



Pullout repair using modified Mason-Allen suture induces better meniscal healing and superior clinical outcomes: A comparison between two surgical methods

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ABSTRACT

Background: Pullout repairs of medial meniscus posterior root tears (MMPRTs) have many surgical options. However, there has been no reliable clinical study conducted to compare the superiority of each pullout repair technique. The current study hypothesized that pullout repairs using a modified Mason-Allen suture with FasT-Fix (F-MMA) would have several advantages in postoperative clinical outcomes and meniscal healing compared with single FasT-Fix. The aim of this study was to investigate the clinical usefulness of these two techniques in treating MMPRTs.

Methods: Thirty-eight patients who had complete MMPRTs were included. All patients underwent trans tibial pullout repairs. To compare the clinical usefulness between pullout repairs using single FasT-Fix and F-MMA techniques, patients were divided into two groups. Second-look arthroscopic evaluations of meniscal healing were performed at one year postoperatively. Clinical outcomes were assessed using: Lysholm and visual analogue scale (VAS) pain scores, and Knee Injury and Osteoarthritis Outcome Score (KOOS).

Results: Single FasT-Fix and F-MMA pullout repairs improved clinical outcomes in patients with MMPRTs. At second-look arthroscopy, VAS pain, KOOS pain, and arthroscopic meniscal healing scores following F-MMA pullout repairs were superior to those after single FasT-Fix pullout repairs.

Conclusions: This study demonstrated that F-MMA suture configuration obtained better meniscal healing and superior clinical outcomes compared with single FasT-Fix repairs in patients with MMPRTs. These results suggest that the F-MMA pullout repair may possibly reduce knee pain in arthroscopic treatments of MMPRTs.

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1. Introduction

A medial meniscus (MM) posterior root can serve as an anchor to control meniscal movement during knee motion and load bearing. Injuries to the MM posterior root, including complete radial and/or oblique tears adjacent to the posterior root attachment, lead to accelerated degradation of the knee joint articular cartilage by disrupting meniscal functions [1]. Medial meniscus posterior root tears (MMPRTs) lead to rapid progression of knee osteoarthritis (OA) by inducing abnormal tibiofemoral joint biomechanics [2,3]. Therefore, in the treatment of MMPRTs, early diagnosis and appropriate surgical intervention are important for obtaining a successful clinical outcome and preventing progression of degenerative knee joint diseases [1,4]. Several meniscus 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 MMPRTs [1,4–7]. LaPrade et al. described that MM posterior root repairs should be indicated in active patients following acute or chronic MMPRTs with no significant knee OA, joint space narrowing, and malalignment [8]. They preferred transtibial pullout repair because of the decreased technical difficulty and ability to restore an anatomic attachment of the MM posterior root [8]. Although there is currently a lack of consensus as to what is the superior technique, transtibial pullout repairs are increasingly being used in clinical practice.

Transtibial pullout repairs using two or three simple stitches demonstrate a high clinical survival rate (99%) in patients with MMPRTs at five years postoperatively [7]. However, there are many surgical options involved in suture configuration, suturing materials, thread composition, and number or diameter of the tibial tunnel. Kodama et al. reported a simple pullout repair technique to stabilize the MM posterior horn using a FasT-Fix all-inside meniscal suture device (Smith & Nephew, Andover, MA, USA) [9]. The FasT-Fix pullout repair technique seems to have an advantage in preserving meniscal position by stabilizing the unstable MM with posterior joint capsule if the pullout thread is broken or worn out during the postoperative follow-up period [10]. Several authors have demonstrated the superiority of a modified Mason-Allen (MMA) suture configuration in a load-to-failure test using porcine menisci compared with two simple stitches [11–13]. The ultimate failure load was significantly greater in the MMA suture using the FasT-Fix (F-MMA) than two simple stitches, and similar to the conventional MMA suture [12,14]. Previous studies have used the transtibial pullout repair using two simple stitches as the major surgical procedure for treating MMPRTs [5,7,8,15]. However, composition of suturing threads, tibial tunnel position, tunnel diameter, and initial tension at suture fixation are different. There is no reliable clinical study to compare the superiority of each suture configuration in the pullout repair of MMPRTs.

