Knee Surgery, Sports Traumatology, Arthroscopy
https://doi.org/10.1007/s00167-017-4827-9

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The percutaneous pie-crusting medial release during arthroscopic procedures of the medial meniscus does neither affect valgus laxity nor clinical outcome

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Received: 29 June 2017 / Accepted: 18 December 2017

Abstract

Purpose To analyze the effect of percutaneous pie-crusting medial release on valgus laxity before and after surgery and on clinical outcomes.

Methods Eight-hundred fourteen consecutive patients who underwent an arthroscopic procedure for the medial compartment of the knee were evaluated retrospectively. Sex, age, type of operation (meniscectomy, meniscal repair, and posterior root repair), type of accompanying surgery (none, cartilage procedure, ligament procedure and osteotomy) were documented. Sixty-four patients who underwent percutaneous pie-crusting medial release (release group) and 64 who did not undergo medial release (non-release group) were matched using the propensity score method. Each patient was evaluated for the following variables: degree of valgus laxity on stress radiographs, Lysholm knee score, visual analog scale score, and International Knee Documentation Committee knee score and grade.

Results At the 24-month follow-up, no significant increase in side-to-side differences in the valgus gap was observed in comparison to the preoperative value in the release group [preoperative, -0.1 ± 1.3 mm; follow-up, -0.1 ± 1.4 mm; (n.s.)]. The follow-up Lysholm score, visual analog scale score and International Knee Documentation Committee knee score and grade were similar between the two groups.

Conclusions Percutaneous pie-crusting medial release is an additional procedure that can be performed during arthroscopic surgery for patients with a narrow medial joint space of the knee. Percutaneous pie-crusting medial release reduces iatrogenic injury to the cartilage and does not produce any residual valgus laxity of the knee.

Level of evidence IV.

Keywords Percutaneous pie-crusting medial release · Medial meniscus · Arthroscopic surgery · Knee

Introduction

Surgical treatment for the torn medial meniscus is one of the most popular arthroscopic procedures, and it requires proper visualization and adequate space for instrument insertion to manage tears of the body or posterior horn. Arthroscopic surgery in the medial compartment of a tight medial tibiofemoral joint may prevent accurate diagnosis and causes iatrogenic articular cartilage damage due to forced instrument insertion [10, 27, 36]. Dick et al. [10] reported that iatrogenic articular cartilage damage was the most common complication with a prevalence of 2% in an analysis of 3714 arthroscopic procedures. Additionally, Klein et al. [27] based on animal experiments, reported that articular lesions caused during arthroscopic procedures did not heal.

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Published online: 28 December 2017

There have been a few studies [7, 22, 33, 36] on the use of percutaneous pie-crusting medial release (PPMR) for a tight medial joint space; however, regarding the clinical outcomes of this procedure, Fakioglu et al. [12], based on an analysis of case series, only reported that the iatrogenic laxity recovered within 3 months, which might indirectly indicate successful healing of the injured medial collateral ligament (MCL). In this study, we analyzed the effect of PPMR on pre-operative and post-operative valgus laxity in the PPMR group and compared clinical outcomes between the PPMR group and group without medial release. The hypothesis were that postoperative valgus laxity would not be increased significantly after the PPMR procedure and that the clinical outcome of the PPMR group would be similar to that of the group without PPMR.

