Semi-quantitative arthroscopic scoring system is related to clinical outcomes in patients after medial meniscus posterior root repair

Abstract

Background: Different methods are available to assess the healing status of repaired root for medial meniscus posterior root tears (MMPRT) using second-look arthroscopy. However, few studies are comparing them or validating their usefulness. Therefore, it was hypothesized that the semi-quantitative arthroscopic score might correlate more with 1-year clinical outcomes in patients with MMPRT than the qualitative evaluation.

Methods: Data of 61 patients who underwent MMPRT pullout repair and second-look arthroscopy were retrospectively evaluated. The semi-quantitative arthroscopic scoring system was divided into three evaluation criteria: scores from 0 to 10 points include the width of the bridging tissue, stability of the repaired root, and synovial coverage. The qualitative evaluation was classified into 4 status; complete healing, lax healing, scar tissue healing, and failed healing according to the stability and mobility of the repaired root. Multivariate linear regression analyses were used to identify predictors of 1-year postoperative clinical outcomes, including Knee Injury and Osteoarthritis Outcome, Lysholm, or International Knee Documentation Committee scores. Spearman's correlation analysis was used to analyze the correlation between second-look arthroscopic score/qualitative evaluation and 1-year postoperative clinical outcomes. In addition, the optimal cutoff point of semi-quantitative arthroscopic score was determined by receiver operating characteristic (ROC) curve. The Mann-Whitney U test was used to compare clinical outcomes between patients with semi-quantitative arthroscopic scores ≥ 8 and scores < 8.

Results: All clinical scores significantly improved 1-year postoperatively. A good correlation was observed between the semi-quantitative score and clinical scores, but none between qualitative evaluation and clinical scores. The optimal cutoff point of semi-quantitative second-look arthroscopic score was 8 points. Significantly, better clinical outcomes were observed in patients with semi-quantitative scores ≥ 8 points.

Conclusions: All postoperative clinical scores were significantly improved. The semi-quantitative arthroscopic score correlates with 1-year clinical outcomes in patients with MMPRT than the qualitative evaluation.

Level of evidence: IV case series study.

1. Introduction

The meniscus transfers load and absorbs shock [1]. It increases the contact surface area between the femoral condyle and the tibial plateau, further playing an important role in maintaining the biomechanical stability of the knee joint as the collagen fibers of the meniscus maintain hoop tension under the pressure, which conducts the load [2]. Medial meniscus (MM) posterior root tear (PRT) results in loss of hoop tension, which loses the load transmission of the meniscus , leading to cartilage degeneration and the progression of osteoarthritis [3].

The treatment of MMPRT has been improved using several techniques [4-6]. Arthroscopic transtibial pullout repair reduces tibial-femoral contact pressure by increasing the contact area, which has achieved satisfactory clinical results [7, 8]. In qualitative second-look arthroscopic evaluation, some researchers have classified 4 healing statuses of the meniscus as complete healing, lax healing, scar healing, and failed healing [9] or 3 healing statuses as complete healing, partial healing, and retear [10]. Seo et al. found that the healing status of the repaired meniscus through qualitative second-look arthroscopic evaluation did not seem to be related to the improvement of clinical symptoms [9]. In order to further explore the relationship between repair status and postoperative clinical outcomes, Furumatsu et al. described a semi-quantitative scoring system that is used to evaluate healing status, showing a good correlation between arthroscopic score and clinical evaluations, such as quality of life (QOL) score and visual analogue scale (VAS) pain score [11].

There is no unified standard for evaluating the healing status of the repaired meniscus or

verifying its correlation with clinical outcomes. Therefore, our study investigated the correlation between semi-quantitative arthroscopic scores and clinical outcomes compared to qualitative evaluation. It was hypothesized that the semi-quantitative arthroscopic score might correlate more with 1-year clinical outcomes in patients with MMPRT than the qualitative evaluation.

