Original article

Transtibial pullout repair of medial meniscus posterior root tear restores physiological internal rotation of the tibia in the knee-flexed position: A retrospective comparative analysis

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ABSTRACT

Background: Medial meniscus posterior root tear (MMPRT) results in joint overloading and degenerative changes in the knee. Favorable clinical outcomes have been reported after transtibial pullout repair of MMPRT. To date, however, *in vivo* tibial rotational changes before and after root repair remain poorly understood. The purpose of this study was to investigate postoperative change in tibial rotation following MMPRT pullout repair.

Hypothesis: Pathological external rotation in the knee-flexed position is caused by MMPRT and is reduced after transtibial pullout repair.

Patients and Methods: Fifteen patients who underwent MMPRT pullout repair and 7 healthy volunteers were included. Magnetic resonance imaging examinations were performed in the 10° and 90° knee-flexed positions. The angles between the surgical epicondylar axis and a line between the medial border of the patellar tendon and the apex of the medial tibial spine were measured. Baseline was defined as a line lying at a right angle to the other, and considered the value positive and negative when the tibia rotated internally and externally, respectively.

Results: In the volunteer's normal knees, tibial internal rotation was +1.00° ± 3.27° at 10° flexion and +4.14° ± 3.46° at 90° flexion. In the MMPRT preoperative knees, tibial internal rotation was +1.07° ± 3.01° at 10° flexion and +1.27° ± 2.96° at 90° flexion. In the postoperative knees, tibial internal rotation was +1.60° ± 2.85° at 10° flexion and +4.33° ± 2.89° at 90° flexion.

Discussion: This study demonstrates that an intrinsic internal rotation of the tibia during knee flexion was not observed in patients with MMPRT because discontinuity of the MM posterior root may induce a pathological external rotation of the tibia during knee flexion and that the MMPRT pullout repair reduces the pathological external rotation of the tibia in the knee-flexed position.

Level of evidence: III comparative retrospective study.

Keywords: Medial meniscus; Posterior root tear; Magnetic resonance imaging; Tibial rotation;

Transtibial pullout repair

Abbreviations:

medial meniscus (MM)

posterior root tear (PRT)

International Knee Documentation Committee (IKDC)

surgical epicondylar axis (SEA)

patellar tendon and the apex of the medial tibial spine (PTMS)

intra-class correlation coefficient (ICC)

1. Introduction

Medial meniscus posterior root tear (MMPRT) decreases the contact area and increases the contact pressure between the femoral condyle and tibial plateau [1], resulting in joint overloading and rapid knee degeneration. Although favorable clinical outcomes are reported after transtibial pullout repair of MMPRT [2,19], unfavorable outcomes are reported for non-operative treatment in patients with MM posterior horn root tears [3] and partial meniscectomy of complete MMPRT [4,5]. Medial meniscus extrusion progresses shortly after MMPRT [6], and is correlated with injury duration in patients with knee osteoarthritis [7, 24]. Patients with decreased meniscus extrusion at 1 year postoperatively had more favorable clinical scores and radiographic findings at midterm follow-up than did those with increased extrusion [8]. Therefore, prompt diagnosis of MMPRT on the basis of clinical signs [25] or a single painful popping event is necessary [9], and MMPRT repair is recommended to prevent subsequent cartilage degeneration or meniscus extrusion [10].

In a robotic arm study, it was reported that tibial external rotation is increased in association with posterior root tear of the medial meniscus, and rotation is restored by posterior root repair [11]. However, to our knowledge, no previous study has reported changes in *in vivo* tibial rotation before and after MMPRT pullout repair. Although magnetic resonance imaging (MRI) can confirm reduction of the MM posterior root to the original footprint of the tibial surface on the basis of disappearance of the giraffe neck sign or cleft/truncation sign after pullout repair, *in vivo* tibial rotational change after root repair is poorly understood.

The purpose of this study was to investigate postoperative change in tibial rotation following MMPRT pullout repair. We hypothesized that MMPRT pullout repair could reduce pathological external rotation in the knee-flexed position.

2. Patients and methods

2.1. Patients

The study was approved by our Institutional Review Board, and all patients and volunteers provided informed consent. This retrospective study analyzed the changes in tibial rotation preoperatively and at 3 months after MMPRT pullout repair in comparison with healthy knees. Forty-two patients who underwent MMPRT pullout repair between March 1, 2016 and October 31, 2017, and 7 healthy volunteers were included. Patients were treated with a FasT-Fix® (Smith & Nephew)-dependent modified Mason-Allen suture using the all-inside technique after creating the tibial bone tunnel with a PRT guide, as previously described [13-17]. Twenty-seven patients were excluded because their postoperative MRI (axial views) data were unavailable. The final sample size (n=15) demonstrated adequate power (>0.90) to detect a significant difference between postoperative tibial rotation at 10° and 90° flexion and between pre- and postoperative tibial rotation at 90° flexion. The Kellgren-Lawrence grade was determined using plain radiographs and MMPRT type, through careful arthroscopic examinations [10]. MRI examinations were performed preoperatively and at 3 months postoperatively (Figures 1 and 2).