Materials and methods

Eight-hundred fourteen consecutive patients, who underwent arthroscopic surgeries for the medial meniscus of the knee between 2010 and 2014 were reviewed retrospectively. Those without (1) an associated MCL injury, (2) contralateral knee injuries, (3) a previous operative history, or (4) associated fractures were excluded. PPMR was performed in 64patients (7.9%), while 750 patients (92.1%) did not receive medial release. Age, sex, body mass index (BMI), the type of operation (meniscectomy, meniscal repair, and posterior horn root repair), associated procedures (no associated procedures, articular cartilage procedure, ligament procedure, and high tibial osteotomy), Kellgren–Lawrence grade [23] measured on preoperative standing anteroposterior knee radiographs, and absolute value of valgus (ABV) and side-to-side difference (SSD) between the affected side and the normal side of valgus laxity measured on preoperative valgus stress radiographs were reviewed. Valgus stress radiographs of the 64 patients who received PPMR were also taken at 24 months postoperatively. Valgus stress radiographs were taken with the knee in 30° of flexion using a Telos device (Telos GmbH, Marburg, Germany) by applying 150 N of valgus force. The amount of valgus laxity was measured using a PACS system (Centricity PACS, GE Medical System Information Technologies, Milwaukee, WI, USA) using the method described by Jacobsen et al. [21], which involves correction of each measurement using an image of a 10-cm magnetic bar taken along with each radiograph. The femur joint line was drawn tangent to the lowest points of the medial and lateral distal femoral condyle. The tibia joint line was drawn to include the sclerotic lines of the medial and lateral tibia plateaus. Another line perpendicular to the tibial joint line and tangent to the medial cortex of the proximal tibia was drawn; this line intersected the femur joint line and tibial joint line on the two different points. The distance between two points was measured as valgus laxity (Fig. 1). To test intra-rater and inter-rater reliabilities of the radiographic assessments, two orthopedic surgeons measured all radiographs twice at an interval of 3 weeks. Intra-class correlation coefficients (ICC) for intra-rater and inter-rater reliabilities of all measurements were calculated. Intra-rater ICCs for each rater were 0.97 and 0.95 and inter-rater ICC was 0.93. Since these results indicated that the reliability of the measurement was excellent according to the criteria of Winer [35], the average values of two separate measurements taken by a single investigator were used in the analyses.

To compare the release group and non-release group, propensity score matching was used to assemble a cohort of patients who received surgeries with or without PPMR who had matching baseline characteristics. Each patient in the non-release group was matched by age, sex, BMI, type of operation (meniscectomy, meniscal repair, and posterior horn root repair), combined procedures (none, cartilage procedure, ligament procedure, and HTO), preoperative Kellgren–Lawrence grade [23], preoperative Lysholm score, preoperative subjective IKDC score, and objective IKDC grade to a patient in the release group. Lysholm score, subjective IKDC score and objective IKDC grade were investigated at postoperative 24 months. And the visual analog scale (VAS) was checked immediately, 1 day, 2 weeks, 3, 6, 24 months after operation.

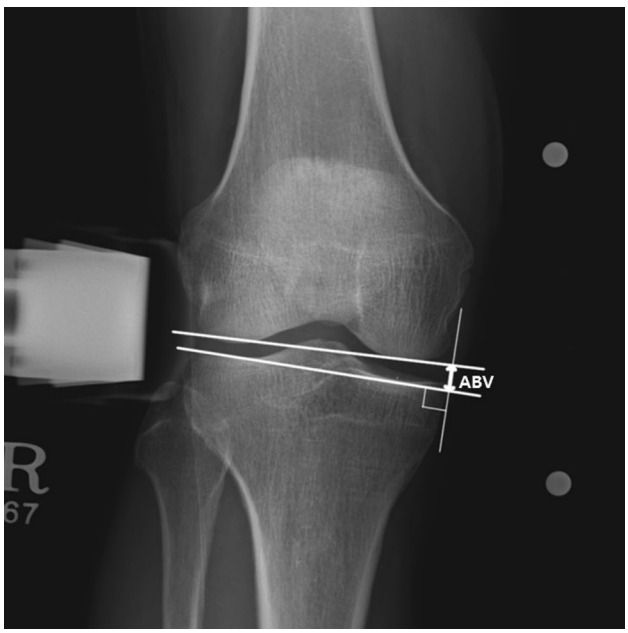

Fig. 1 The amount of valgus laxity was measured using the method described by Jacobsen et al. [21] with correction of each measurement made by utilizing a 10 cm magnetic bar taken along with each radiograph

