

Abstract

Introduction: Recently, transtibial pullout repair of the medial meniscus (MM) posterior root tear (MMPRT) has become widely accepted and provides satisfactory clinical outcomes.

Widening after cyclic loading or ultimate failure load using different suture materials and configurations has been studied. However, no study has compared the clinical outcomes using different suture materials. This study aimed to evaluate the clinical outcomes after performing MMPRT pullout repair using different suture materials. We hypothesized that better clinical outcomes would be achieved using ultra-high-molecular-weight polyethylene (UHMWPE) suture tape compared to normal polyester sutures.

Methods: Thirty-seven patients who underwent MM posterior root repair between November 2019 and May 2020 were retrospectively investigated. Pullout repair was performed using a hollow No. 0 polyester suture (n = 14) and UHMWPE suture tape (n = 23). Clinical outcomes were assessed preoperatively and at 1 year postoperatively using the Lysholm knee score, Knee Injury and Osteoarthritis Outcome Score, and visual analogue scale (VAS) pain score. The meniscal healing status was assessed using an arthroscopic scoring system (range, 0–10).

Results: All clinical scores were improved significantly in both groups. However, significantly higher meniscal healing scores and decreased VAS pain scores were observed in

the UHMWPE group (7.3 ± 0.9 and 7.7 ± 11.3 , respectively) than in the polyester group (5.6 ± 2.7 and 18.4 ± 18.6 , respectively; $P < 0.05$). Suture cut-out and loss of the root continuity were observed in some cases (three cases [21.4%] in the polyester group and one case [4.3%] in the UHMWPE group).

Conclusion: Both suture materials led to satisfactory clinical outcomes at 1 year postoperatively, whereas the UHMWPE suture tape was useful for obtaining good meniscal healing and decreasing the VAS pain score.

Keywords: Clinical outcome; Medial meniscus; Meniscal healing; Posterior root tear; Suture material.

¹

¹ Abbreviations: MM, Medial meniscus; MME, Medial meniscus extrusion; MRI, Magnetic resonance imaging; PRT, Posterior root tear; KOOS, Knee Injury and Osteoarthritis Outcome Score; UHMWPE, Ultra-high-molecular-weight polyethylene; IKDC, International Knee Documentation Committee; VAS, visual analogue scale

Introduction

Medial meniscus (MM) posterior root tears (PRTs) are of interest to researchers, and several clinical, biomechanical, and histological studies on MMPRT have been conducted [1-4]. MMPRT leads to disrupted hoop stress distribution, kinematic change of the knee, severe MM extrusion (MME), and degenerative changes [1,5]. Therefore, transtibial pullout repair of MMPRT is recommended to regulate MME/femorotibial relation (rotation), increase contact area, reduce contact pressure, and prevent the subsequent development of osteoarthritis, as repair leads to satisfactory clinical outcomes and long-term survival [1-3,6,7]. Accurate diagnosis and early repair are recommended for the treatment of MMPRT before MME or subchondral insufficiency fracture of the knee progresses [8-10].

Second-look arthroscopic findings after MMPRT repair have been reported by some authors (qualitatively and quantitatively) [11-14]. The semi-quantitative arthroscopic score is reported to correlate with clinical outcomes, such as the Knee Injury and Osteoarthritis Outcome Score (KOOS), which measures the quality of life [14,15]. Furthermore, the relationship between semi-quantitative scores and surgical technique and that between semi-quantitative scores and specific magnetic resonance imaging (MRI) were also examined [16-19].

There have been many studies that aimed to improve clinical outcomes or suture strength,

46 such as enhancement of meniscal healing by stem cells [20,21], aiming guide [22], bone
47 tunnel creation [23-25], surgical technique [26,27], suture configuration [28,29], and
48 biomechanical strength of other suture materials [30,31]. Various suture materials have been
49 used during arthroscopic procedures, such as absorbable monofilament polydioxanone
50 sutures [32,33], braided nonabsorbable polyester sutures [11,34], and high-strength sutures
51 composed of ultra-high-molecular-weight polyethylene (UHMWPE) [18]. Among these
52 materials, UHMWPE-containing sutures are stronger and stiffer than conventional sutures,
53 making them suitable for repair. Additionally, UHMWPE is available in a tape form
54 (UHMWPE suture tape), and many studies have reported the biomechanical superiority of
55 UHMWPE suture tape to UHMWPE suture [35-39]. A wider suture tape could fill the hole
56 created for the passage of the suture through the tissue. Additionally, a flat/wide repair
57 material improves the ultimate load of knot breakage without altering stability, thus leading to
58 better distribution of forces to avoid suture cut-out [31,40]. However, there are currently few
59 studies comparing clinical outcomes using different suture materials. In addition, there are no
60 recommendations on the choice of suture materials for MMPRT repair, although there have
61 been many reports comparing their biomechanical properties. Therefore, this study aimed to
62 compare the clinical outcomes between cases using polyester suture and UHMWPE suture

