

Original paper

Arthroscopic scoring system of meniscal healing following medial meniscus posterior root repair

Abstract

Purpose Medial meniscus posterior root tear (MMPRT) leads to a rapid degradation of articular cartilage. In the treatment of MMPRT, transtibial pullout repair demonstrates a high clinical survival rate. However, there is no reliable method to evaluate the meniscal healing after surgery. We propose an arthroscopic scoring system for evaluating the meniscal healing status. The aim of this study was to investigate the correlations between second-look arthroscopic scores and clinical outcomes after transtibial pullout repair.

Methods Twenty patients who had MMPRTs underwent transtibial pullout repairs. Clinical outcomes were assessed using the Japanese Knee Injury and Osteoarthritis Outcome Score (KOOS) and pain score evaluated by visual analogue scale at preoperatively and 1 year postoperatively. The healing status of repaired MM was assessed at 1 year postoperatively using a semi-quantitative arthroscopic scoring system (total, 10 points) composed of 3 evaluation criteria: (i) anteroposterior width of bridging tissues, (ii) stability of the MM posterior root, and (iii) synovial coverage of the sutures. Linear regression analysis was used to assess the correlation between second-look arthroscopic scores and clinical outcomes.

Results Transtibial pullout repairs of MMPRTs significantly improved clinical evaluation scores at 1 year postoperatively. A median of second-look arthroscopic scores was 6.5 (5.75–8). A good correlation was observed between the arthroscopic score and KOOS quality of life (QOL) subscale. A moderate negative correlation between the arthroscopic score and pain score was observed.

Conclusions This study demonstrated that our semi-quantitative scoring system of meniscal healing correlated with the KOOS QOL subscale following MMPRT transtibial pullout repair. Our results suggest that the second-look arthroscopic score using this system may be a useful scale to determine and compare the healing status of the MM posterior root.

Keywords Arthroscopic scoring, Meniscal healing, Medial meniscus, Posterior root tear, Transtibial pullout repair

Introduction

The posterior root of the medial meniscus (MM) can serve as an anchor to regulate the meniscal shift during the knee motion and load bearing. Injuries to the MM posterior root, including complete radial and/or oblique tears adjacent to the posterior root attachment and posterior horn, lead to accelerated degeneration of the knee joint articular cartilage by disrupting meniscal functions [1]. In addition, the MM posterior root tear (MMPRT) leads to progression of osteoarthritis and/or spontaneous osteonecrosis of the knee by inducing abnormal biomechanics of the tibiofemoral joint [2,3]. Therefore, conservative treatments of MMPRTs are associated with worsening osteoarthritis and poor clinical outcome [4]. Moreover, partial meniscectomy for MMPRT provides no benefit in preventing osteoarthritic progression [5]. There is no significant difference in clinical scores, progression to arthroplasty, or overall failure rate between partial meniscectomy and non-operative management for MMPRTs [6]. Patients who undergo partial meniscectomy for MMPRTs still progress to significant osteoarthritis, poor clinical outcomes, and a high arthroplasty rate at over 5-year follow-up [6]. In the treatment of the MMPRT, early diagnosis and appropriate surgical intervention are important in obtaining a successful clinical outcome and preventing rapid progression of degenerative knee diseases [1, 7]. Arthroscopic meniscus repairs for MMPRTs seem to achieve favorable clinical outcomes [8-10]. Arthroscopic repairs of the MMPRT can reduce a mean tibiofemoral contact pressure by increasing a tibiofemoral contact area in a human cadaveric knee study [11]. Several repair techniques such as transtibial pullout repair, suture anchor-dependent repair, direct all-inside repair, and posterior reattachment of the MM posterior root have been developed for arthroscopic treatments of the MMPRT [1, 7]. Among them, transtibial pullout repair demonstrates a high clinical survival rate (99%) at 5 years postoperatively [10]. However, there is no reliable method to evaluate the healing and functional status of the MM posterior root after the MMPRT repair.