For arthroscopic surgery of the medial meniscus, a high anterolateral portal was created at the intersection of the lateral border of the patellar tendon and the inferior border of the patella, which was more 1 cm medial and 0.5–1 cm superior than the conventional anterolateral portal which is usually located at least 1 cm above the lateral joint line and approximately 1 cm lateral to the lateral border of the patellar tendon [26]. The anteromedial portal was made after approaching the lesion using a spinal needle, depending on the location and procedure performed. Use of the PPMR procedure was determined according to the situation: (1) when the medial gap was so narrow that it was impossible to inspect the entire meniscus lesion, or (2) if the scope or instrument could not be inserted to complete the meniscal procedure correctly. In most patients, when the knee was flexed by 30° and valgus and external forces were manually applied, the narrowest part of the medial gap was less than 5 mm in the initial probe measurement [9]. For PPMR, the posterior third of the medial collateral ligament just above the medial meniscus was targeted with a 19-gauge intravenous catheterization needle (Fig. 2) [7, 31, 33]. The posteromedial ligamentocapsular complex was carefully pierced after identifying the course of the saphenous nerve and vein using transillumination with the arthroscope, two to four times until a stretching sound was audible or sensed and the medial joint space was seen to widen to the extent that the planned procedure was judged possible without any difficulty (Fig. 3). Once the needle was inserted into the subcutaneous tissue, it was not retracted, and additional punctures were performed parallel to the fibers of the superficial MCL.

Patients who underwent only meniscectomy were recommended to wear an MCL brace, the Breg X2K High Performance (Breg Inc., East Carlsbad, CA, USA) for 4 weeks after the operations, and the brace was prescribed prophylactically to prevent further injury of the MCL due to valgus forces. Patients were allowed to do weight-bearing and range of motion exercise. For patients who underwent meniscal repair or additional procedures, standard rehabilitative protocols of an initial 2 weeks of maximum protection (immobilization at 0° of flexion, toe-touch weight bearing), 4 weeks of protected range of motion (30°–70° of flexion), and controlled knee extensor–flexor strengthening and full weight bearing after 6 weeks. Stationary cycling and moderate intensity running were allowed between 3 and 6 months after surgery; and full return to activity was permitted at 7 months after surgery, as described by DeHaven et al. [11], and maintained in addition to use of a brace. The study was performed with approval from the institutional review board of the severance hospital, yonsei university college of medicine (ID Number: 4-2012-0305).

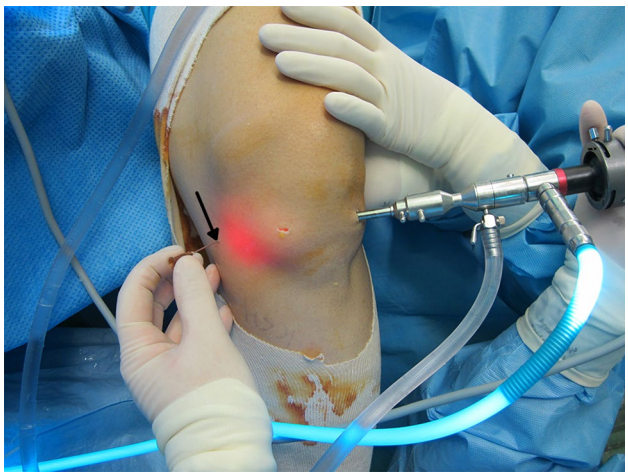

Fig. 2 Percutaneous pie-crusting medial release was performed with the knee in 30° of flexion while maintaining manual valgus and external rotation force. The posterior third of the medial collateral ligament just above the medial meniscus was targeted with a 19-gauge intravenous catheterization needle (black arrow)

