Original paper

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 is no reliable clinical study to compare the superiority of each pullout repair technique. We 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 the single FasT-Fix pullout repairs. The aim of this study was to investigate the clinical usefulness of these two techniques in the treatment of MMPRTs.

Methods:

Thirty-eight patients who had complete MMPRTs were included. All patients underwent transtibial pullout

repairs. We divided the patients into two groups to compare the clinical usefulness between pullout repairs using single FasT-Fix and F-MMA techniques. Second-look arthroscopic evaluations of meniscal healing were performed at 1 year postoperatively. We assessed clinical outcomes using the Lysholm, visual analogue scale (VAS) pain scores, and Knee Injury and Osteoarthritis Outcome Score (KOOS).

Results:

Single FasT-Fix or 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 the F-MMA suture configuration obtained better meniscal healing and superior clinical outcomes in patients with MMPRTs compared with the single FasT-Fix repairs. Our results suggest the F-MMA pullout repair may have a possibility to reduce the knee pain in arthroscopic treatments of MMPRTs.

Keywords: Medial meniscus; Posterior root tear; Transtibial pullout repair; Clinical outcome; Meniscal healing

1. Introduction

A medial meniscus (MM) posterior root can serve as an anchor to control the meniscal movement 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, lead to accelerated degradation of the knee joint articular cartilage by disrupting meniscal functions [1]. MM posterior root tears (MMPRTs) lead to rapid progression of knee osteoarthritis by inducing abnormal biomechanics of the tibiofemoral joint [2, 3]. Therefore, in the treatment of MMPRTs, early diagnosis and appropriate surgical intervention are important in 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. describe that MM posterior root repairs should be indicated in active patients following acute or chronic MMPRTs with no significant knee osteoarthritis, joint space narrowing, and malalignment [8]. They prefer transtibial pullout repair because of the decreased technical difficulty and the ability to restore an anatomic attachment of the MM posterior root [8]. Although there is currently a lack of consensus on what is the superior technique, transtibial pullout repairs are increasingly used in clinical practice.

Transtibial pullout repairs using two or three simple stiches demonstrate a high clinical survival rate (99%) in patients with MMPRTs at 5 years postoperatively [7]. However, there are many surgical options involved in suture configuration, suturing materials, thread’s composition, and number or diameter of the tibial tunnel. Kodama et al. report 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 postoperative follow-up period [10]. Several authors demonstrate the superiority of a modified Mason-Allen (MMA) suture configuration in a load-to-failure test using porcine menisci compared with two simple stiches [11-13]. The ultimate failure load is significantly greater in the MMA suture using the FasT-Fix (F-MMA) than two simple stiches and similar to the conventional MMA suture [12, 14]. In previous studies, transtibial pullout repair using two simple stiches

is the major surgical procedure in the treatment of MMPRTs [5, 7, 8, 15]. However, composition of suturing threads, tibial tunnel position, tunnel diameter, and initial tension at suture fixation are different from each other. There is no reliable clinical study to compare the superiority of each suture configuration in the pullout repair of MMPRTs. Based on these findings, we 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 investigate the clinical usefulness of these two pullout repair techniques in the arthroscopic treatment of MMPRTs, prospectively.

2. Materials & methods

This study received the approval of our Institutional Review Board, and written informed consent was obtained from all patients. Thirty-eight patients (33 women and 5 men) who had episode 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 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 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 9 mm from the attachment [18, 19]. All the patients underwent transtibial pullout repair for the treatment of MMPRT between April 2015 and August 2017. We divided the patients into two groups to compare the clinical usefulness between pullout repairs using FasT-Fix alone and F-MMA technique. We allocated the patients 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 the MMPRT were determined by careful arthroscopic examinations according to the meniscal root tear classification [20]. Second-look arthroscopic evaluation of meniscal healing [10] and fixation device removal were performed in all patients at 1 year postoperatively.

2.1. Surgical procedures and postoperative cares

Indications for transtibial pullout repair of MMPRTs were patients with femorotibial angle < 180˚ 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. A type 2 MMPRT was evaluated on probing [20]. In the group of pullout repair using FasT-Fix alone, posterior horn of the MM was grasped using a single FasT-Fix 360 reverse curve (Fig. 1a and b) [9]. The needle was penetrated into the meniscal horn and posterior joint capsule using the oblique or horizontal mattress suture technique via the anteromedial portal, and the knot of the inserted FasT-Fix was fastened adequately. 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 (Fig. 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 articular surface of the medial femoral condyle [16]. A 2.4-mm guide pin was inserted at an angle of 50° 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 in this study. 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 was gradually increased up to 30˚, 60˚, and 90˚ under partial weight bearing condition (1/3, 1/2, and 2/3 of body weight). After 5 or 6 weeks, patients were allowed full weight bearing and 120˚ of knee flexion.