2.2. MRI evaluation

Open MRI scanning was performed preoperatively and at 3 months postoperatively using an OASIS 1.2 T device (Hitachi Medical, Chiba, Japan) with a coil under the 10° and 90° knee-flexed position under a non-weight-bearing condition. To standardize the position of the knee in each patient, lower leg and foot were held using sandbags and formed styrene in 0˚ of dorsal flexion of the ankle with keeping the second metatarsal bone horizontally. Standard OASIS sequences included an axial T2-weighted multi-echo sequence (repetition time/echo time of 4,438 ms/84 ms) with a 90° flip angle. The slice thickness was 4 mm with a 0-mm gap. The field of view was 16 cm with an acquisition matrix size of 352 × 320.

We used a picture archiving and communication system (FUJIFILM Holdings Corporation, Tokyo, Japan) to measure the tibial rotation. Axial views were taken parallel to the medial tibial plateau, and after assessing all axial slices for each knee, measurements were taken from a view in which we could identify the intercondylar tibial ridge. Then, we measured tibial rotation on the basis of the angle formed between the surgical epicondylar axis (SEA) and a line between the medial border of the patellar tendon and the apex of the medial tibial spine (PTMS) (Figures 1, 2), which is reportedly a good reference line for medial meniscus rotation [18]. Baseline was defined as the lines lying at right angles to one another, and the value was positive and negative when the tibia rotated internally and externally, respectively.

2.3. Statistical analysis

Data are reported as mean ± standard deviation. Statistical analysis and sample size/power calculation were performed using EZR software (Saitama Medical Center Jichi Medical University, Tochigi, Japan). The *t*-test and Wilcoxon signed rank were used to compare values. Statistical significance was set at $p<0.05$. Two orthopedic surgeons independently measured the angle formed between SEA and PTMS. Each observer performed each measurement twice, with a 2-week interval. Inter-observer and intra-observer reliabilities were assessed using the intra-class correlation coefficient (ICC). The interobserver and intraobserver reliabilities for the measurements were satisfactory with the mean ICC values being 0.91 and 0.95, respectively.

3. Results

3.1. Demographic data and MRI findings

Table 1 reports the patients' demographic and clinical characteristics. The mean age of the volunteers was 26.8 (range, 22-33) years. The mean age at the time of surgery was 59.8 (range, 35-72) years, and the mean duration from injury to surgery was 15.5 (range, 1-42) weeks. Giraffe neck sign was observed in 14/15 patients (93.3%) and cleft/truncation signs were observed in 13/15 patients (86.7%) before surgery. Those signs each became negative in all patients and in 12/13 patients (92.3%) after surgery. Restoration of medial extrusion over 0.50 mm was identified in only one case.

3.2. Tibial rotation on serial MRI

In the volunteers' normal knees, tibial internal rotation was +1.00° ± 3.27° at 10° flexion and +4.14° ± 3.46° at 90° flexion. In the MMPRT preoperative knees, tibial internal rotation was +1.07° ± 3.01° at 10° flexion and +1.27° ± 2.96° at 90° flexion. In the postoperative knees, tibial internal rotation was +1.60° ± 2.85° at 10° flexion and +4.33° ± 2.89° at 90° flexion.

In the normal and postoperative knees, significantly greater tibial internal rotation was observed at 90° flexion than at 10° ($p < 0.05$), whereas in the preoperative knees, no significant difference in tibial rotation was observed between 90° and 10° flexion ($p > 0.05$) (Figure 3).

At 90° flexion, significantly increased tibial internal rotation was observed in the postoperative knees compared with the preoperative knees ($p < 0.001$), whereas no difference was observed between the postoperative and normal knees ($p > 0.05$). At 10° flexion, no significant differences in tibial rotation were observed among the groups ($p > 0.05$) (Figure 4). In most cases, although significant difference could be identified, the amount of change in absolute value was small and the standard deviation was relatively high.

4. Discussion

The most important finding of this study was that intrinsic internal rotation of the tibia during knee flexion was not observed in patients with MMPRTs, and MMPRT pullout repair restored physiological tibial internal rotation of middle-aged patients in the 90° knee-flexed position. Our hypothesis is confirmed.

