadriceps setting exercises immediately after surgery. Early weight-bearing ambulation was allowed as necessary, and gradual muscle strengthening exercise was encouraged as soon as possible. This retrospective study was approved by our internal institutional review board (Asan Medical Center, project No. 2018-1179).

Statistical analysis

Statistical analyses were performed using the IBM SPSS Statistics version 18.0 software for Windows (SPSS Inc., Chicago, IL, USA) and R version 2.8.1 (R Foundation for Statistical Computing, Vienna, Austria). Continuous variables (age, BMI, anatomical axis, and follow-up period) were analyzed using the Student *t* test or Mann–Whitney *U* test. Categorical variables (gender and medial cartilage state) were analyzed using the Pearson Chi-square test. Propensity scores were calculated using a logistic regression analysis of the covariates (age, gender, BMI, anatomical axis on standing AP radiographs, cartilage state of the medial femoral condyle and medial tibial plateau, and follow-up period). Each patient in the MM PRT and MM NRT groups was matched depending on the nearest propensity score at a 1:1 ratio without replacement (greedy algorithm). The caliper was set to 0.2 of the standard deviation of the logit of the propensity score. Model classification ability was assessed using c-statistics ($c = 0.509$), and model calibration ability was assessed using the Hosmer–Lemeshow test ($p = 0.193$). To evaluate the balance before and after matching, we calculated the standardized mean difference for each covariate [5, 6]. Kaplan–Meier analysis and log-rank test were used to assess joint survival and compare the overall survival rate. A subgroup analysis of joint survival according to preoperative anatomical alignment and preoperative Kellgren–Lawrence grade (grade 0 or 1 vs grade 2 or 3) was performed. The preoperative anatomical alignment was classified as neutral (2°–10° valgus) or varus (< 2° valgus) [47]. The Student *t* test was used for comparing the modified Lysholm score. Post-hoc analysis of the Student *t* test results was performed to determine the statistical power using the G-power version 3.1.5 software. A Cohen medium effect size of 0.5, an alpha level of 0.05, and a sample size of 110 in an unpaired two-tailed *t* test suggested a power (1-beta) level of 0.958.

Results

Table 1 shows the patients' characteristics in the total and propensity-matched cases. All variables were well balanced, with a standardized mean difference of < 0.2. After matching, failures were found in 30 patients (27.3%) in the

Table 1 Characteristics of the patients who underwent arthroscopic partial medial meniscectomy before and after propensity score matching

Variables	Total no. of cases ($n=453$)				Propensity-matched cases ($n=220$)			
	MM PRT ($n=288$)	MM NRT ($n=165$)	SMD	p value	MM PRT ($n=110$)	MM NRT ($n=110$)	SMD	p value
Age, years (SD, range)	58.9 (7.6, 43 to 78)	53.9 (9.2, 41 to 74)	0.588	< 0.001	57.3 (6.8, 43 to 77)	57.6 (7.1, 41 to 74)	0.043	n.s
Gender, male/female (%)	24(8.3):264(91.7)	43(26.1):122(73.9)	0.483	< 0.001	11(10):99(90)	8(7.3):102(92.7)	0.097	n.s
BMI, kg/m^2 (SD, range)	26.2 (2.9, 19.0 to 38.3)	25.2 (3.1, 17.5 to 38.3)	0.346	< 0.001	25.4 (2.8, 19.0 to 32.9)	25.8 (3.1, 20.3 to 38.3)	0.131	n.s
Anatomical axis[a] ° (SD, range)	− 1.7 (2.8, − 10 to 5)	− 1.8 (3.0, − 9 to 10)	0.039	n.s	− 1.4 (3.1, − 10 to 5)	− 1.8 (2.9, − 10 to 5)	0.143	n.s
Follow-up period, years (SD, range)	9.2 (3.0, 4.4 to 17.2)	9.4 (3.3, 4.3 to 17.4)	0.051	n.s	9.3 (3.0, 4.9 to 16.5)	9.4 (3.3, 4.3 to 17.3)	0.041	n.s
Medial cartilage (outerbridge grade, n)								
MFC grade 0/1/2/3/4	1/16/26/126/119	5/49/27/41/43	0.831	< 0.001	0/10/15/43/42	0/9/17/41/43	0.066	n.s
MTP grade 0/1/2/3/4	20/27/17/78/146	0/2/35/76/52	0.861	< 0.001	0/0/13/44/53	0/0/9/50/51	0.145	n.s