2.2. Clinical scores

Clinical evaluations (Table 2) were performed at the time of pullout repair (preoperative scores, Table 2) and second-look arthroscopy (postoperative scores, Table 3). We assessed clinical outcomes 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, 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).

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 was composed of 3 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 set at 10 points. Two or more orthopaedic surgeons evaluated meniscal healing scores retrospectively 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 differences between two groups were analyzed using the Mann-Whitney U-tests. Genders were compared using the Fisher's exact test. 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 $P < 0.05$.

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 two groups

preoperatively (Table 1 and 2). Pullout repairs using the FasT-Fix alone significantly improved clinical outcomes such as Lysholm knee, VAS pain, IKDC, and KOOS scores at 1 year postoperatively (Fig. 2a). F-MMA pullout repairs also improved clinical scores in patients with MMPRTs, except for symptoms subscale of KOOS (fig. 2b). In clinical evaluations at second-look arthroscopy, VAS pain, KOOS pain, 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 our 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 the short-term follow-up period, the pullout repair using F-MMA suture configuration may be more useful to reduce the knee pain than that using the FasT-Fix alone.

Arthroscopic pullout repairs can reduce a tibiofemoral contact pressure by increasing a tibiofemoral contact area in an experimental MMPRT model using human cadaveric knees [21]. Several studies demonstrate that arthroscopic meniscus repairs such as transtibial pullout repair and suture anchor repair for MMPRTs can result in favorable clinical outcomes postoperatively [5-7]. A pullout repair using two simple stiches (No. 2-0 PDS sutures) and two tibial tunnels improves VAS pain score from 74 preoperatively to 25 at a mean follow-up of 33 months [15]. This technique increases 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) improves the mean Lysholm score from 55 to 93 at a mean of 27 months follow-up [5]. A suture anchor repair also increases the Lysholm score from 54 to 93 at a mean of 26 months follow-up [5]. During a longer follow-up period (a mean of 85 months), a transtibial pullout repair using two or three simple stiches (No. 1 PDS sutures) improves the mean Lysholm score from 52 preoperatively to 83 at the final follow-up [7].

In our study, the FasT-Fix (No. 2-0 suture) single-tunnel pullout repair increased the mean Lysholm score from 56.8 to 85.9 at 1 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 (Table 2 and 3). Based on these findings, we consider that our 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 had 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 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 treatments of MMPRTs [22, 23]. We consider that the reason why improvements in clinical scores showed no association with arthroscopic meniscal healing status in several literatures may depend on qualitative second-look evaluation systems involved in three- or four-staged classification such as complete/incomplete/no healing and complete/lax/scar tissue/failed healing [22, 23]. On the other hand, Furumatsu et al. demonstrate 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 was 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, our 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 osteoarthritis [24]. Early diagnosis and appropriate surgical interventions are considered to be important in the treatment of MMPRTs. In our study, both of the 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 (Fig. 3). 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. We consider 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]. The other devices, such as interference screws, buttons, and anchor screws, for fixation of pullout sutures [26] would have similar clinical outcomes if the knee flexion angle and initial tension at the suture fixation are the same as our procedure. We consider that an extremely strong tension of suture fixation 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.

There are several limitations in this study. The arthroscopic scoring system of MM posterior root repair used in this manuscript was published by our own institute. There may be some authors' biases. Several authors demonstrate that moderate to high meniscal healing rate following MM pullout repairs by MRI assessments [5, 15]. We observed a bridging tissue formation between the MM posterior horn and root attachment in all cases by MRI analyses at 3 months and 1 year postoperatively. However, it may be difficult to evaluate the status of meniscal healing and connecting fibers semi-quantitatively by standard MRI analyses. Technical improvements will be required to evaluate the healing status of MM posterior root precisely using MRI examinations. In addition, 1-year postoperative follow-up period may be 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 the single FasT-Fix pullout repairs. Our results suggest the F-MMA pullout repair may have a possibility to

reduce the postoperative knee pain than the single FasT-Fix pullout repair in arthroscopic treatments of MMPRTs.

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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 have no conflict of interest.

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Figure legends

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

Figure 2. Clinical scores at preoperative and postoperative evaluations. Pullout repairs using FasT-Fix alone (a) or F-MMA suture technique (b). Light grey bars, preoperative scores. Dark grey bars, postoperative scores. * $P < 0.05$. ** $P < 0.01$.