2. Materials and methods

2.1. Patients

This study received the approval of our Institutional Review Board. The written informed consent was obtained from all patients. Between December 2016 and June 2019, 68 consecutive patients underwent pullout sutures for MMPRT. All patients were diagnosed as MMPRT using magnetic resonance imaging (MRI). The indications for patient selection were as follows: patients with continuous knee pain, varus alignment < 5°, MRI revealed a ghost sign, radial tear sign, cleft sign, or giraffe neck sign. The exclusion criteria were: follow-up time < 1 year, Kellgren–Lawrence grade ≥ 3 with severe cartilage degeneration, previous history of meniscus injury or knee surgery.

2.2. Surgical technique and postoperative rehabilitation

Arthroscopy was performed using conventional anteromedial and anterolateral portals. According to the PRT classification [12], the type of MMPRT was determined by arthroscopy. Three suture techniques were used: FasT-Fix dependent modified Mason-Allen suture

(F-MMA), two simple stitches (TSS), TSS with additional posteromedial suture (TSS-PM). The F-MMA suture was performed in patients using Ultrabraid and FasT-Fix all-inside meniscal repair device (Smith & Nephew, Andover, MA, USA) and screw (Meira, Aichi, Japan) with the knee flexed at 45° and 20 N between December 2016 and December 2017. The TSS was performed in patients using two No. 2 polyethylene sutures and a bioabsorbable interference screw (Smith & Nephew) between January 2018 and November 2018. Finally, the TSS-PM was performed in patients with an additional posteromedial pullout repair using an all-inside meniscal repair device (FasT-Fix) between November 2018 and June 2019. Using the MMPRT aiming guide (Smith & Nephew, Andover, MA, USA), a tibial tunnel with a diameter of 4.0 or 4.5 mm was created at the anatomical insertion of the MM posterior root . Tibial fixation was performed at 20°-45° knee flexion with an initial tension of 20-30 N.

During rehabilitation, the patients were initially kept at partial weight bearing 2 weeks postoperatively. After 2 weeks postoperatively, partial weight bearing (20 kg) was allowed to progress to full weight bearing (+ 20 kg/week). At 4-6 weeks postoperatively, most patients were allowed full weight-bearing (depending on the patient's weight). Patients were allowed 30° of knee flexion at 2 weeks, 60° of knee flexion at 3 weeks, and 90° of knee flexion at 4 weeks postoperatively. Knee flexion was permitted to reach 90° at 8 weeks and 120° in the next 4 weeks postoperatively. Deep flexion was restricted at 12 weeks postoperatively. Sports activity such as jogging was allowed after MRI evaluation of the repaired MM posterior root at 12 weeks postoperatively.

2.3. Assessment methods

The clinical outcomes were evaluated 1-year postoperatively using the International Knee Documentation Committee (IKDC) score, Knee Injury and Osteoarthritis Outcome Score (KOOS), Lysholm score, Tegner activity score, and pain visual analog scale (VAS). The KOOS includes pain, symptoms, activities of daily living (ADL), sport and recreation activities (Sport/rec), and knee-related quality of life (QOL) outcomes. Lysholm score is an overall score on a point scale from 0 to 100 which has a generally recognized and accepted classification standard. An assignment is given as "excellent" for 95 to 100 points; "good" for 84 to 94 points, "fair" for 65 to 83 points, or "poor" for less than 65 points as described [13]. We defined the "excellent" and "good" patients as the improved group, and the "fair" and "poor" patients as the moderate group at 1-year postoperatively.

All patients were re-examined by second-look arthroscopy. The semi-quantitative arthroscopic scoring system was described [11] and divided into three evaluation criteria: (1) the anterior and posterior width of the bridging tissue between the posterior horn of MM and the root attachment, (2) the stability of the posterior root of the repaired MM, and (3) the synovial coverage of the suture (Table2). The width of the anterior and posterior meniscus was defined as broad (> 5 mm, 4 points), narrow (2–5 mm, 2 points), and filamentous (< 2 mm, 0 point) bridging tissue (Figure 1). During 20° or 60° knee flexion exploration, the stability of the MM posterior root was evaluated by meniscus lifting and anterior drawing (Figure 2). Good stability (4 points) was defined as continuous meniscus without lifting on probing during 20° knee flexion. Fair stability (3 points) was defined as the root that was not raised at knee flexion of 60°, regardless of the degree of lifting during 20° knee flexion. The loose state (2 points) was defined as the repaired posterior root with lifting at 60° knee flexion