MM PRT medial meniscus posterior root tear, *MM NRT* medial meniscus non-root tear, *SMD* standardized mean difference, *BMI* body mass index, *SD* standard deviation, *MFC* medial femoral condyle, *MTP* medial tibial plateau

[a]A negative value means valgus alignment, whereas a positive value means varus alignment

MM PRT group and in 35 patients (31.8%) in the MM NRT group. MM PRT group showed 20 cases of TKA conversion, 1 case of arthroscopic MM revision meniscectomy, and 9 cases of Kellgren-Lawrence grade 4 osteoarthritis at follow-up. The MM NRT group showed 24 cases of TKA conversion, 1 case of arthroscopic MM revision meniscectomy, and 10 cases of Kellgren–Lawrence grade 4 osteoarthritis at follow-up. The joint survival rate in the MM PRT group was 92.7% (95% confidence interval [CI] 86.0–96.3%) at 5 years and 76.3% (95% CI 64.6–84.6%) at 10 years. The joint survival rate in the MM NRT group was 87.2% (95% CI 79.4–92.2%) at 5 years and 78.4% (95% CI 67.9–85.9%) at 10 years. The 5- and 10-year joint survival rates between the two groups were not significantly different (n.s.). The estimated mean survival time was 12.5 years (95% CI 11.5–13.5%) in the MM PRT group and 11.7 years (95% CI 10.7–12.7%) in the MM NRT group. The overall survival rates in the MM PRT and MM NRT groups were analyzed using the log-rank test, and no significant difference was found between the two groups (n.s.; Fig. 1).

Subgroup analyses of joint survival according to anatomical alignment and Kellgren–Lawrence grade were performed (Table 2, Figs. 2 and 3). The 5- and 10-year joint survival rates and overall survival rate between the two groups were not significantly different (n.s.)

The clinical outcomes are shown in Table 3. The mean modified Lysholm score was improved from 63.5 ± 16.7 preoperatively to 83.7 ± 14.5 at the last follow-up in the MM PRT group ($p < 0.001$) and from 64.8 ± 13.4 preoperatively to 84.9 ± 14.2 at the last follow-up in the MM NRT group ($p < 0.001$). No significant differences in the preoperative and postoperative modified Lysholm scores and changes in the score were found between the two groups.

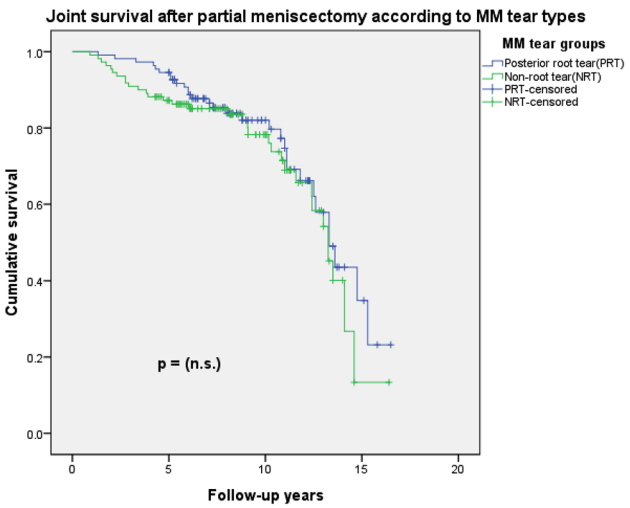

Fig. 1 Kaplan–Meier analysis of the joint survival of patients after partial meniscectomy between subgroups of medial meniscus (MM) tear. Terminal events were defined as cases that required any reoperation (including arthroscopic revision surgery for MM, realignment osteotomy, and total knee arthroplasty) and Kellgren–Lawrence grade 4 osteoarthritis on the follow-up radiograph

Table 2 Subgroup analyses of joint survival according to anatomical alignment and Kellgren–Lawrence grade

	MM PRT		MM NRT		*p* value
	5-years survival rate (95% CI)	10-years survival rate (95% CI)	5-years survival rate (95% CI)	10-years survival rate (95% CI)	
Anatomical alignment					
Neutral knee	96.4 (86.5–99.1)	90.2 (73.7–96.5)	90.5 (81.1–95.4)	87.0 (74.1–93.8)	n.s
Varus knee	88.9 (76.9–94.8)	63.4 (44.4–77.4)	77.0 (59.3–87.8)	54.7 (33.6–71.6)	n.s
KL grade					
KL 0 or 1	96.5 (89.5–98.9)	87.2 (74.7–93.8)	91.1 (79.9–96.2)	79.7 (46.7–93.4)	n.s
KL 2 or 3	79.2 (56.9–90.8)	46.7 (22.2–68.0)	81.3 (68.0–89.5)	63.5 (46.3–76.4)	n.s