Based on these findings, it was hypothesized that pullout repair using the F-MMA technique would have several advantages in postoperative clinical outcomes and meniscal healing status compared with the FasT-Fix pullout repair. The aim of this study was to prospectively investigate the clinical usefulness of these two pullout repair techniques in the arthroscopic treatment of MMPRTs.

2. Materials and methods

This study received the approval of the Institutional Review Board, and written informed consent was obtained from all patients. Thirty-eight patients (33 women and five men) who had episodes of a sudden posteromedial painful popping, continuous knee pain, and complete radial MMPRT (type 2) between January 2015 and July 2017 were included (Table 1). Patients who had radiographic knee OA Kellgren–Lawrence \geq grade III and a previous history of meniscus injury or knee surgery were excluded. All the patients were diagnosed as having MMPRTs with magnetic resonance imaging (MRI) examinations and met operative indications for arthroscopic transtibial pullout repair [3,9,14,16,17]. 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 nine millimeters from the attachment [18,19].

All the patients underwent transtibial pullout repair for the treatment of MMPRT between April 2015 and August 2017. Patients were divided into two groups to compare the clinical usefulness between pullout repairs using FasT-Fix alone and F-MMA technique. Patients were allocated to each pullout repair technique according to the period of surgical treatment. Pullout repairs using FasT-Fix alone were performed between April 2015 and September 2016 ($n = 17$). Pullout repairs using F-MMA technique were performed between October 2016 and August 2017 ($n = 21$). Types of MMPRT were determined by careful arthroscopic examinations according to meniscal root tear

Table 1
Patient demographics.

	FasT-Fix	F-MMA	P value
Number of patients	17	21	
Gender, men/women	1/16	4/17	0.355 ^a
Age, years	59.2 \pm 9.8	61.7 \pm 7.4	0.194
Height, m	1.56 \pm 0.06	1.57 \pm 0.07	0.459
Body weight, kg	66.4 \pm 15.8	63.9 \pm 8.7	0.278
Body mass index, kg/m ²	27.1 \pm 5.8	26.1 \pm 3.3	0.263
Duration from injury to pullout repair, days	123 \pm 60	93 \pm 73	0.114

F-MMA, FasT-Fix-dependent modified Mason-Allen. Data of age, height, body weight, and body mass index are displayed as a mean \pm standard deviation. Statistical differences in age, height, body weight, and body mass index between two groups were analyzed using Mann–Whitney U-test.

^a Fisher's exact test.

classification [20]. Second-look arthroscopic evaluation of meniscal healing and fixation device removal were performed in all patients at one year postoperatively [10].

2.1. Surgical procedures and postoperative care

Indications for transtibial pullout repair of MMPRTs were patients with femorotibial angle $<180^\circ$ and Kellgren–Lawrence grades 0–II, which was confirmed with pre-operative standing radiographs, at the current institute. A standard arthroscopic examination was performed through routine anteromedial and anterolateral portals. A type 2 MMPRT was evaluated on probing [20]. In the group of pullout repair using FasT-Fix alone, the MM posterior horn was grasped using a single FasT-Fix 360 reverse curve (Figure 1a and b) [9]. The needle penetrated the meniscal horn and posterior joint capsule using the oblique or horizontal mattress suture technique via the anteromedial portal, and the inserted FasT-Fix knot was adequately fastened. The free end of the FasT-Fix suture was preserved. The uncut free end of the FasT-Fix suture was used for transtibial pullout repair. In the F-MMA pullout repair group, No. 2 Ultrabraid and FasT-Fix 360 reverse curve (Smith & Nephew) were used to stabilize the MM posterior horn in the MMA suture configuration (Figure 1c and d) [14]. An MMPRT aiming guide (Smith & Nephew) was placed at an anatomic insertion of the MM posterior root [16]. The MMPRT guide can be narrowed to create an accurate tibial bone tunnel at the anatomic attachment of the MM posterior root, without damaging the medial femoral condyle articular surface [16]. A 2.4-mm guide pin was inserted at a 50° angle to the articular surface, and a tibial tunnel was created with a 4.5-mm cannulated drill. Ultrabraid and/or 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.