and no anterior drawing at 20° knee flexion. Useless meniscus continuity (1 point) was defined as bridging tissue with anterior drawing during 20° knee flexion. Posterior root separation was defined as a completely unstable state (0 point). In synovial coverage, the suture coverage rates of good (2 points), fair (1 point), and poor (0 points) were determined by the results of arthroscopy (Figure 3). The score of perfect meniscus healing was 10 points.

The patients were also evaluated using qualitative methods as described above [9]. Patients with a stability score of 4 points were designated as the complete healing group; 2–3 points, lax healing group; 1 point, scar tissue healing group; 0 point, failed healing group. Each category, such as width, stability, and synovial coverage, was evaluated on-the-spot consultation during surgery.

2.4. Statistical analysis

Statistical analysis was performed using SPSS Statistics, version 25.0 (IBM Corp., Armonk, NY, USA). Data are expressed as mean ± standard deviation (SD). Multivariate linear regression analyses were used to assess potential associations. Spearman's correlation analysis was used to analyze the correlation between second-look arthroscopic score/evaluation and 1-year postoperative clinical outcomes. Receiver operating characteristic (ROC) curve analysis was used to determine the cutoff value of semi-quantitative arthroscopic score. The Mann-Whitney U test was used to compare clinical outcomes between patients with semi-quantitative arthroscopic scores ≥ 8 and scores < 8. A difference of $P < 0.05$ was considered statistically significant.

3. Results

Postoperative second-look arthroscopic evaluation was performed in all cases at 1-year. Among the 68 patients, four patients with history of meniscus knee surgery and three patients with radiographic knee osteoarthritis of Kellgren–Lawrence grade ≥ 3 were excluded; the remaining 61 (14 men and 47 women) were enrolled in the current study for analysis. In the qualitative evaluation, 5 knees with complete healing, 54 knees with lax healing, and 2 knees with scar tissue healing, whereas no failed healing was found.

Table 1 shows the demographic and baseline characteristics of the 61 patients. The 1-year postoperative KOOS were significantly higher than preoperative KOOS ($P < 0.01$), which included pain (77.53 ± 14.48 vs. 56.00 ± 20.54), symptoms (71.94 ± 16.26 vs. 63.94 ± 19.43), ADL (81.87 ± 14.04 vs. 66.16 ± 20.76), Sport/rec (49.71 ± 25.42 vs. 26.12 ± 24.75), and QOL (53.87 ± 20.73 vs. 30.16 ± 18.58). Compared to preoperative scores, the 1-year postoperative Lysholm scores (85.04± 9.36 vs. 59.28 ± 12.86) and IKDC scores (60.32 ± 15.22 vs. 38.25 ± 16.31) significantly increased ($P < 0.01$), whereas VAS pain (13.69 ± 14.22 vs. 40.12 ± 26.72) was significantly decreased ($P < 0.01$). All the 1-year postoperative clinical scores were significantly improved compared to the preoperative scores (Figure 4).

There was no significant difference in the 1-year clinical scores and semi-quantitative arthroscopy scores among F-MMA, TSS, and TSS-PM (Table 3). The semi-quantitative score was more significantly related to the clinical scores than other factors such as age, BMI, MMPRT classifications and surgical techniques at 1-year postoperatively (Table 4). In addition, semi-quantitative second-look arthroscopic scores were significantly correlated with 1-year postoperative clinical scores and stability was more correlated with clinical scores than

the width and synovial coverage in the sub-scores (Table 5). However, no correlation was observed between qualitative arthroscopic evaluation and most clinical scores (Table 5). Sixty-one patients were divided into 2 groups based on Lysholm scores, 42 patients in improved group and 19 patients in moderate group. The optimal semi-quantitative second-look arthroscopic score was 8 according to ROC curve (Figure 5). In the semi-quantitative evaluation, there were 22 patients with semi-quantitative scores ≥ 8 and 39 patients with semi-quantitative scores < 8. Significantly better clinical outcomes were observed in patients with semi-quantitative scores ≥ 8 points (Table 6). No statistically significant difference was observed in clinical scores between complete healing and lax healing in qualitative arthroscopic evaluation (Table 7).