MM PRT medial meniscus posterior root tear, *MM NRT* medial meniscus non-root tear, *CI* confidence interval, *KL* Kellgren–Lawrence

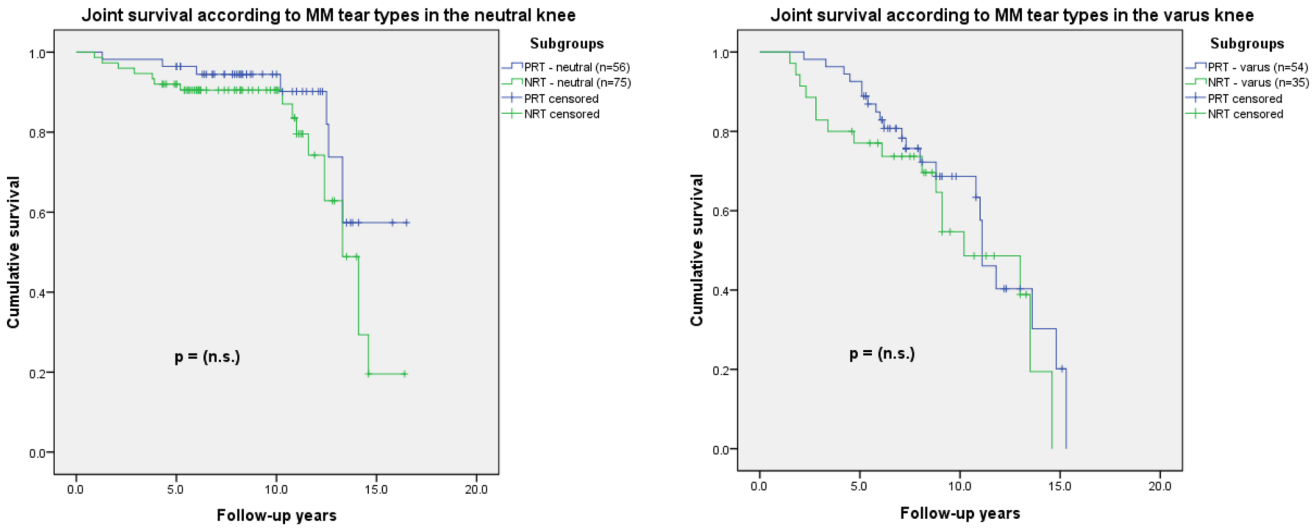

Fig. 2 Kaplan–Meier analysis of joint survival according to medial meniscus (MM) tear types and alignment