No intraoperative complications were observed in the MM posterior root repairs. After the pullout repair, patients were initially kept non-weight bearing in the knee immobilizer for two weeks. Between two and four weeks, knee flexion exercise was gradually increased up to 30° , 60° , and 90° under partial weight bearing conditions (one third, half, and two thirds of body weight). After five or six weeks, patients were allowed full weight bearing and 120° of knee flexion.

2.2. Clinical scores

Clinical evaluations were performed at the time of pullout repair (pre-operative scores, Table 2) and second-look arthroscopy (postoperative scores, Table 3). Clinical outcomes were assessed using the Lysholm knee score, Tegner activity score, pain score evaluated by visual analogue scale (VAS), International Knee Documentation Committee (IKDC) subjective knee evaluation form, and Japanese Knee Injury and Osteoarthritis Outcome Score (KOOS). The KOOS consists of five subscales: pain, symptoms,

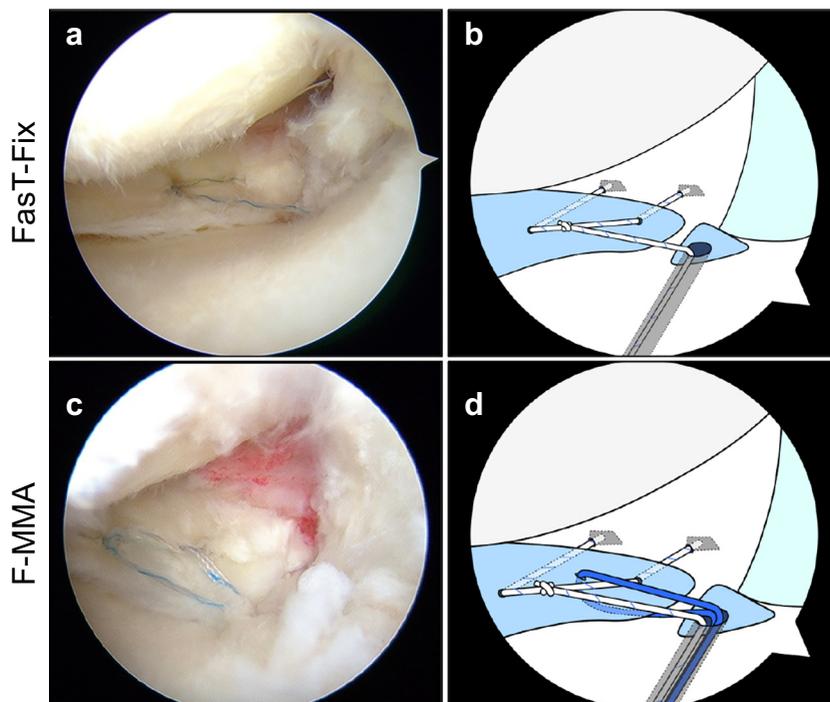


Figure 1. Two types of pullout repair (suture configurations). a and b: Allen (F-MMA) pullout repair using FasT-Fix alone. Posterior horn of the medial meniscus was grasped using a single FasT-Fix 360 reverse curve. c and d: FasT-Fix modified Mason-Allen pullout repair using No. 2 Ultrabraid and FasT-Fix 360 reverse curve. The uncut free ends of the FasT-Fix suture and/or Ultrabraid were retrieved from the tibial tunnel at an anatomic attachment of the medial meniscal posterior root. Note that the FasT-Fix needle was penetrated into the meniscal horn and posterior joint capsule.

Table 2
Preoperative clinical characteristics.

	FasT-Fix	F-MMA	P value
Lysholm knee score	56.8 ± 11.9	61.3 ± 9.0	0.110
Tegner activity score	1.4 ± 1.0	1.9 ± 0.9	0.068
Pain score (VAS)	53.9 ± 18.5	45.1 ± 29.2	0.146
IKDC score	31.5 ± 12.7	38.3 ± 14.2	0.069
KOOS			
Pain	50.7 ± 14.4	56.7 ± 26.2	0.190
Symptoms	54.0 ± 18.0	62.9 ± 17.5	0.075
ADL	57.1 ± 16.1	66.8 ± 21.3	0.064
Sport/Rec	17.7 ± 17.6	26.9 ± 21.4	0.083
QOL	24.4 ± 17.3	33.3 ± 19.2	0.070

F-MMA, FasT-Fix-dependent modified Mason-Allen. VAS, visual analogue scale. IKDC, International Knee Documentation Committee. KOOS, Knee Injury and Osteoarthritis Outcome Score. ADL, activities of daily living. Sport/Rec, sport and recreation function. QOL, knee-related quality of life. Data are displayed as a mean ± standard deviation.

activities of daily living, 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).