A structural healing assessment using magnetic resonance imaging (MRI) can barely evaluate the continuity and signal intensity of the MM posterior root. Complete structural healing is observed 50% of the patients following the MMPRT transtibial pullout repair at 2 years postoperatively [8]. The other study shows that complete healing after transtibial pullout repair is observed just one patient out of 18 MMPRT patients at a mean of 19 months postoperatively [12]. In second-look arthroscopic evaluation after the MMPRT pullout

repair, meniscal healing status is defined differently each other [13, 14]. Seo et al. classify the healing status of repaired meniscus as complete healing, lax healing, scar tissue healing, and failed healing at second-look arthroscopy [13]. Nha et al. evaluate the meniscal healing arthroscopically using a classification composed of complete healing, incomplete healing, and no healing [14]. In addition, these studies include the patients who required high tibial osteotomy concomitant with transtibial pullout repair. Moreover, utility and clinical relevance of second-look arthroscopic classification for evaluating the effect of MMPRT transtibial pullout repair are not investigated in these studies. Here, we propose an arthroscopic scoring system of meniscal healing following the MMPRT transtibial pullout repair. The aim of this study was to investigate the correlations among arthroscopic evaluation of the repaired posterior root, clinical findings, and meniscal healing after the MMPRT transtibial pullout repair.

Methods

This study received the approval of our Institutional Review Board, and written informed consent was obtained from all patients. Twenty patients (18 women and 2 men) who had episode of the posteromedial painful popping, continuous knee pain, and MMPRT between July 2015 and December 2016 were included (Table 1). Patients who had radiographic knee osteoarthritis involved in the Kellgren-Lawrence grade III or more and previous history of meniscus injury or knee surgery were excluded. All the patients were diagnosed having the MMPRT with MRI examinations and met operative indications for the MMPRT pullout repair [15-17]. The presence of the MMPRT was defined according to characteristic MRI findings such as cleft, giraffe neck, ghost, radial tear, and meniscal extrusion signs of the MM posterior root within 9 mm from the attachment [18, 19]. All the patients underwent transtibial pullout repair for the treatment of MMPRT between October 2015 and February 2017. A median age of the patients was 64.5 years at the pullout repair. Types of the MMPRT were determined by careful arthroscopic examinations according to the meniscal root tear classification (Table 1) [20]. There was no patient who underwent meniscectomy alone. Second-look arthroscopic evaluation and fixation device removal were performed in all patients at 1 year postoperatively.

Surgical procedure and postoperative care

Indications for transtibial pullout repair of the MMPRT were patients with femorotibial angle $< 180^\circ$ and Kellgren–Lawrence grade 0–II, which is confirmed with preoperative standing radiographs, in our institute. A standard arthroscopic examination was performed through routine anteromedial and anterolateral portals. The severity of a MMPRT was evaluated on probing (Fig. 1A). No. 2 Ultrabraid and FasT-Fix reverse curve (Smith & Nephew, Andover, MA, USA) were used to stabilize the MM posterior horn in a modified Mason-Allen suture configuration (Fig. 1B) [15, 17]. A 4.5-mm tibial tunnel was created at an anatomic insertion of the MM posterior root using a PRT aiming guide (Smith & Nephew) [16]. Ultrabraid and uncut free-end of the FasT-Fix sutures were retrieved through the tibial tunnel. Tibial fixation of the sutures was performed using double-spike plate and screw (Meira, Aichi, Japan) at 45° of knee flexion with an initial tension of 20 N. After the pullout repair, patients were initially kept non-weight bearing in the knee immobilizer for 2 weeks. Between 2 and 4 weeks, knee flexion exercise is gradually increased up to 90° under partial weight bearing condition. After 5 or 6 weeks, patients were allowed full weight bearing and 120° of knee flexion.

Clinical outcome evaluation

Clinical evaluations (Table 2) were performed at the time of pullout repair (preoperative score) and second-look arthroscopy (postoperative score). We assessed clinical outcomes using the Japanese Knee Injury and Osteoarthritis Outcome Score (KOOS), Lysholm knee score, Tegner activity score, International Knee Documentation Committee (IKDC) subjective knee evaluation form, and pain score evaluated by visual analogue scale (VAS). The KOOS consists of five subscales: pain, symptoms, activities of daily living (ADL), sport and recreation function (Sport/Rec), and knee-related quality of life (QOL). Pain intensity of the knee was assessed with a 100-mm VAS, ranging from 0 mm (no pain) to 100 mm (worst possible pain).