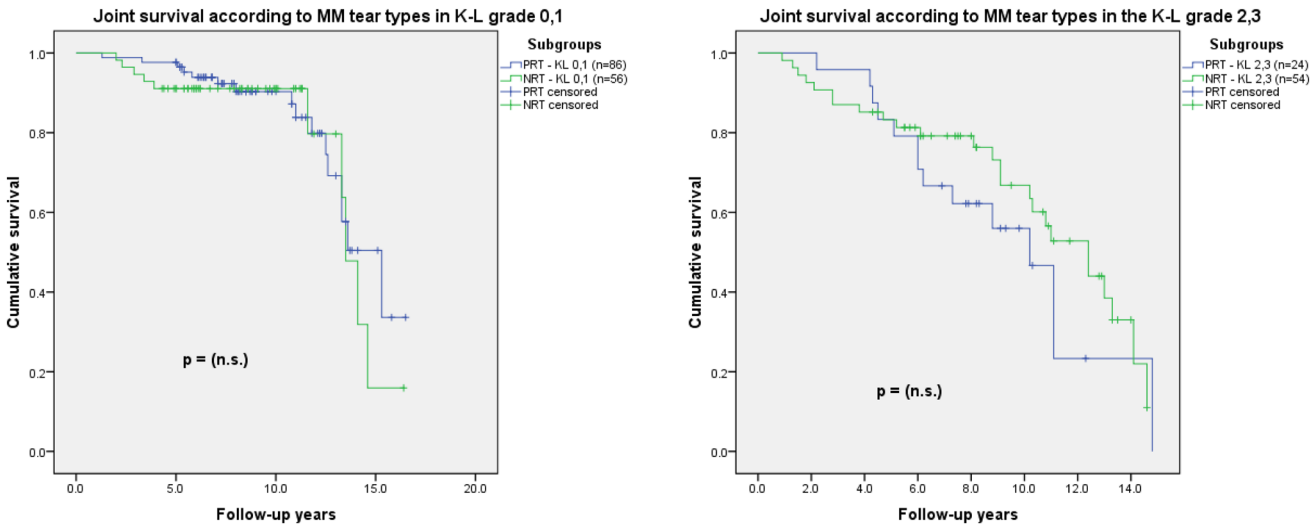

Fig. 3 Kaplan–Meier analysis of joint survival according to medial meniscus (MM) tear types and Kellgren–Lawrence (K-L) grade

Table 3 Clinical outcomes between the subgroups of medial meniscus tears

Variables	MM PRT	MM NRT	*p* value
Modified Lysholm score			
Preoperative (SD, range)	63.5 (16.7, 22–94)	64.8 (13.4, 34–90)	n.s
Postoperative (SD, range)	83.7 (14.5, 27–100)	84.9 (14.2, 39–100)	n.s
Difference (Δ) (SD, range)	21.9 (17.0, -27–73)	20.1 (17.1, – 17–55)	n.s

MM PRT medial meniscus posterior root tear, *MM NRT* medial meniscus non-root tear, *SD* standard deviation

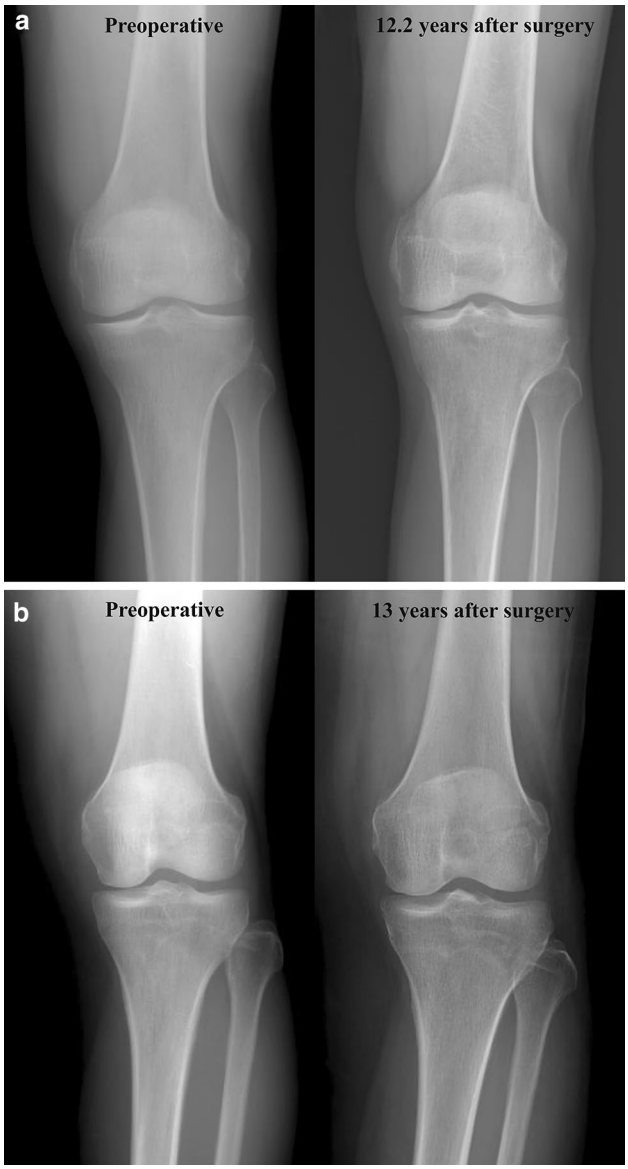

Fig. 4 Preoperative and latest standing anteroposterior radiographs of the left knee. **a** Preoperative radiograph of a 58-year-old woman with medial meniscus posterior root tear and the latest radiograph taken 12.2 years after surgery. **b** Preoperative radiograph of a 53-year-old woman with medial meniscus non-root tear (degenerative horizontal tear) and latest radiograph taken 13 years after surgery. Both patients showed improved mechanical symptoms of meniscus tear after partial medial meniscectomy, with little arthritic change over a long-term follow-up period