It is well known that the tibia rotates internally from 0° to 120° in normal knee, the so-called medial pivot, and shows a bilateral femoral condyle roll back from 120° to full flexion [21]. A cadaveric study with a 100N axial load using a robotic arm reported that tibial external rotation increased in association with MMPRT in 30°, 60°, and 90° knee-flexed positions; no significant difference was found in the knee-extended position, and external rotation in the knee-flexed position was restored by posterior root repair [20]. However, extrapolating these data to the clinical population is difficult because muscle contractions, proprioception, and healing were not considered. Furthermore, arthroscopic repair was not performed. Our results are consistent with those of this cadaveric study reporting increased tibial external rotation with MMPRT, which was restored by posterior root repair. Intrinsic internal rotation of the tibia during knee flexion was not observed in patients with MMPRTs.

The MM extrudes posteriorly with MMPRT in the knee-flexed position [22]; thus, given the disruption of the original MM mechanism as a secondary stabilizer, posterior translation of the medial femoral condyle cannot be prevented by the MM posterior segment, and MMPRT may induce pathological tibial external rotation during knee flexion via discontinuity of the MM posterior root. The dynamic stability structures of the knee posteromedial corner, including the MM posterior root, are important [23]; we consider that MMPRT pullout repair restores MM function as a joint stabilizer against tibial external rotation, resulting in internal rotation.

This study has several limitations. First, given its retrospective design, relatively small number of patients, and insufficient results of second-look arthroscopy due to short-term follow-up, the duration from injury to surgery was not investigated in the study, although a longer duration may lead to the progression of degenerative change and tibial external rotation. However, the sample size had acceptable statistical power for the endpoint. Second, the non-weight bearing condition and evaluation only from the 10° and 90° knee-flexed position might not be precise enough to detect subtle tibial rotational changes. Third, the initial fix tension was not considered. Pullout repair is essential for MMPRT, because the end-to-end suture technique is not suitable, and we performed tibial fixation using the double-spike plate and screw, with the knee flexed in neutral rotation at 45° and a 20N initial tension. It is possible that the fixed tension or rotation would affect postoperative tibial rotation. Additional MRI investigations involving long-term follow-up and larger sample sizes are required.

5. Conclusions

MMPRT may induce pathological external rotation of the tibia during knee flexion because of the discontinuity of the MM posterior root.

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Disclosure of Interests

We have no Conflict of Interest.

Contributions of authors

Takayuki Furumatsu designed the study. Yoshiki Okazaki and Shin Masuda contributed to the analysis and interpretation of data. All authors have contributed to data collection and interpretation and critically reviewed the manuscript. All authors approved the final version of the manuscript, and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Table 1. Demographic and clinical characteristics

	MMPRT group	Volunteer group	*P* value
Number of patients	15	7	
Age (years)	59.8 ± 9.7	27.6 ± 4.65	< 0.001*
Men/women	2/13	3/4	
Height (m)	1.56 ± 0.06	1.65 ± 0.09	0.009*
Weight (kg)	65.9 ± 13.7	55.7 ± 12.3	0.11
BMI (kg/m^2)	27.0 ± 4.62	20.3 ± 2.64	0.002*
Root tear classification type 1/2/3/4/5	0/13/0/2/0	N/A	
Kellgren-Lawrence grade I/II	10/5	N/A	
Duration from injury to surgery (weeks)	15.5 ± 13.9	N/A	

Data are presented as mean ± standard deviation. Medial meniscus posterior root tear (MMPRT). Body mass index (BMI). Not available (N/A).

* Statistically significant

Figure legends

Figure 1. Magnetic resonance images of a normal left knee.

(A) Surgical epicondylar axis (SEA) (solid line) in 10° knee-flexed position.

(B) Internal rotation (+1°) in 10° knee-flexed position. An angle is formed by a solid line perpendicular to the SEA and a dotted line connecting the medial border of the patellar tendon (circle) and apex of the medial tibial spine (filled circle).

(C) SEA (solid line) in 90° knee-flexed position.

(D) Internal rotation (+5°) is identified in 90° knee-flexed position.

Figure 2. Magnetic resonance images of a knee with medial meniscus posterior root tear and a repaired left knee.

(A) Preoperative image. External rotation (−1°) in 10° knee-flexed position. An angle is formed by the solid line perpendicular to the surgical epicondylar axis and the dotted line linking the medial border of the patellar tendon (circle) and apex of the medial tibial spine (filled circle).

(B) Preoperative image. External rotation (−1°) in 90° knee-flexed position.

(C) Postoperative image. External rotation (−1°) in 10° knee-flexed position.

(D) Postoperative image. Internal rotation (+2°) in 90° knee-flexed position.

Figure 3. Magnetic resonance imaging-based tibial internal rotation in 10° and 90° knee-flexed positions.

(A) Normal knee. *$P < 0.05$.

(B) Preoperative knee.

(C) Postoperative knee. *$P < 0.001$.

Figure 4. Magnetic resonance imaging-based tibial internal rotation in 90° knee-flexed position.

(A) Normal and preoperative knees. *$P < 0.05$.

(B) Preoperative and postoperative knees. **$P < 0.001$.