tape, including the meniscal healing status and the rate of incidence of suture cut-out/loss of the root continuity (useless or detached root) at second-look arthroscopy. We hypothesized that better meniscal healing status and clinical outcomes would be achieved using UHMWPE suture tape compared with those using polyester sutures.

Materials and methods

Patients and ethical considerations

Forty-eight patients who underwent surgery for MMPRT between December 2019 and April 2020 were prospectively evaluated. Second-look arthroscopy was performed to evaluate meniscal healing 1 year postoperatively. Transtibial pullout repair of the MMPRT was indicated in patients with a femorotibial angle $<180^\circ$, radiographic Kellgren–Lawrence grade of 0–2, mild cartilage lesions (Outerbridge grade I or II), and a body mass index $<35 \text{ kg/m}^2$. Of the 46 patients, 11 were excluded because they had a partial tear of the MM posterior root ($n = 3$), underwent different repair techniques or additional surgeries during pullout repair such as ligament reconstruction ($n = 4$), and had no second-look arthroscopy ($n = 4$). After applying the exclusion criteria, 37 patients were included for further analyses (Fig. 1). The medical records were reviewed to examine patient characteristics, including age, height, body

weight, and duration from injury to surgery. All patients were diagnosed with MMPRT based on MRI findings, such as cleft, giraffe neck, and ghost signs, as well as radial tear and meniscal extrusion (>3 mm) [41,42]. The MMPRT classification was defined using arthroscopy according to a previous study [43]. The patients were divided into two groups to compare the clinical efficacy of suture materials using #0 polyester hollow sutures (Macaroni, Stryker Japan KK, Tokyo, Japan; Fig. 2, n = 14) and UHMWPE suture tapes (n = 23), including Ultra Tape (Fig. 3, n = 10, Smith & Nephew, Andover, MA, USA) and Suture Tape (n = 13, Arthrex, Naples, FL, USA). All protocols were approved by the Institutional Review Board (# 1857), and informed consent was obtained from all participants included in the study.

Surgical technique

A standard arthroscopic examination was performed using a 4-mm-diameter 30° view angle arthroscope (Smith & Nephew, London, UK). A probe was introduced through the anteromedial portal to confirm the MMPRT. To increase the space in patients with tight medial compartments, we used outside-in pie-crusting of the medial collateral ligament with a standard 18-gauge (1.2×40 mm) hypodermic needle (Terumo Corporation, Tokyo, Japan)

[44].

We used a Knee Scorpion™ suture passer (Arthrex, Inc.) to pass two #0 polyester hollow sutures composed of polyester multi-threads without a core thread (Macaroni, Stryker Japan KK; Fig. 2) or UHMWPE suture tapes (Ultra tape, Smith & Nephew, Fig. 3; Suture Tape, Arthrex) vertically through the meniscal tissue. The first suture was inserted into the inner part of the MM posterior horn with a safety margin of approximately 10 mm from the edge of the tear. The second suture was inserted into the outer part, more than 5 mm away from the tear. An all-inside suture device, such as the FasT-Fix meniscal repair system (Smith & Nephew) and JuggerStitch meniscal repair device (Zimmer Biomet, Warsaw, IN, USA), were inserted through the anterolateral portal. In this procedure, the first anchor of the device was inserted into the inferior surface of the MM posterior segment, and the second anchor was inserted directly into the articular capsule in the posteromedial direction [45].

The MM posterior root attachment was confirmed before placing a custom-made posterior root-aiming device (PRT guide, Smith & Nephew; Unicorn Meniscal Root guide, Arthrex Inc.) [22] at the anatomic center of the posterior root attachment, as described previously [46]. A 2.4-mm guide pin was inserted at a 45° angle to the root attachment with the aiming device, and a 4.0-mm cannulated drill was used to overdrill the tibial tunnel. After

removing the inner guide pin alone, all five sutures were pulled out through the cannulated drill using a suture relay technique. Tibial fixation of the pullout sutures was performed using a 5.0-mm bioabsorbable screw with an initial tension of 10–20 N in 30° knee flexion.