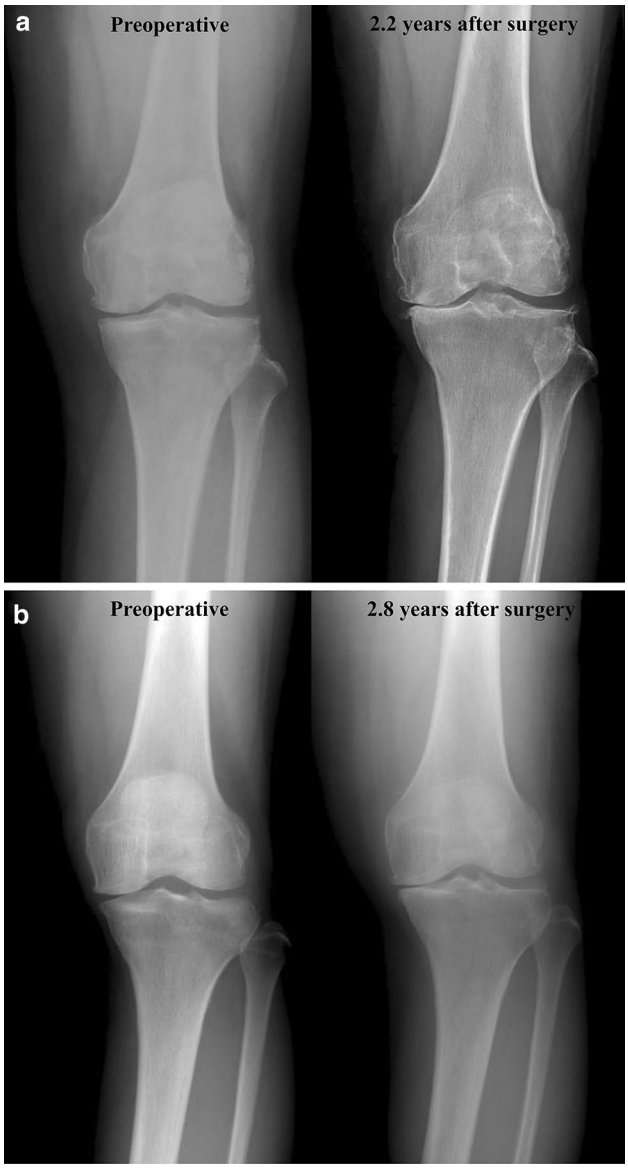

Fig. 5 Preoperative and follow-up standing anteroposterior radiographs of the left knee. **a** Preoperative radiograph of a 58-year-old woman with medial meniscus posterior root tear and the follow-up radiograph taken 2.2 years after surgery. **b** Preoperative radiograph of a 50-year-old woman with medial meniscus non-root tear (degenerative flap and horizontal tear) and the follow-up radiograph taken 2.8 years after surgery. Both patients complained of arthritic pain after partial medial meniscectomy over a short-term follow-up period and underwent total knee arthroplasty

Figures 4 and 5 are examples of standing AP radiographs of the MM PRT and MM NRT patients, showing similar clinical courses.

Discussion

The most important finding of this study is that APM for degenerative MM PRT shows comparable results in terms of joint survival and clinical outcome with APM for MM NRT. To our knowledge, this is the first comparative study about joint survival and clinical outcome after partial meniscectomy between tears of the MM posterior root and MM itself (with intact posterior root). Both groups showed a similar frequency of failures, estimated mean survival time, and overall survival rate. The subgroup analysis according to alignment and joint degeneration also showed comparable results. Moreover, the patient's mechanical symptoms improved, and no significant differences in clinical outcome were found over a long follow-up period. Therefore, degenerative MM PRT does not show worse results than degenerative MM NRT in terms of joint survival and clinical outcome after arthroscopic partial meniscectomy. After matching confounding factors, it is difficult to conclude that the type of medial meniscus tear determines joint survival after partial meniscectomy.