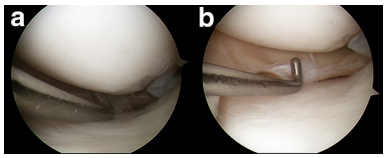

Fig. 3 Arthroscopic visualization through the anterolateral portal for the medial tibio-femoral joint space of the left knee, **a** before medial release, gap of medial joint space was measured about 4 mm (the length of the probe tip is 5 mm), **b** after medial release, joint space gap was widened to about 7 mm in length

Statistical analysis

The paired t-test was performed to compare the amount of laxity measured on valgus stress radiograph preoperatively before anesthesia and at 24 months after the surgery for the 64 patients in the release group. Sixty-four of 814 patients in the non-release group were extracted using propensity score matching (Table 1); their Lysholm score, subjective IKDC score, and objective IKDC grade at 24 months postoperatively and, the VAS of both groups measured over time were analyzed using the independent *t* test and Chi-square analysis. All statistical analyses were performed using IBM SPSS statistics 20 software (IBM Corp., Armonk, NY, USA). Data are presented as mean ± standard deviation or medians (range) for continuous variables, and frequencies and rates for categorical variables. Statistical significance was set at a p value of 0.05.

The cohort size was calculated based on the Lysholm score and then the SSD of valgus gap as the primary outcome. In cases of a significance level (alpha) of 5% and 1-beta (power) of 80%, the criterion for non-inferiority of the patients who received release with respect to the

Table 1 Patient characteristics before and after propensity score matching between the medial release and non-release groups

	Medial release group ($n=64$)	Medial non-release group			
		Before matching ($n=750$)	p value	After 1:1 matching ($n=64$)	p value
Age[a] (year)	40.9 ± 12.5	46.5 ± 14.1	0.047	42.6 ± 15.8	(n.s.)
BMI[a] (kg/m^2)	24.6 ± 2.7	25.2 ± 3.5	(n.s.)	25.1 ± 3.5	(n.s.)
Gender[b]			0.050		(n.s.)
Male	41 (64.1%)	330 (44%)		39 (60.9%)	
Female	23(35.9%)	420(56%)		25 (39.1%)	
Type of operation[b]			0.003		(n.s.)
Meniscal repair	34(53.1%)	170(22.7%)		27 (42.2%)	
Menisectomy	25 (39.1%)	521(69.5%)		31 (48.4%)	
Meniscus root repair	5 (7.8%)	59 (7.8%)		6 (9.4%)	
Combined procedure[b]			0.008		(n.s.)
None	18 (28.1%)	206 (27.5%)		23 (35.9%)	
Cartilage procedure	16 (25.0%)	329 (43.9%)		19 (29.7%)	
Ligament procedure	30 (46.9%)	145 (19.3%)		18 (28.1%)	
Osteotomy	0 (0%)	70 (9.3%)		4 (6.3%)	
Preoperative Kellgren–Lawrence grade[b]			(n.s.)		(n.s.)
0	36 (56.2%)	297 (39.6%)		33 (51.5%)	
1	14 (21.9%)	233 (31.1%)		14 (21.9%)	
2	14 (21.9%)	129 (17.2%)		12 (18.8%)	
3	0 (0%)	82 (10.9%)		3 (4.7%)	
4	0 (0%)	9 (1.2%)		2 (3.1%)	
Preoperative Lysholm score[a]	50.7 ± 24.9	54.3 ± 24.8	(n.s.)	57.0 ± 26.0	(n.s.)
Preoperative IKDC subjective score[a]	42.0 ± 19.5	44.9 ± 18.4	(n.s.)	46.6 ± 19.2	(n.s.)
Preoperative IKDC objective grade[b]			(n.s.)		(n.s.)
A	20 (31.3%)	279 (37.2%)		23 (35.9%)	
B	16 (25.0%)	251 (33.5%)		22 (34.4%)	
C	13 (20.3%)	166 (22.1%)		10 (15.6%)	
D	15 (23.4%)	54 (7.2%)		9 (14.1%)	

BMI body mass index, *IKDC* International Knee Documentation Committee

[a]The values are given as the mean and standard deviation

[b]The values are given the number of patients, with the percentage in parentheses