Second-look arthroscopic scoring system

The healing status of the MM following transtibial pullout repair was assessed by second-look arthroscopy. Our semi-quantitative arthroscopic scoring system was composed of 3 evaluation criteria: (i) anteroposterior width of bridging tissues between the MM posterior horn and root attachment, (ii) stability of

the repaired MM posterior root, and (iii) synovial coverage of the sutures (Table 3). Anteroposterior width of bridging tissues was measured using a scaling probe. In the anteroposterior width, 4, 2, and 0 points were assigned to broad (> 5 mm), narrow (2–5 mm), and filamentous (< 2 mm) bridging tissues, respectively. Stability of the MM posterior root was assessed by meniscus lifting and anterior drawing on probing at 20° or 60° of knee flexion (Fig. 1, C–F). A good stability (4 points) was defined as meniscal continuity with no lifting on probing at 20° of knee flexion. A fair stability (3 points) was defined as the root with no lifting on probing at 60° of knee flexion regardless of showing a lifting on probing at 20° of flexion. The repaired posterior root that showed lifting on probing at 60° of knee flexion but no anterior drawing at 20° of flexion was determined as a loose condition (2 points). A useless meniscal continuity (1 point) was defined as the bridging tissue that showed anterior drawing on probing at 20° of knee flexion. A detached posterior root was defined as a totally unstable status (0 point). Good (2 points), fair (1 point), and poor (0 point) synovial coverages of the sutures were defined as conditions that were almost covered, partially covered by synovial tissues, and totally exposed or ruptured, respectively. A perfect score on the meniscal healing set at 10 points.

Statistical analysis

Data were presented as medians and first–third quartiles. Differences between the preoperative and postoperative clinical outcome scores were compared using the Wilcoxon signed-rank tests. Statistical analyses were performed using EZR (Saitama Medical Center, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing). Significance was set to $P < 0.05$. Linear regression analysis was used to assess the correlation between second-look arthroscopic scores and clinical outcomes. A good correlation was represented by $R^2 \geq 0.50$, moderate correlation by $R^2 \geq 0.30$, and weak correlation by $R^2 < 0.30$.

Results

Transtibial pullout repair of the MMPRT significantly improved all the clinical evaluation scores at 1 year postoperatively (Table 2). A median of the KOOS QOL score increased from 34.65 to 58.15 following the MM pullout repair ($P < 0.001$). A median of the pain score (VAS) decreased from 52 to 7.5 at the

second-look arthroscopic assessment ($P < 0.001$).

A median of second-look arthroscopic scores was 6.5 (5.75–8). In the meniscal healing status, filamentous anteroposterior width of bridging tissues and detached posterior root were not observed at second-look arthroscopy.

A good correlation was observed between second-look arthroscopic score and KOOS QOL score at 1 year after the pullout repair ($R^2 = 0.587$, Fig. 2A). The best fit equation for predicting each value was the following: $\text{KOOS QOL} = 7.326 \times \text{arthroscopic score} + 12.009$. A moderate negative correlation between second-look arthroscopic score and pain score was observed (Fig. 2B). The regression equation was linear: $\text{pain} = -6.535 \times \text{arthroscopic score} + 57.628$ ($R^2 = 0.317$). Correlations between second-look arthroscopic score and the other clinical scores were not detected: KOOS Pain ($R^2 = 0.060$), KOOS Symptoms ($R^2 = 0.009$), KOOS ADL ($R^2 = 0.026$), KOOS Sport/Rec ($R^2 = 0.150$), Lysholm ($R^2 = 0.001$), Tegner ($R^2 = 0.088$), and IKDC ($R^2 = 0.020$).