The treatment of degenerative MM PRT in middle-aged patients remains controversial. Theoretically, the repair of the posterior root attachment may restore the joint hoop stress and decrease the peak contact pressure on the tibiofemoral joint [3]. Several clinical studies reported favorable clinical outcomes of MM PRT repair [23, 34, 41]. Furthermore, recent studies showed that repair of medial meniscus root tears with pre-existing intact cartilage and well-aligned knee leads to less progression of osteoarthritis [21, 30]. Therefore, refixation was the generally recommended treatment for medial meniscus root tear. Although surgery provides benefits for an isolated meniscal root tear with early knee osteoarthritis, meniscal root repair should be considered carefully on the basis of the strict surgical indications, especially considering age, alignment, and cartilage status [2, 16]. The strict surgical criteria for root repair are often not applicable to patients that orthopedic surgeons attend to in clinics. Furthermore, meniscal root repair does not always show good results and often show poor healing rate, increased meniscal extrusion, and progression of the medial compartment cartilage defect in the short follow-up period [33]. APM may be considered as a treatment option with a simple technique and short operative and recovery times and as a palliative treatment for some middle-aged patients with mild varus alignment and mild arthritic change who do not meet the surgical indications for root repair [11, 38]. Therefore, both treatment methods of partial meniscectomy and meniscal root repair must be undertaken carefully according to individual characteristics. In our study, we aimed to analyze the effect of tear morphology on the long-term outcome of knees and to determine whether significant differences in joint survival and outcome could be found between MM PRT and MM NRT after partial meniscectomy in middle-aged patients with degenerative MM tears who underwent the partial meniscectomy.

APM was generally performed to relieve the mechanical symptoms of meniscal tears [9, 17]. However, APM cannot restore the biomechanical function of the knee. Moreover, several studies reported poor clinical results after APM for MM PRT. Krych et al. analyzed the efficacy of partial meniscectomy in comparison with the non-operative treatment of MM PRT [36]. They reported no significant difference in clinical outcomes and overall failure rates between the partial meniscectomy and non-operative treatment groups. They also reported that 14 (54%) patients of the 26 with MM PRT showed progression to total knee replacement at a mean period of 54.3 months. Han et al. reported that 9 (19%) of their 46 patients with MM PRT underwent reoperation, and those who had advanced arthritic change preoperatively had poor clinical outcomes [25]. However, these were not large population studies with long-term results, and results were not compared according to the types of MM tear. A similar failure rate of APM, in 30 (27.3%) of the 110 patients with MM PRT and in 35 (31.8%) of the 110 patients with MM NRT, showed after adjustments for confounding variables in this study.

Numerous risk factors are involved in the incidence and progression of knee osteoarthritis, such as age, gender, obesity, alignment, history of trauma, and level of activities [12, 14, 22, 26]. Moreover, whether a significant correlation exists between osteoarthritic changes in radiographs and clinical symptoms remains unclear [10, 43]. In fact, APM of MM PRT clearly cannot restore the normal biomechanics of the knee joint and prevent osteoarthritis progression. In the present study, the natural course of APM was analyzed according to the type of degenerative MM tear after adjustments for confounding variables such as age, gender, BMI, alignment, and cartilage status of the medial compartment, using propensity score matching analysis. Contrary to our expectation, similar joint survival and clinical outcome after APM were shown between MM PRT and MM NRT. Several factors probably affect the prognosis after partial meniscectomy, and joint failure and clinical outcome after surgery may not be drastically determined according to the meniscal tear type only.

This study has several limitations. First, this was a retrospective study with potential selection bias. Propensity score matching was used in this study to control for confounding variables. This led to the exclusion of unmatched patients in both groups from the analysis. On the other hand,

through propensity score matching, we could compare how homogeneous groups such as those in prospective studies. Second, alignment as a confounding factor was measured in the anatomical axis on standing AP radiographs, not in the mechanical axis on whole-leg radiographs. Third, joint survival was assessed on the basis of surgical and radiographic failures. Other factors for reoperation or the patient's clinical symptoms were not considered. Thus, joint survival could vary according to the definition of failure. Fourth, we did not investigate the radiological outcomes or features of osteoarthritis between the two groups. This topic could be studied in the future. Fifth, the MM tear morphology was only classified into two groups, MM PRT and MM NRT. Thus, we could not analyze the effect of the detailed subtypes of meniscal tear. Different tear patterns obviously have different biomechanical consequences. However, only comparative analysis of MM PRT and MM NRT was attempted in this study. Moreover, the detailed types of NRT were difficult to accurately distinguish because most degenerative tears have complex patterns and more than one tear component. Sixth, the effect of resection amount after partial medial meniscectomy was not assessed.

Conclusion

In middle-aged patients with degenerative MM PRT, joint survival and clinical outcome showed comparable results with those with MM NRT after partial meniscectomy. Arthroscopic partial meniscectomy is one of the effective treatments for MM PRT with consideration of various patient factors.

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Compliance with ethical standards

Conflict of interest All authors declared that they have no conflicts of interest.

Ethical approval Ethical approval for the study was given by the Ethics Committee of Asan Medical Center.

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