4. Discussion

The most important finding of this study was that the semi-quantitative arthroscopic score correlates more with 1-year clinical outcomes in patients with MMPRT than the qualitative evaluation. In addition, patients with semi-quantitative scores ≥ 8 points had better clinical outcomes than those < 8 points, whereas no significant difference was found in complete healing and lax healing using qualitative arthroscopic evaluation.

MMPRT is prone to occur when the patient is descending, exercising, or twisting the knee joint [14]. Severe knee varus is also a risk factor for MMPRT to increase the contact pressure on the medial compartment of the knee joint and accelerate the progression of OA, which is predictive for a clinical failure after MMPRT [15]. For cases of severe knee varus alignment,

it may be necessary to perform high tibial osteotomy to improve postoperative knee function [16]. The treatment of MMPRT has been improved [4, 17]. Arthroscopic partial meniscectomy has a certain effect on relieving symptoms in most patients although it can hardly restore the function of the meniscus [10]. Transtibial pullout repair has significantly achieved satisfactory clinical results and restored meniscus function [8, 18]. It can improve tibiofemoral contact area and reduce the symptoms of the knee, which can delay the progression of knee osteoarthritis [19]. The F-MMA sutures has the largest failure load, greater than the TSS technique [20]. However, excessive mechanical stress on the MM's suture part may result in a cut or pullout [21]. In a 1-year postoperative evaluation, the TSS-PM technique did not show better clinical scores and meniscal healings than the F-MMA and TSS techniques [22]. This indicates that different suture techniques have no significant effect on clinical scores. MM extrusion and cartilage injury will progress rapidly after MMPRT, and pullout repair should be carried out as soon as possible [23]. Although surgery did not significantly reduce the medial MME, it can significantly reduce the posterior MME and improve the clinical outcomes [24]. Similarly, the progression of OA cannot be completely suppressed, but clinical results can be significantly improved [25].

The healing status of the repaired root is an important therapeutic index for restoring the anatomy and function of the meniscus, but the correlation between the second-look arthroscopic score and clinical outcomes remains uncertain [26]. Some studies have suggested that there is no correlation between healing status and clinical scores [9, 10]. However, these studies used a qualitative evaluation of healing status and sample sizes were small. Furumatsu et al. reported that the semi-quantitative arthroscopic score (total 10 points) was significantly

214 correlated with clinical outcomes (KOOS QOL) when more patients were included [11]. In
215 this study, the stability of the MM repaired root (0-4 points) had more correlation with clinical
216 scores than other factors. The stability of MM posterior root is directly related to the extrusion,
217 which causes cartilage damage and accelerates the progression of osteoarthritis [27]. We
218 consider that the stability of the repaired posterior root was an important factor in improving
219 clinical scores. In the natural process of meniscus healing, the synovium plays a key role and
220 is induced to the damaged part of the meniscus, which is conducive to the repair of the
221 meniscus [28]. In animal experiments, transplanted synovial mesenchymal stem cells increase
222 the proteoglycan content and organization of collagen fibers at the injury site of the meniscus
223 [29]. Many studies have shown that the bone marrow mesenchymal stem cells released in the
224 intra-bone tunnel also contribute to the healing of the meniscus with the improvement of
225 collagen I, osteocalcin, and osteopontin mRNA levels [30]. Therefore, factors released in the
226 bone tunnel possess an intrinsic therapeutic potential that contributes to meniscus healing.