Lysholm score was considered to have been met if the upper limit of the one-sided 90% confidence interval (CI) for the difference between the groups was less than 10.1. Additionally, the standard deviation adopted from a previous study was 19.4 [8]. The margin used for the upper limit of the 90% CI and standard deviation adopted from a previous study of SSD of valgus gap were 2.0 and 1.8 mm, respectively [28].The cohort size was calculated for the two variables, and we found that a minimum of 46 subjects were needed for each group. Thus the sample size of 64 patients in each group of this study could be considered sufficient in this study.

Results

The distribution of the two groups by type of operation was as follows: meniscal repair [release group = 34 (53.1%); non release group = 27 (42.2%)], meniscectomy [release group = 25 (39.1%); non release group = 31 (48.4%)], meniscal root repair [release group = 5 (7.8%); non release group = 6 (9.4%)] (Table 1). There was no significant difference in the VAS score between the two groups at any time point during the 24 months. Although the VAS score at 1 day after the operation was higher in

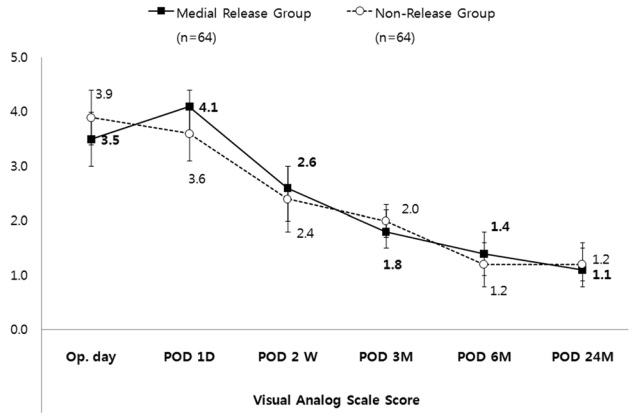

Fig. 4 Comparison of VAS between the medial release and non-release groups for 24 months

the release group than in the non-release group, there was no statistically significant difference. There was a trend of decline over time in both the groups (Fig. 4). In the release group, valgus stress radiographs at 24 months postoperatively showed no significant increases in the SSD and ABV of valgus laxity compared to the preoperative examination results [preoperative SSD, -0.1 ± 1.3 mm; postoperative SSD, -0.1 ± 1.4 mm; (n.s.), preoperative ABV, 8.2 ± 1.8 mm; postoperative ABV, 7.9 ± 2.2 mm; (n.s.)] (Table 2). The 90% CI of the SSD of valgus gap ranged from -1.51 to 1.37 mm, which met the criterion for non-inferiority of the 24-month follow-up measurements after PPMR with respect to abnormal valgus laxity compared with preoperative measurements using a margin of 2.0 mm for the upper limit of the 90% CI.

At the 24 month follow-up visit, the mean Lysholm score was 85.1 ± 17.2 points for the release group and 83.9 ± 20.4 points for the non-release group; these values were not significantly different (n.s.).

The 90% CI of the Lysholm difference between the two groups at the 24-month follow-up ranged from -10.59 to 9.24, which met the criterion for non-inferiority of the release group with respect to the Lysholm score compared with the non-release group using the non-inferiority margin of 10.1 for the upper limit of the 90% CI. Therefore, it was concluded that the Lysholm score and SSD of valgus gap of the release group were not statistically inferior to those of the non-release group. Furthermore, grade frequencies of the IKDC objective form and the IKDC subjective score did not differ significantly between groups [82.4 ± 19.3 points for the release group, 81.3 ± 20.1 points for the non-release group (n.s.)] (Table 3).

Table 2 Comparison between preoperative and 24-month follow-up valgus laxity measurements in the medial release group ($n = 64$)

	Preoperative	Follow-up	*p* value
Side to side difference	-0.1 ± 1.3	-0.1 ± 1.4	(n.s.)
Degree of valgus laxity	8.2 ± 1.8	7.9 ± 2.2	(n.s.)