2.3. Arthroscopic meniscal healing scores

The healing status of the MM following transtibial pullout repair was assessed by second-look arthroscopy, according to the Furumatsu scoring system [10]. A semi-quantitative arthroscopic scoring system comprised three evaluation criteria: (i) anteroposterior width of bridging tissues between the MM posterior horn and root attachment (0, 2, and 4 points); (ii) stability of the repaired MM posterior root (0, 1, 2, 3, and 4 points); and (iii) synovial coverage of the sutures (0, 1, and 2 points) [10]. A perfect score on the meniscal healing was set at 10 points. Two or more orthopedic surgeons retrospectively evaluated meniscal healing scores in a blinded manner. A mean of each evaluation score was determined as a value of each patient.

2.4. Statistical analysis

Data were presented as a mean ± standard deviation. Statistical between-group differences were analyzed using the Mann–Whitney U tests. Genders were compared using the Fisher's Exact test. Differences between the pre-operative and postoperative clinical outcome scores were compared using 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 $P < 0.05$.

3. Results

Mean ages of the FasT-Fix and F-MMA groups were 59.2 and 61.7 years at the pullout repair, respectively (Table 1). Patient demographics and clinical characteristics were similar in the two groups pre-operatively (Tables 1 and 2). F-MMA pullout repairs using the FasT-Fix alone significantly improved clinical outcomes such as Lysholm knee, VAS pain, IKDC, and KOOS scores at one year postoperatively (Figure 2a). FasT-Fix modified MMA pullout repairs also improved clinical scores in patients with MMPRTs, except for the symptoms subscale of KOOS (Figure 2b). In clinical evaluations at second-look arthroscopy, VAS pain, KOOS pain,

Table 3
Clinical characteristics at second-look arthroscopy (1 year postoperatively).

	FasT-Fix	F-MMA	P value
Lysholm knee score	85.9 ± 6.7	86.4 ± 8.0	0.429
Tegner activity score	3.0 ± 0.8	3.0 ± 0.7	0.500
Pain score (VAS)	21.6 ± 22.5	4.5 ± 5.3	0.004**
IKDC score	59.4 ± 15.2	67.2 ± 14.5	0.082
KOOS			
Pain	75.1 ± 20.5	89.7 ± 8.1	0.007**
Symptoms	76.7 ± 16.2	80.5 ± 14.6	0.248
ADL	85.5 ± 12.5	91.1 ± 7.0	0.062
Sport/Rec	43.5 ± 29.4	65.0 ± 26.5	0.021*
QOL	59.7 ± 17.9	65.7 ± 18.1	0.181
Arthroscopic score ^a	6.0 ± 1.6	7.2 ± 1.4	0.026*

F-MMA, FasT-Fix-dependent modified Mason-Allen. VAS, visual analogue scale. IKDC, International Knee Documentation Committee. KOOS, Knee Injury and Osteoarthritis Outcome Score. ADL, activities of daily living. Sport/Rec, sport and recreation function. QOL, knee-related quality of life. Data are displayed as a mean ± standard deviation.

^a Meniscal healing score at second-look arthroscopy (total, 10 points).

* $P < 0.05$.