Discussion

The most important finding in this study was that the semi-quantitative second-look arthroscopic score of meniscal healing correlated with the KOOS QOL subscale following MMPRT transtibial pullout repair. Although the other clinical evaluation scores improved by the MMPRT pullout repair, the second-look arthroscopic score did not have a significant correlation with these clinical outcomes except for postoperative KOOS QOL and pain scores. Several authors describe that the healing status of the MM at second-look arthroscopy is not associated with improved clinical scores such as the Lysholm knee score and Hospital for Special Surgery score following surgical treatment of the MMPRT [13, 14]. The reason why clinical improvement showed no association with arthroscopic meniscal healing status in these literatures may depend on qualitative evaluation systems of second-look arthroscopic findings. We consider that it would be difficult to find a correlation between clinical outcome scores and meniscal healing status using three- or four-staged classification on second-look arthroscopy. Moreover, the Lysholm knee score is not suitable for evaluating middle-aged or older patients who have MMPRTs during light activities such as using stairs and squatting [21]. Our study demonstrated that the semi-quantitative scoring system of meniscal healing, ranging from 0 to 10,

had good correlation with the KOOS QOL score and moderate correlation with the pain score (Fig. 2) at second-look arthroscopy following MMPRT transtibial pullout repair. Our results suggest that the second-look arthroscopic score using this system may be a useful scale to determine and compare the healing status of the MM posterior root. In addition, the KOOS QOL composed of 4 simple questionnaires at 1 year postoperatively may be a possible score to predict the future clinical outcome and meniscal function during the follow-up period after MMPRT repair. The status of the MM medial extrusion can affect postoperative clinical outcome of the MMPRT transtibial pullout repair [22]. Patients with decreased MM extrusion (3.5 ± 1.4 mm) at 1 year post-MMPRT pullout repairs have more favorable clinical outcomes and radiographic findings at 5-year follow-up than those with increased MM extrusion (5.1 ± 1.4 mm) at 1 year postoperatively [9]. Further investigations will be required to evaluate the usefulness of our arthroscopic scoring system and transtibial pullout repair in the treatment of MMPRT.

Despite filamentous anteroposterior width of bridging tissues and detached posterior root were not observed at second-look arthroscopy, meniscal healing status showed various scores ranged from 3 to 9. In the criterion for stability of the repaired MM posterior root, 7 knees out of 20 knees (35%) showed a fair stability that was defined as the repaired posterior root with no lifting on probing at 60° of knee flexion regardless of showing a lifting on probing at 20° of flexion. This may be caused by meniscal translation during knee motion and the suture fixation method at the pullout repair. Both medial and lateral menisci translate posteriorly on the tibial plateau during knee flexion. In normal knees, the posterior translation of the MM is a mean of 3.3 mm during deep knee flexion by an MRI analysis [23]. Masuda et al. have reported that the posterior shift of the MM posterior margin is a mean of 8.6 mm during knee flexion in patients suffering from the MMPRT [24]. These findings suggest that a firm stabilization of the MM posterior horn at the knee-extended position may induce a suture cutout through the repaired MM and result in a clinical failure following the MMPRT pullout repair. Tensile forces of the MM posterior horn increase to 20 N during knee flexion between 30° and 90° under loading conditions [25]. In our institute, tibial fixation of the sutures was performed at 45° of knee flexion with a tension of 20 N to avoid suture cutout and rupture. To obtain a good stability (no lifting) on probing at 20° of flexion, a lower knee flexion angle will be required at the suture fixation rather than 45° of flexion. However, tensile forces applied to the MM posterior horn and repaired tissue vary in tibial tunnel

position, property of suture thread, and suture configuration. In addition, the posterior translation of the MM differs for each patient. Severity of meniscal bulging/swelling that expresses a giraffe neck sign on the MM posterior segment may also affect the posterior translation of repaired MM following the MMPRT pullout repair [19]. We consider that an optimization of the suture fixation for each patient will be necessary to obtain a better clinical outcome during the long-term follow-up period.

Conclusions

This study demonstrated that our semi-quantitative scoring system of meniscal healing correlated with the KOOS QOL subscale following MMPRT transtibial pullout repair. Our results suggest that the second-look arthroscopic score using this system may be a useful scale to determine and compare the postoperative healing status of the MM posterior root in the treatment of MMPRT.

Acknowledgments

We thank Drs. Hiroto Inoue, Tomohito Hino, Yusuke Kamatsuki, Yoshiki Okazaki, Shin Masuda, and Yuki Okazaki for their clinical supports.

Compliance with ethical standards

Informed consent

Informed consent was obtained from all patients for being included in this study.