Table 3 Comparison of clinical variables between the medial release and non-release groups at the 24-month follow-up

	Release group ($n = 64$)	Non-release group ($n = 64$)	*p* value
Lysholm score[a]	85.1 ± 17.2	83.9 ± 20.4	(n.s.)
IKDC subjective score[a]	82.4 ± 19.3	81.3 ± 20.1	(n.s.)
IKDC objective grade[b]			(n.s.)
A	43 (67.2%)	40 (62.5%)	
B	11 (17.2%)	18 (28.1%)	
C	7 (10.9%)	4 (6.3%)	
D	3 (4.7%)	2 (3.1%)	

IKDC International Knee Documentation Committee

[a]The values are given as the mean and standard deviation

[b]The values are given the number of patients, with the percentage in parentheses

Discussion

As hypothesized, the principal findings of this study were that there was no significant difference in clinical outcomes between the release and non-release groups and performing PPMR in addition to meniscal surgery did not result in significant medial instability at the 24-month postoperative follow-up compared to the contralateral side.

Arthroscopic surgery of the medial meniscus is one of the most commonly performed procedures of the knee with or without surgery for combined other lesions. However, in certain operations, difficulties in arthroscopic visualization and instrument access have resulted in diagnostic error and insufficient treatment, leading to continuous symptoms that have required revision surgery [6, 15, 16, 36, 37]. Furthermore, a narrow medial joint space makes it difficult to acquire adequate space for instrument access, which can result in inadvertent irreversible injury to the articular cartilage [7, 10, 27, 33] As a solution, several additional techniques to secure visualization and instrument access during arthroscopic surgery have been proposed [2, 22, 25, 26, 36]. Spahn [36] applied intra-articular medial capsule and medial collateral ligament release as suggested by Leon et al. [29] to treat varus arthritic knee, whereas others have suggested using the posteromedial portal for direct inspection of lesions of the posterior horn of the medial meniscus [2, 6, 26, 30] and accessing the inframeniscal portal for instrument assessment

[19, 22, 25]. However, the aforementioned procedures are technically difficult, associated with possible morbidity, and are only useful for specific lesions; therefore, they are not widely applicable to general arthroscopic procedures.

The PPMR technique performed in this study uses the anterior portal, which is familiar to most surgeons and does not require additional portals, and is therefore, a relatively easy method for acquiring adequate visualization and working space. Agneskirchner and Lobenhoffer [1] first introduced this technique in 2004 by applying the pie-crusting technique used during soft tissue balancing in knee arthroplasty. Its application in arthroscopic surgeries has been recently reported by several authors [3, 9, 12, 33, 34]. Park et al. [33] reported that they used this technique in all operations in their report on "Arthroscopic pullout repair of posterior root tear of the medial meniscus case series". There are nevertheless still concerns regarding iatrogenic MCL injury and its clinical sequelae. Fakioglu et al. [12] analyzed the clinical outcomes of all 18 patients who underwent arthroscopic partial meniscectomy in addition to PPMR with the Lysholm score and medial joint space width on valgus stress radiographs. However, this was a case series study. Claret et al. [9] reported a retrospective clinical study of 140 patients undergoing arthroscopic meniscectomy with or without MCL, and PPMR was conducted. At the 2-month follow-up, they found the significantly higher Lysholm scores in the PPMR group than in the control. After 6 months, the scores were virtually equal between the two groups. The results of our study were similar in that all the previous studies concluded that the PPMR did not affect clinical outcome or abnormal valgus laxity during the follow-up. Previous studies, however, have focused on patients who underwent only meniscectomy. The frequency of use and outcomes of PPMR in various meniscal procedures such as meniscal repair and meniscal root repair, were investigated in our study. Of the 56 patients who underwent arthroscopic meniscectomy, 25 patients (44.6%) underwent PPMR and 31 patients (55.4%) did not. Among the 61 patients who underwent meniscal repair, 34 patients (55.7%) underwent PPMR compared with 27 patients (44.3%) of the non-release group. In meniscal repair, a larger space for inserting instruments such as a suture passer and adequate visualization are needed. We analyzed the results of using PPMR more frequently in the meniscal repair procedure because of this need. Luchi et al. [20] reported that the vertical suture had more desirable biomechanical properties, which includes widening of the suture after cyclic load, ultimate failure load and stiffness compared to the horizontal suture for meniscal repair. The vertical suture requires a wider medial gap than the horizontal suture for medial meniscus repair, therefore, use of PPMR helps the procedure to produce better biomechanical properties of sutures. Besides, no studies about the medial release of tight medial compartments undergoing knee arthroscopy, have quantitatively analyzed abnormal valgus laxity and clinical outcomes compared to a control group over a 24 month follow-up period like our study.

