



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

Takayuki Furumatsu¹ · Shinichi Miyazawa¹ · Masataka Fujii¹ · Takaaki Tanaka¹ · Yuya Kodama¹ · Toshifumi Ozaki¹

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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 one year post-operatively using a semi-quantitative arthroscopic scoring system (total, 10 points) composed of three 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 one year post-operatively. 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 five year follow-up [6]. In the treatment of the MMPRT, early diagnosis and appropriate surgical

✉ Takayuki Furumatsu
matino@md.okayama-u.ac.jp

¹ Department of Orthopaedic Surgery, Okayama University Hospital, 2-5-1 Shikata-cho, Kita-ku, Okayama 700-8558, Japan

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 favourable 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 five years post-operatively [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 two years post-operatively [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 post-operatively [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 one year post-operatively.

Surgical procedure and post-operative 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 pre-operative 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.

Table 1 Patient demographics

		First–third quartiles
Number of patients	20	
Gender, men/women	2/18	
Root tear classification	0/17/0/3/0	
Type 1/2/3/4/5		
Age, years	64.5	57.25–67
Height, m	1.545	1.51–1.60
Body weight, kg	66.5	57.25–69.5
Body mass index, kg/m ²	26.64	25.04–28.33

Data of age, height, body weight, and body mass index are displayed as medians

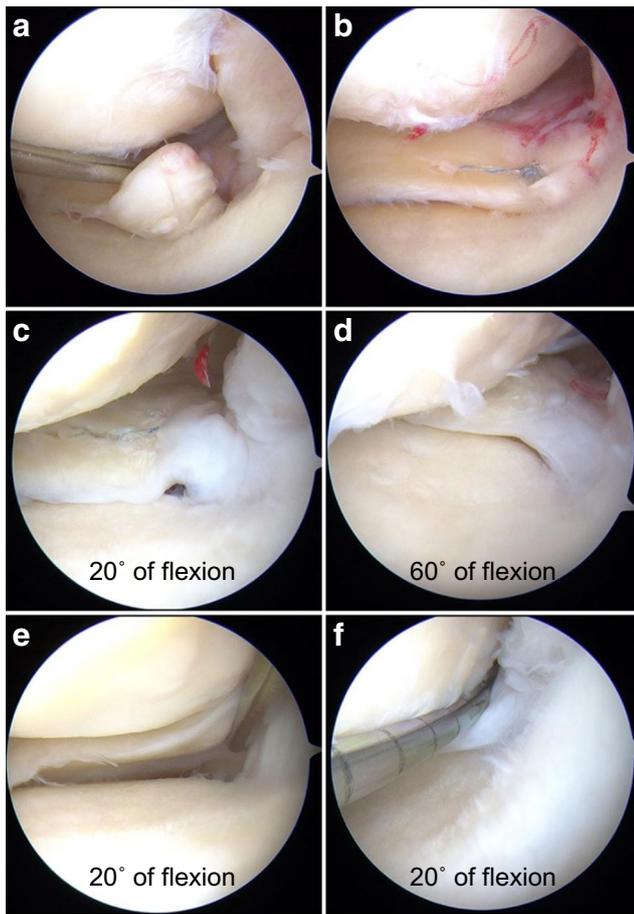


Fig. 1 Arthroscopic findings. **a** Type 2 MMPRT was observed at transtibial pullout repair (the left knee). **b** MM posterior horn was stabilized by a modified Mason-Allen suture using the FasT-Fix. **c–f** Second-look arthroscopic images at 1 year post-operatively. **c** Laxity of the repaired MM 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

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 five or six 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 (post-operative 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 sub-scales: 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 three 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. 1c–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 coverage 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 pre-operative and post-operative 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