** $P < 0.01$.

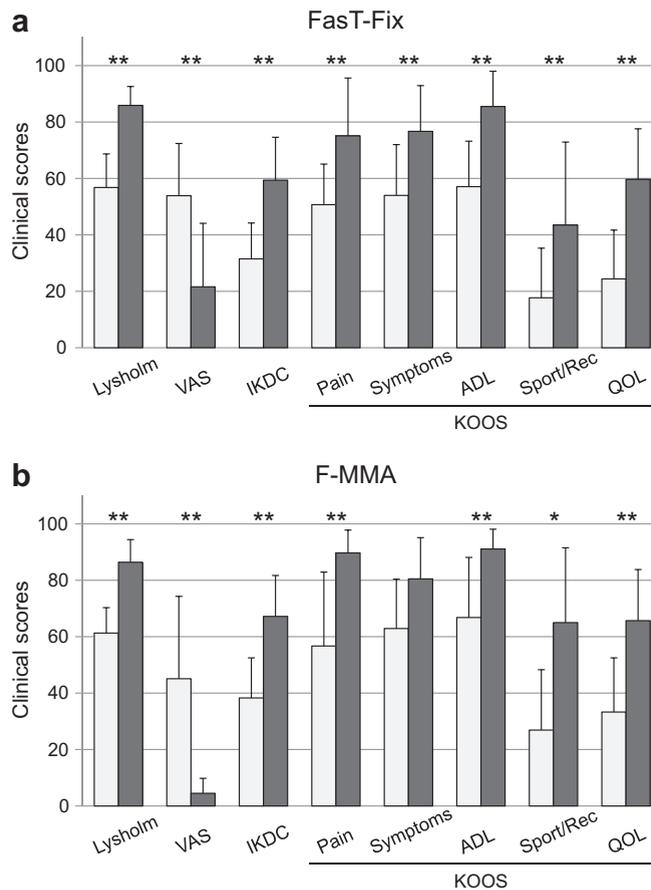


Figure 2. Clinical scores at pre-operative and postoperative evaluations. Pullout repairs using FasT-Fix alone (a) or FasT-Fix modified Mason-Allen suture technique (b). Light gray bars are pre-operative scores. Dark gray bars are postoperative scores. ADL, activities of daily living; IKDC, International Knee Documentation Committee; F-MMA, FasT-Fix modified Mason-Allen; Sport/Rec, sport and recreation function; QOL, knee-related quality of life; VAS, visual analogue scale. * $P < 0.05$. ** $P < 0.01$.

and KOOS Sport/Rec scores following F-MMA pullout repairs were superior to those after FasT-Fix pullout repairs (Table 3). In addition, arthroscopic meniscal healing scores were higher in the F-MMA group (a mean of 7.2 points) than in the single FasT-Fix group (a mean of 6.0 points, Table 3).

4. Discussion

The most important finding in this study was that the F-MMA pullout repairs obtained better meniscal healing and superior clinical outcomes in patients with MMPRTs compared with the single FasT-Fix pullout repairs. These results confirmed the hypothesis that the F-MMA technique would have several advantages in postoperative clinical outcomes and meniscal healing status compared with the FasT-Fix pullout repair. Although these two pullout repair techniques would achieve favorable postoperative clinical outcomes during a short-term follow-up period, the pullout repair using F-MMA suture configuration may be more useful in reducing knee pain than the FasT-Fix alone.

Arthroscopic pullout repairs reduced tibiofemoral contact pressure by increasing tibiofemoral contact area in an experimental MMPRT model using human cadaveric knees [21]. Several studies have demonstrated that arthroscopic meniscus repairs such as the transtibial pullout repair and suture anchor repair for MMPRTs can result in favorable clinical outcomes postoperatively [5–7]. A pullout repair using two simple stitches (No. 2–0 PDS sutures) and two tibial tunnels improved VAS pain score from 74 pre-operatively to 25 at a mean follow-up of 33 months [15]. This technique increased the mean Lysholm knee score from 48.3 to 83.2 at final follow-up [15]. A transtibial single-tunnel pullout repair using one vertical mattress suture (No. 2 Ethibond) improved the mean Lysholm score from 55 to 93 at a mean of 27 months of follow-up [5]. A suture anchor repair also increased the Lysholm score from 54 to 93 at a mean of 26 months of follow-up [5]. During a longer follow-up period (a mean of 85 months), a transtibial pullout repair using two or three simple stitches (No. 1 PDS sutures) improved the mean Lysholm score from 52 pre-operatively to 83 at the final follow-up [7].