227 There are many other methods to classify the healing status of the repaired root. Seo et al.
228 classified the healing status into 4 status; complete healing, lax healing, scar tissue healing,
229 and failed healing according to the stability and mobility of the repaired root [9]. Kim et al.
230 categorised the healing status into 3 status; normal, loose, and no tension according to the
231 fixation strength around the repaired root and the restoration of peripheral hoop tension [10].
232 To validate the difference between qualitative and semi-quantitative evaluations in
233 second-look arthroscopy, we used the same patients to compare the differences in clinical
234 scores in each group according to the two methods. According to the qualitative method, there
235 was no significant difference in clinical scores between the complete healing group and the

lax healing group. In this study, we found that when semi-quantitative score was ≥ 8, the clinical scores were significantly higher than those of patients < 8. We suggest that adding the width of the bridging tissue and the coverage of the synovial coverage can more objectively reflect the healing status. This proves that the semi-quantitative method is more useful for predicting postoperative clinical scores.

This study has several limitations. First, the retrospective nature of the study may have led to a selection bias. Second, the follow-up period was only 1 year, which may have affected the study results. Third, there were only 2 patients with scar tissue healing and no patient with failed healing, which meant a lack of comparison in the qualitative comparison of clinical scores. Finally, the postoperative rehabilitation may be related to the healing status of the posterior root of the MM, which should be considered in further research.

5. Conclusions

All postoperative clinical scores were significantly improved than those at the preoperative stage and more correlated with the semi-quantitative arthroscopic score than the qualitative evaluation in assessing the healing status of the repaired root.

References

[1]. Makris EA, Hadidi P, Athanasiou KA. The knee meniscus: structure-function, pathophysiology, current repair techniques, and prospects for regeneration. Biomaterials2011;32(30):7411-31.

[2]. Harner CD, Mauro CS, Lesniak BP, Romanowski JR. Biomechanical consequences of a tear of the posterior root of the medial meniscus. Surgical technique. J Bone Joint Surg Am2009 Oct 1;91 Suppl 2:257-70.

[3]. Lee DH, Lee BS, Kim JM, Yang KS, Cha EJ, Park JH, Bin SI. Predictors of degenerative medial meniscus extrusion: radial component and knee osteoarthritis. Knee Surg Sports Traumatol Arthrosc2011 Feb;19(2):222-9.

[4]. Lee DW, Ha JK, Kim JG. Medial meniscus posterior root tear: a comprehensive review. Knee surgery & related research2014;26(3):125-34.

[5]. Chung KS, Ha JK, Yeom CH, Ra HJ, Jang HS, Choi SH, Kim JG. Comparison of Clinical and Radiologic Results Between Partial Meniscectomy and Refixation of Medial Meniscus Posterior Root Tears: A Minimum 5-Year Follow-up. Arthroscopy2015 Oct;31(10):1941-50.

[6]. Bonasia DE, Pellegrino P, D'Amelio A, Cottino U, Rossi R. Meniscal Root Tear Repair: Why, When and How? Orthop Rev (Pavia)2015 Jun 3;7(2):5792.

[7]. Chung KS, Ha JK, Ra HJ, Nam GW, Kim JG. Pullout Fixation of Posterior Medial Meniscus Root Tears: Correlation Between Meniscus Extrusion and Midterm Clinical Results. Am J Sports Med2017 Jan;45(1):42-9.