The patients were initially kept at non-weight-bearing with a knee immobilizer for 2 weeks postoperatively. At 4–5 weeks, full weight bearing was permitted depending on the patient's weight. Knee flexion exercise was limited to 90° for the first 4 weeks and 120° for the next 4 weeks. Deep knee flexion was limited to 12 weeks postoperatively.

Clinical scores

Clinical evaluations were performed preoperatively and at 1 year postoperatively. These were evaluated using the KOOS, Lysholm knee score, International Knee Documentation Committee score, and visual analogue scale (VAS) pain score (range, 0–100). The KOOS is composed of five subscales: pain, symptoms, activities of daily living, sport and recreation functions (Sport/Rec), and knee-related quality of life.

Arthroscopic meniscal healing scores

At 1 year after pullout repair, the healing status of the MM posterior root was evaluated using second-look arthroscopy according to the arthroscopic scoring system previously described [14]. We used the semi-qualitative arthroscopic scoring system because its usefulness has been validated. The scoring system was reported to be well correlated with clinical outcomes and superior to qualitative evaluation in assessing the healing status of the repaired root [15]. This semi-quantitative arthroscopic scoring system is composed of three evaluation criteria: (i) anteroposterior width of bridging tissues (0–4), (ii) stability of the repaired MM posterior root (0–2), and (iii) synovial coverage of the sutures (0–2). The total scores range from 0 to 10. Two orthopedic surgeons evaluated the meniscal healing scores in a blinded manner. The mean of each evaluation score was determined for each patient.

Statistical analyses

Data are reported as means $\pm$ standard deviations. All statistical analyses were performed using EZR software (Saitama Medical Center, Jichi Medical University, Tochigi, Japan) [47]. Intra-patient and inter-patient differences in measured values were evaluated using the Wilcoxon signed-rank test and Mann–Whitney U test. Statistical significance was set at $P < 0.05$. The inter-observer reproducibility and intra-observer repeatability of the meniscal

healing score were considered high, with mean intraclass correlation coefficient values of 0.85 and 0.92, respectively.

Results

The study population and patient recruitment strategy are presented in Fig. 1. The patient demographic information is shown in Table 1; no statistically significant differences were observed between the two groups. No statistically significant differences in preoperative clinical scores were observed between the two groups (Table 2). All clinical scores improved significantly in both groups (Fig. 4). A significantly higher **total** meniscal healing score was observed in the UHMWPE (7.3 ± 0.9) than in the polyester group (5.6 ± 2.1 , $P < 0.01$, power = 0.80) (Table 3). **Width, stability, and synovial coverage point were 3.91 ± 0.42 , 2.35 ± 0.65 , and 1.04 ± 0.47 and 3.14 ± 1.51 , 1.86 ± 1.03 , and 0.57 ± 0.51 in the UHMWPE and in the polyester group, respectively.** Furthermore, a significantly decreased VAS pain score was observed in the UHMWPE group (7.7 ± 11.3) compared to that in the polyester group (18.4 ± 18.6 ; $P < 0.05$, power = 0.54). Suture cut-out and loss of the root continuity (useless or detached root) were observed in three cases (21.4%) in the polyester group and one case (4.3%) in the UHMWPE group ($P = 0.14$). No statistically significant differences in

demographic data and preoperative/postoperative clinical outcomes were observed between patients treated with Ultra Tape and Suture Tape.

Discussion

The most important finding of this study is that both suture materials led to satisfactory clinical outcomes at 1 year postoperatively. Our hypothesis that better meniscal healing status and clinical outcomes would be obtained using the UHMWPE suture tape was partially supported because pullout repair using UHMWPE suture tape led to better meniscal healing scores and lower VAS pain scores compared with those using the #0 polyester. Recently, interest in MMPRT is increasing and various fields of study have developed, such as clinical, technical, biomechanical, and biological studies [1,2,4-6,8-10,16,18,24,26,28,32,44,48,49]. Although many studies have compared the biomechanical properties of suture materials [31,36-39], only few studies have compared the clinical outcomes or arthroscopic findings following meniscal repair using different suture materials.

In the present study, good clinical outcomes were obtained after pullout repair using both suture materials, which is comparable with the results of previous studies [10,16]. Furthermore, a significantly higher meniscal healing score was observed in the UHMWPE

group than in the polyester group in second-look arthroscopy, although no statistically significant difference was observed in each sub-category (width, stability, synovial coverage). Although there was no statistically significant difference in clinical outcomes, UHMWPE suture tape tended to have advantages regarding some factors, such as the rate of narrow bridging tissue ≤ 5 mm and the rate of useless or detached root (suture cut-out and loss of the root continuity). The absence of a statistically significant difference in the rate of useless or detached roots may be caused by the small sample size. Judging from only this study, we cannot conclude that both materials can lead to similar results. Furthermore, in addition to better meniscal healing at second-look arthroscopy, the UHMWPE suture tape was also superior to the #0 polyester in obtaining a lower VAS pain score.