Table 2 Clinical outcomes

	Pre-operative score (first–third quartiles)	Post-operative score (first–third quartiles)	<i>P</i> value
KOOS			
Pain	56 (42–70)	89 (70–94)	< 0.001
Symptoms	68 (49–80)	80.5 (68–89)	0.018
ADL	71.5 (53–79)	91.2 (82–95)	< 0.001
Sport/rec	22.5 (10–50)	60 (29–85)	0.003
QOL	34.65 (19–46)	58.15 (50–71)	< 0.001
Lysholm knee score	60 (56–79)	86.5 (83–94)	< 0.001
Tegner activity score	2 (1–2)	3 (3–4)	< 0.001
IKDC score	37.9 (29–50)	64.4 (50–69)	< 0.001
Pain score (VAS)	52 (29–68)	7.5 (2–18)	< 0.001

Data are displayed as medians and first–third quartiles

KOOS Knee Injury and Osteoarthritis Outcome Score, *ADL* activities of daily living, *Sport/Rec* sport and recreation function, *QOL* knee-related quality of life, *IKDC* International Knee Documentation Committee, *VAS* visual analogue scale

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 one year post-operatively (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, fila-

mentous 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 one 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 ($R^2 = 0.020$).

Table 3 Arthroscopic scoring system of the meniscal healing following transtibial pullout repair

Anteroposterior width of bridging tissues	Stability of the medial meniscus posterior root (lifting and/or anterior drawing at 20° or 60° of knee flexion)	Synovial coverage of the sutures
4 Broad (> 5 mm)	4 Good 3 Fair	No lifting on probing at 20° of flexion
2 Narrow (2–5 mm)	2 Loose 1 Useless	Lifting on probing at 20° of flexion, but no lifting at 60° of flexion
0 Filamentous (< 2 mm)	0 Detached	Lifting on probing at 60° of flexion, but no anterior drawing at 20° of flexion
		Anterior drawing on probing at 20° of flexion
		Totally unstable
		2 Good Almost covered
		1 Fair Partially covered
		0 Poor Totally exposed or ruptured

Numbers in italics denote each score. Width, 0/2/4 points. Stability, 0/1/2/3/4 points. Coverage, 0/1/2 points. Perfect score, 10 points

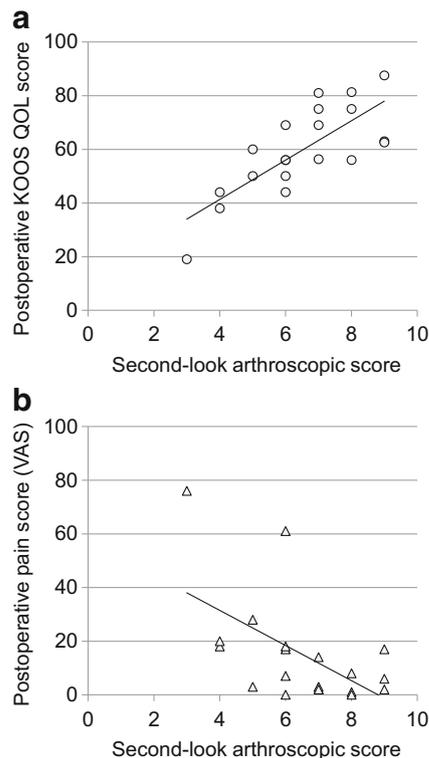


Fig. 2 Correlations between second-look arthroscopic scores and postoperative clinical outcomes. **a** Correlation between meniscal healing score and KOOS QOL score at second-look arthroscopy. The regression equation was linear: $\text{KOOS QOL} = 7.326 \times \text{arthroscopic score} + 12.009$ ($R^2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

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 post-operative 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 four simple questionnaires at one year post-operatively 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 one year post-MMPRT pullout repairs have more favourable clinical outcomes and radiographic findings at 5-five year follow-up than those with increased MM extrusion (5.1 ± 1.4 mm) at one year post-operatively [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, seven 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.

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Compliance with ethical standards

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

Conflict of interest The authors declare that they have no competing interests.

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