Conflict of interest

The authors have no conflict of interest.

Funding information

No funding sources were provided for this study.

References

1. Bhatia S, LaPrade CM, Ellman MB, LaPrade RF (2014) Meniscal root tears: significance, diagnosis, and treatment. *Am J Sports Med* 42(12):3016-3030
2. Yamagami R, Taketomi S, Inui H, Tahara K, Tanaka S (2017) The role of medial meniscus posterior root tear and proximal tibial morphology in the development of spontaneous osteonecrosis and osteoarthritis of the knee. *Knee* 24(2):390-395
3. Furumatsu T, Kodama Y, Kamatsuki Y, Hino T, Okazaki Y, Ozaki T (2017) Meniscal extrusion progresses shortly after the medial meniscus posterior root tear. *Knee Surg Relat Res* 29(4):295-301
4. Krych AJ, Reardon PJ, Johnson NR, Mohan R, Peter L, Levy BA, Stuart MJ (2017) Non-operative management of medial meniscus posterior horn root tears is associated with worsening arthritis and poor clinical outcome at 5-year follow-up. *Knee Surg Sports Traumatol Arthrosc* 25(2):383-389
5. Han SB, Shetty GM, Lee DH, Chae DJ, Seo SS, Wang KH, Yoo SH, Nha KW (2010) Unfavorable results of partial meniscectomy for complete posterior medial meniscus root tear with early osteoarthritis: a 5- to 8-year follow-up study. *Arthroscopy* 26(10):1326-1332
6. Krych AJ, Johnson NR, Mohan R, Dahm DL, Levy BA, Stuart MJ (2018) Partial meniscectomy provides no benefit for symptomatic degenerative medial meniscus posterior root tears. *Knee Surg Sports Traumatol Arthrosc* 26(4):1117-1122
7. Bonasia DE, Pellegrino P, D'Amelio A, Cottino U, Rossi R (2015) Meniscal root tear repair: why, when and how? *Orthop Rev (Pavia)* 7(2):5792
8. Kim JH, Chung JH, Lee DH, Lee YS, Kim JR, Ryu KJ (2011) Arthroscopic suture anchor repair versus pullout suture repair in posterior root tear of the medial meniscus: a prospective comparison study. *Arthroscopy* 27(12):1644-1653
9. Chung KS, Ha JK, Ra HJ, Kim JG (2016) A meta-analysis of clinical and radiographic outcomes of posterior horn medial meniscus root repairs. *Knee Surg Sports Traumatol Arthrosc* 24(5):1455-1468
10. Chung KS, Noh JM, Ha JK, Ra HJ, Park SB, Kim HK, Kim JG (2018) Survivorship analysis and clinical outcomes of transtibial pullout repair for medial meniscus posterior root tears: a 5- to 10-year follow-up