[8]. Moon HK, Koh YG, Kim YC, Park YS, Jo SB, Kwon SK. Prognostic factors of

276 arthroscopic pull-out repair for a posterior root tear of the medial meniscus. Am J Sports
277 Med2012 May;40(5):1138-43.
278 [9]. Seo HS, Lee SC, Jung KA. Second-look arthroscopic findings after repairs of posterior
279 root tears of the medial meniscus. Am J Sports Med2011 Jan;39(1):99-107.
280 [10]. Kim SB, Ha JK, Lee SW, Kim DW, Shim JC, Kim JG, Lee MY. Medial meniscus
281 root tear refixation: comparison of clinical, radiologic, and arthroscopic findings with medial
282 meniscectomy. Arthroscopy2011 Mar;27(3):346-54.
283 [11].Furumatsu T, Miyazawa S, Fujii M, Tanaka T, Kodama Y, Ozaki T. Arthroscopic scoring
284 system of meniscal healing following medial meniscus posterior root repair. Int Orthop2019
285 May;43(5):1239-45.
286 [12]. LaPrade CM, James EW, Cram TR, Feagin JA, Engebretsen L, LaPrade RF.
287 Meniscal root tears: a classification system based on tear morphology. Am J Sports Med2015
288 Feb;43(2):363-9.
289 [13]. Collins NJ, Misra D, Felson DT, Crossley KM, Roos EM. Measures of knee
290 function: International Knee Documentation Committee (IKDC) Subjective Knee Evaluation
291 Form, Knee Injury and Osteoarthritis Outcome Score (KOOS), Knee Injury and Osteoarthritis
292 Outcome Score Physical Function Short Form (KOOS-PS), Knee Outcome Survey Activities
293 of Daily Living Scale (KOS-ADL), Lysholm Knee Scoring Scale, Oxford Knee Score (OKS),
294 Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Activity Rating
295 Scale (ARS), and Tegner Activity Score (TAS). Arthritis Care Res (Hoboken)2011 Nov;63
296 Suppl 11(0 11):S208-28.
297 [14]. Bae JH, Paik NH, Park GW, Yoon JR, Chae DJ, Kwon JH, Kim JI, Nha KW.

298 Predictive value of painful popping for a posterior root tear of the medial meniscus in
299 middle-aged to older Asian patients. Arthroscopy2013 Mar;29(3):545-9.
300 [15]. Kim C, Bin SI, Kim JM, Lee BS, Kim TH. Progression of radiographic
301 osteoarthritis after partial meniscectomy in degenerative medial meniscal posterior root tears
302 was greater in varus- than in neutral-aligned knees: a minimum 5-year follow-up. Knee Surg
303 Sports Traumatol Arthrosc2020 Nov;28(11):3443-9.
304 [16]. Liu X, Chen Z, Gao Y, Zhang J, Jin Z. High Tibial Osteotomy: Review of
305 Techniques and Biomechanics. J Healthc Eng2019;2019:8363128.
306 [17]. Chung KS, Ha JK, Ra HJ, Kim JG. A meta-analysis of clinical and radiographic
307 outcomes of posterior horn medial meniscus root repairs. Knee Surg Sports Traumatol
308 Arthrosc2016 May;24(5):1455-68.
309 [18]. Lee JK, Jung M, Yang JH, Song SY, Shin YS, Cha M, Jung D, Seo YJ. Repair
310 versus nonrepair of medial meniscus posterior root tear: A systematic review of patients'
311 selection criteria, including clinical and radiographic outcomes. Medicine (Baltimore)2020
312 Mar;99(10):e19499.
313 [19]. LaPrade RF, Matheny LM, Moulton SG, James EW, Dean CS. Posterior Meniscal
314 Root Repairs: Outcomes of an Anatomic Transtibial Pull-Out Technique. Am J Sports
315 Med2017 Mar;45(4):884-91.
316 [20]. Feucht MJ, Grande E, Brunhuber J, Burgkart R, Imhoff AB, Braun S.
317 Biomechanical evaluation of different suture techniques for arthroscopic transtibial pull-out
318 repair of posterior medial meniscus root tears. Am J Sports Med2013 Dec;41(12):2784-90.
319 [21]. LaPrade RF, LaPrade CM, Ellman MB, Turnbull TL, Cerminara AJ, Wijdicks CA.

Cyclic displacement after meniscal root repair fixation: a human biomechanical evaluation. Am J Sports Med2015 Apr;43(4):892-8.

[22]. Furumatsu T, Hiranaka T, Okazaki Y, Kintaka K, Kodama Y, Kamatsuki Y, Ozaki T. Medial meniscus posterior root repairs: A comparison among three surgical techniques in short-term clinical outcomes and arthroscopic meniscal healing scores. J Orthop Sci2021 Feb 10.

[23]. Krych AJ, LaPrade MD, Hevesi M, Rhodes NG, Johnson AC, Camp CL, Stuart MJ. Investigating the Chronology of Meniscus Root Tears: Do Medial Meniscus Posterior Root Tears Cause Extrusion or the Other Way Around? Orthop J Sports Med2020 Nov;8(11):2325967120961368.