In the current study, the FasT-Fix (No. 2–0 suture) single-tunnel pullout repair increased the mean Lysholm score from 56.8 to 85.9 at one year postoperatively. In addition, the F-MMA (No. 2 and 2–0 sutures) pullout repair improved the Lysholm score from

61.3 to 86.4 (Tables 2 and 3). Based on these findings, it was concluded that the pullout repair techniques obtained favorable clinical outcomes similar to previous reports in patients with MMPRTs. However, the Lysholm knee score may not be suitable for evaluating middle-aged or older patients who have MMPRTs, and for comparing several pullout repair techniques in the treatment of MMPRTs.

This study demonstrated that VAS pain, KOOS pain, KOOS Sport/Rec, and arthroscopic meniscal healing scores following F-MMA pullout repairs were superior to those after single FasT-Fix pullout repairs (Table 3). However, postoperative Lysholm, Tegner, and IKDC scores were similar in these two pullout repair techniques. These results suggest that clinical evaluation systems for young and active patients cannot detect a small difference in postoperative clinical outcomes following several types of transtibial pullout repairs in patients with MMPRTs. Postoperative VAS pain score, KOOS pain, and KOOS Sport/Rec subscales may be useful for evaluating the effect of pullout repair on meniscal healing in patients with MMPRTs. Several authors have described 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 treatments for MMPRTs [22,23].

It is believed that the reason why improvements in clinical scores showed no association with arthroscopic meniscal healing status in several studies may depend on qualitative second-look evaluation systems involved in three-stage or four-stage classification such as complete/incomplete/no healing and complete/lax/scar tissue/failed healing [22,23]. However, Furumatsu et al. demonstrated that the semi-quantitative arthroscopic score of meniscal healing shows significant correlations with the KOOS, QOL and VAS pain scores at second-look arthroscopy following transtibial pullout repairs in patients with MMPRTs [10]. The Furumatsu meniscal healing score is a useful scale to compare the superiority between these two transtibial pullout repair techniques, by evaluating the healing status of the MM posterior root. In addition, the results suggest that VAS pain score, KOOS pain, and KOOS Sport/Rec subscales may be useful for comparing the superiority of each pullout repair technique if informed consent to second-look arthroscopic evaluation is not obtained from the patients.

Transtibial pullout repairs for appropriate patients with MMPRTs provide improvements in knee function, pain, and activity level, which may aid in delayed progression of knee OA [24]. Early diagnosis and appropriate surgical interventions are considered to be important in the treatment of MMPRTs. In the current study, both single FasT-Fix and F-MMA pullout repairs significantly improved clinical outcome scores in patients with sudden posteromedial painful popping episodes and complete radial type 2 MMPRTs. Among these two techniques, the F-MMA pullout repair was a more reliable technique to induce better meniscal healing than the single FasT-Fix pullout repair. It is considered that one vertical loop suture using No. 2 Ultrabraid may have an additional effect on meniscal healing by preventing a pathological posteromedial shift of the MM [25]. Other devices, such as interference screws, buttons, and anchor screws, for fixation of pullout sutures would have similar clinical outcomes if the knee flexion angle and initial tension at the suture fixation were the same as the current procedure [26]. An extremely strong suture fixation tension may induce a suture cutout following the MMPRT pullout repair. A longer follow-up study will be required to determine the superiority between these two pullout repair techniques in the treatment of MMPRTs.

This study had several limitations. The arthroscopic scoring system of MM posterior root repair was previously published by the current institution. There may have been some author biases. Several authors demonstrated a moderate-to-high meniscal healing rate following MM pullout repairs by MRI assessments [5,15]. The current study observed a bridging tissue formation between the MM posterior horn and root attachment in all cases by MRI analyses at three months and one year postoperatively. However, it may be difficult to semi-quantitatively evaluate the status of meniscal healing and connecting fibers by standard MRI analyses. Technical improvements will be required to precisely evaluate the healing status of MM posterior root using MRI examinations. In addition, a one-year postoperative follow-up period may be too short to evaluate the clinical outcomes following MM posterior root repair.

5. Conclusions

This study demonstrated that transtibial pullout repairs using the F-MMA suture configuration obtained better meniscal healing and superior clinical outcomes in patients with MMPRTs compared with single FasT-Fix pullout repairs. The results suggest that F-MMA pullout repair may be able to reduce postoperative knee pain better than single FasT-Fix pullout repair in arthroscopic treatments of MMPRTs.

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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.

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