The meniscus-suture interface is the site where early failure occurs most likely. The suture material is required to provide low displacement, high stiffness, and maximum load, and it is an important factor that affects the tensile strength. These characteristics would keep the reattached meniscus root in place during the healing process. The sutures containing UHMWPE can absorb large amounts of energy and remain flexible [38]. Biomechanical studies have demonstrated that UHMWPE has superior initial fixation strength, less widening after cyclic loading, and higher ultimate failure load or stiffness than

198 conventional suture materials [31,35,36,39]. Based on these studies, the UHMWPE suture
199 tape appeared to have better biomechanical properties and to be a superior and suitable
200 material for repairing MMPRT than conventional or UHMWPE sutures. Suture tapes have
201 been used increasingly for repairing degenerated tissues, such as the rotator cuff [50];
202 similarly, MMPRT may be a good indication for using UHMWPE because MMPRT is
203 caused by the degenerative properties of the posterior root. A suture tape has a broader
204 surface area and can distribute the load over a broader area, which may increase the load
205 required for suture cut-out and reduce the failure of repair [31]. Similar to the cited studies,
206 which demonstrated the superior biomechanical properties of UHMWPE suture tape, better
207 meniscal healing was obtained in cases that used the UHMWPE suture tape than in those
208 that used #0 polyester.

209 This study had some limitations. First, the postoperative follow-up period was short,
210 and the sample size was too small to evaluate and compare the clinical outcomes. Second, the
211 other suture configurations, such as cinch sutures and Mason-Allen sutures, were not
212 examined. Third, a biomechanical study was not performed. Finally, two different kinds of
213 UHMWPE sutures (Ultra Tape or Fiber Tape) were used but not evaluated separately. Various
214 configurations using UHMWPE, such as simple suture, simple multiple sutures, cinch suture,

215 and Mason–Allen suture, should be used in future research. Further evaluation with a
216 long-term follow-up period or biomechanical testing is needed to deepen our knowledge.

217

218 **Conclusion**

219 Both suture materials led to good clinical outcomes at 1 year postoperatively, whereas the
220 UHMWPE suture tape was useful for obtaining good meniscal healing and decreasing the
221 VAS pain score.

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229 **Conflict of interest**

230 None declared.

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232 **Availability of data and material**

233 The data and materials of the study are available upon request by contacting the
234 corresponding author.

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Figure captions

Fig. 1 Flowchart showing study population and patient recruitment.

Fig. 2 Arthroscopic findings during primary surgery using #0 polyester (pullout repair) and second-look arthroscopy (right knee). (A) White arrowheads indicate MM posterior root tear. (B) Final appearance after pullout and fixation. (C) Narrow anteroposterior width of bridging tissue (width, 2 points) is observed with poor synovial coverage (coverage, 0 point) and loss of all-inside suture. (D) Anterior drawing on probing at 20° of knee flexion is observed (stability, 1 point; total, 3 points).

MFC, medial femoral condyle; MTP, medial tibial plateau; MM, medial meniscus

Fig. 3 Arthroscopic findings during primary surgery using UHMWPE tape (pullout repair) and second-look arthroscopy (right knee). (A) White arrowheads indicate MM posterior root tear. (B) Final appearance after pullout and fixation. (C) Broad anteroposterior width of bridging tissue (width, 4 points) is observed with fair synovial coverage (coverage, 1 point). (D) Anterior drawing at 20° of knee flexion was not observed (stability, 2 points; total, 7

428 points).

429 MFC, medial femoral condyle; MTP, medial tibial plateau; MM, medial meniscus

430

431 **Fig. 4** Preoperative and postoperative clinical scores using (A) #0 polyester and (B)

432 UHMWPE suture tape. With both materials, all scores significantly improved at 1 year

433 postoperatively (Wilcoxon signed-rank test).

434 KOOS, Knee Injury and Osteoarthritis Outcome Score; ADL, activities of daily living;

435 Sport/Rec, sport and recreation function; QOL, quality of life; IKDC, International Knee

436 Documentation Committee subjective knee evaluation form; VAS, visual analogue scale. *P

437 <0.05.