[24]. Zhang X, Furumatsu T, Okazaki Y, Okazaki Y, Hiranaka T, Xue H, Kintaka K, Yamauchi T, Ozaki T. Medial meniscus posterior root repair reduces the extruded meniscus volume during knee flexion with favorable clinical outcome. Knee Surg Sports Traumatol Arthrosc2021 Mar 11.

[25]. Kaplan DJ, Alaia EF, Dold AP, Meislin RJ, Strauss EJ, Jazrawi LM, Alaia MJ. Increased extrusion and ICRS grades at 2-year follow-up following transtibial medial meniscal root repair evaluated by MRI. Knee Surg Sports Traumatol Arthrosc2018 Sep;26(9):2826-34.

[26]. Feucht MJ, Kühle J, Bode G, Mehl J, Schmal H, Südkamp NP, Niemeyer P. Arthroscopic Transtibial Pullout Repair for Posterior Medial Meniscus Root Tears: A Systematic Review of Clinical, Radiographic, and Second-Look Arthroscopic Results. Arthroscopy2015 Sep;31(9):1808-16.

342 [27]. Hein CN, Deperio JG, Ehrensberger MT, Marzo JM. Effects of medial meniscal
343 posterior horn avulsion and repair on meniscal displacement. Knee2011 Jun;18(3):189-92.
344 [28]. Mizuno K, Muneta T, Morito T, Ichinose S, Koga H, Nimura A, Mochizuki T,
345 Sekiya I. Exogenous synovial stem cells adhere to defect of meniscus and differentiate into
346 cartilage cells. J Med Dent Sci2008 Mar;55(1):101-11.
347 [29]. Ozeki N, Kohno Y, Kushida Y, Watanabe N, Mizuno M, Katano H, Masumoto J,
348 Koga H, Sekiya I. Synovial mesenchymal stem cells promote the meniscus repair in a novel
349 pig meniscus injury model. J Orthop Res2021 Jan;39(1):177-83.
350 [30]. Teng C, Zhou C, Xu D, Bi F. Combination of platelet-rich plasma and bone marrow
351 mesenchymal stem cells enhances tendon-bone healing in a rabbit model of anterior cruciate
352 ligament reconstruction. J Orthop Surg Res2016 Sep 7;11(1):96.
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Figure legends

Fig. 1 Second-look arthroscopic findings of anteroposterior (AP) width of bridging tissues. a. An example with broad AP width (> 5 mm, 4 points). b. An example with narrow AP width (2–5 mm, 2 points). c. An example with filamentous AP width (<2 mm, 0 points).

Fig. 2 Second-look arthroscopic findings of stability of the medial meniscus posterior root. a. No lifting on probing at 20° of flexion (good, 4 points). b. Lifting on probing at 20° of flexion (fair, 3 points). c No lifting on probing at 60° of flexion (fair, 3 points). d. Lifting on probing at 60° of flexion (loose, 2 points). e. No anterior drawing on probing at 20° of flexion (loose, 2 points). f. Anterior drawing on probing at 20° of flexion (useless, 1 point).

Fig. 3 Second-look arthroscopic findings of synovial coverage with the sutures. a. An example of almost covered synovial tissues (good, 2 points). b. An example of partially covered synovial tissues (fair, 1 point). c. An example or totally exposed sutures. (poor, 0 point).

Fig. 4 Comparison of clinical outcomes between preoperatively and 1-year postoperatively. KOOS, Knee Injury and Osteoarthritis Outcome Score. ADL, activities of daily living. Sport/Rec, sport and recreation function. QOL, quality of life. IKDC, International Knee Documentation Committee subjective knee evaluation form. VAS, visual analogue scale. *P < 0.01.

Fig. 5 Threshold for semi-quantitative score for improved clinical scores at 1-year postoperatively. The calculated cut-off value (8 points) has a specificity of 84% and sensitivity of 45% with AUC of 0.67. P< 0.05. AUC, area under curve.