study. *Arthroscopy* 34(2):530-535

11. LaPrade CM, Foad A, Smith SD, Turnbull TL, Dornan GJ, Engebretsen L, Wijdicks CA, LaPrade RF (2015) Biomechanical consequences of a nonanatomic posterior medial meniscal root repair. *Am J Sports Med* 43(4):912-920
12. Kaplan DJ, Alaia EF, Dold AP, Meislin RJ, Strauss EJ, Jazrawi LM, Alaia MJ (2017) Increased extrusion and ICRS grades at 2-year follow-up following transtibial medial meniscal root repair evaluated by MRI. *Knee Surg Sports Traumatol Arthrosc* (in press)
13. Seo HS, Lee SC, Jung KA (2011) Second-look arthroscopic findings after repairs of posterior root tears of the medial meniscus. *Am J Sports Med* 39(1):99-107
14. Nha KW, Lee YS, Hwang DH, Kwon JH, Chae DJ, Park YJ, Kim JI (2013) Second-look arthroscopic findings after open-wedge high tibia osteotomy focusing on the posterior root tears of the medial meniscus. *Arthroscopy* 29(2):226-231
15. Kodama Y, Furumatsu T, Fujii M, Tanaka T, Miyazawa S, Ozaki T (2016) Pullout repair of a medial meniscus posterior root tear using a FasT-Fix all-inside suture technique. *Orthop Traumatol Surg Res* 102(7):951-954
16. Furumatsu T, Kodama Y, Fujii M, Tanaka T, Hino T, Kamatsuki Y, Yamada K, Miyazawa S, Ozaki T (2017) A new aiming guide can create the tibial tunnel at favorable position in transtibial pullout repair for the medial meniscus posterior root tear. *Orthop Traumatol Surg Res* 103(3):367-371
17. Fujii M, Furumatsu T, Kodama Y, Miyazawa S, Hino T, Kamatsuki Y, Yamada K, Ozaki T (2017) A novel suture technique using the FasT-Fix combined with Ultrabraid for pullout repair of the medial meniscus posterior root tear. *Eur J Orthop Surg Traumatol* 27(4):559-562
18. Choi SH, Bae S, Ji SK, Chang MJ (2012) The MRI findings of meniscal root tear of the medial meniscus: emphasis on coronal, sagittal and axial images. *Knee Surg Sports Traumatol Arthrosc* 20(10):2098-2103
19. Furumatsu T, Fujii M, Kodama Y, Ozaki T (2017) A giraffe neck sign of the medial meniscus: A characteristic finding of the medial meniscus posterior root tear on magnetic resonance imaging. *J Orthop Sci* 22(4):731-736
20. LaPrade CM, James EW, Cram TR, Feagin JA, Engebretsen L, LaPrade RF (2015) Meniscal root tears: a

classification system based on tear morphology. *Am J Sports Med* 43(2):363-369

21. Bae JH, Paik NH, Park GW, Yoon JR, Chae DJ, Kwon JH, Kim JI, Nha KW (2013) Predictive value of painful popping for a posterior root tear of the medial meniscus in middle-aged to older Asian patients. *Arthroscopy* 29(3):545-549
22. Furumatsu T, Kamatsuki Y, Fujii M, Kodama Y, Okazaki Y, Masuda S, Ozaki T (2017) Medial meniscus extrusion correlates with disease duration of the sudden symptomatic medial meniscus posterior root tear. *Orthop Traumatol Surg Res* 103(8):1179-1182
23. Yao J, Lancianese SL, Hovinga KR, Lee J, Lerner AL (2008) Magnetic resonance image analysis of meniscal translation and tibio-menisco-femoral contact in deep knee flexion. *J Orthop Res* 26(5):673-684
24. Masuda S, Furumatsu T, Okazaki Y, Kodama Y, Hino T, Kamatsuki Y, Miyazawa S, Ozaki T (2018) Medial meniscus posterior root tear induces pathological posterior extrusion of the meniscus in the knee-flexed position: An open magnetic resonance imaging analysis. *Orthop Traumatol Surg Res* 104(4):485-489
25. Markolf KL, Jackson SR, McAllister DR (2012) Force measurements in the medial meniscus posterior horn attachment: effects of anterior cruciate ligament removal. *Am J Sports Med* 40(2):332-338

Figure legends

Figure 1. Arthroscopic findings. (A) Type 2 MMPRT was observed at transtibial pullout repair (the left knee). (B) MM posterior horn was stabilized by a modified Mason-Allen suture using the FasT-Fix. (C-F) Second-look arthroscopic images at 1 year postoperatively. (C) Laxity of the repaired MM posterior root at 20° of knee flexion. The suture was partially covered by synovial tissues. (D) At 60° of knee flexion, the MM posterior root showed a “fair” stability with no lifting on probing. (E) Lifting on probing at 20° of knee flexion. (F) No anterior drawing at 20° of knee flexion. The meniscal healing score of this patient was a total of 8 (4/3/1) at second-look arthroscopy.

Figure 2. Correlations between second-look arthroscopic scores and postoperative clinical outcomes. (A) Correlation between meniscal healing score and KOOS QOL score at second-look arthroscopy. The regression equation was linear: $\text{KOOS QOL} = 7.326 \times \text{arthroscopic score} + 12.009$ ($R^2 = 0.587$). (B) Correlation between meniscal healing score and pain score at second-look arthroscopy. The regression equation was linear: pain = $-6.535 \times \text{arthroscopic score} + 57.628$ ($R^2 = 0.317$).