The use of propensity score matching in observational studies has become increasingly popular because it allows investigators to control for selection bias and confounding factors [4, 5]. A strength of the current study is that propensity score matching was used to compare the release and non-release group; this is the only case–control study on this topic to date.

The superficial MCL is the primary stabilizer against valgus force according to several biomechanical studies [17, 18, 24]. Gardiner et al. [13, 14] reported that the posterior MCL region proximal to the knee joint line receives the highest strain during knee valgus force application. In our study, release of the posterior third of the superficial MCL layer just proximal to the joint line was performed while manual valgus force was applied. Arthroscopic visualization of the medial joint-line opening allowed control of the amount of the extent of release for each specific operation. Literatures reported that satisfactory clinical outcomes have been gained for MCL injures after conservative treatment because of good healing potential due to an abundant vascular supply [32, 38]. Most grade I and II lesions achieve healing with brace application for 2–6 weeks with a protected range of motion and rehabilitation. Superficial MCL injuries by the percutaneous pie-crusting method in the current study could be classified as grade I or II lesions, which have been proven on magnetic resonance imaging (MRI) studies by Fakioglu et al. [12]. Though the use of a brace is unnecessary in the treatment of grades I and II lesions of the MCL, the brace we used was a prophylactic one to prevent further injury of the MCL due to valgus forces. At the 24-month postoperative follow-up, we confirmed that performing PPMR in addition to meniscal surgery did not result in significant abnormal valgus laxity of the affected side compared to the contralateral side. The structure to be aware of during PPMR is the saphenous nerve at the medial aspect of the knee that runs adjacent to the saphenous vein between the sartorius and gracilis posterior to the medial femoral epicondyle. Due to the cautious insertion of the needle (described in "Materials and methods"), complications associated with the saphenous nerve did not occur in any of the patients.

This study has several limitations. First, the study was retrospective in nature, which is associated with the risk of selection bias. Therefore, we performed multivariate analysis and used propensity score matching to reduce bias. Second, there was no direct radiographic evaluation such as MRI to actually evaluate the area of MCL release and to confirm healing of the MCL at follow-up. Third, the manual valgus force applied during arthroscopic surgery was not quantified, which means that variable amounts of valgus forces applied in different patients could have led to differences in

the extent of the medial gap, thereby affecting the decision to perform PPMR.

When performing arthroscopic surgery for the medial compartment of knee in patients with a narrow medial joint space, PPMR allows easier use of the surgical instruments without damaging the articular cartilage. And PPMR is a safe procedure could be performed without any concern about iatrogenic valgus laxity.

Conclusion

PPMR is a useful additional procedure to perform during arthroscopic surgery for patients with a narrow medial joint space of the knee. In particular, PPMR did neither affect valgus laxity nor clinical outcome at the time of the final follow-up.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Funding The authors received no financial support for the Research, authorship, and/or publication of this article.

Ethical approval The study was approved by the Ethical committee of the institution.

Informed consent Patients were informed, and they consented to conduct the study.

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