Factors associated with medial meniscal subluxation in knees with medial meniscus tears: a cross-sectional study

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Abstract

Background Previous studies have indicated that medial meniscal subluxation (MMS) is associated with special types of medial meniscus tears (MMT) and chondral lesions. However, most of these studies lacked arthroscopic findings and did not adjust for possible confounders. The purpose of this study was to explore factors associated with MMS in patients with MMT using multivariate logistic regression analysis.

Methods A retrospective analysis of 115 patients who underwent arthroscopic surgery for MMT was conducted. The medial meniscal extrusion (MME) distance was measured on a single mid-coronal magnetic resonance (MR) image, and the MMS group included patients with MME distance ≥3 mm (55 patients with 55 knees). Other patients were included as the control group (60 patients with 60 knees). Demographic and clinical data were collected as variates. A multivariate logistic regression analysis was performed to identify factors associated with MMS.

Results In a univariate analysis, the Outerbridge classification (P=0.002) and the type of MMT (P<0.001) were significantly different between the MMS group and the control group. According to unadjusted and age- and body mass index (BMI)-adjusted multivariate logistic regression analysis, the type of MMT was an independent factor associated with MMS. Compared with horizontal tears, radial tears, posterior medial meniscus root tears (PMMRT) and complex tears had approximately 6-fold (adjusted OR 6.468, 95% CI 1.509–27.718, P=0.012), 10-fold (adjusted OR 10.324, 95% CI 1.719–61.989, P=0.011) and 4-fold (adjusted OR 4.458, 95% CI 1.602–12.408, P=0.004) higher associations with MMS, respectively.

Conclusion The type of MMT was an independent factor associated with MMS in knees with MMT. Radial tears, PMMRT and complex tears were more likely than horizontal tears to result in MMS. The results suggest that MMT combined with MMS should be noted when managing MMT, especially radial tears, PMMRT and complex tears. Moreover, the results indicate that we must not only preserve the meniscus as much as possible but also restore its position to as close to normal as possible.

Background

The menisci are crescent-shaped wedges of fibrocartilage with bony attachments on the tibial plateau. The primary function of the menisci is to transmit load by increasing congruity between the rounded femoral condyles and the flattened surface of the tibial plateau, and other functions include shock absorption, lubrication, proprioception, and joint stability [1-5]. Intact menisci occupy approximately 60% of the contact area between the articular surfaces and transmit >50% of the total axial load of the knee joint [6]. These functions may be compromised when menisci are torn or positioned abnormally.

Medial meniscal extrusion (MME) is defined as medial displacement of the medial meniscus beyond the margin of the tibial plateau. MME results from considerable disruption of either the meniscal root or the circumferential fiber bundles of the medial meniscus, which impairs the ability to resist the hoop strain that stretches the meniscus in a radial direction during weight-bearing [7-10]. A meniscal extrusion distance ≥3 mm is considered a pathological condition, and some authors have termed this condition medial meniscal subluxation (MMS) [7, 11].

According to a finite element analysis study, MMS was associated with increased loading of all knee structures, especially the tibial cartilage, and a positive correlation was found between the degree of MMS and the amount of loading on the tibial cartilage [12]. The conclusion of this research may explain the results of previous longitudinal studies showing that MMS or MME was related to cartilage degeneration and subchondral bone changes that predict knee osteoarthritis [13, 14].

Previous studies have indicated that MMS or major MME (an MME distance >3 mm) is associated with medial meniscus tears (MMT), especially extensive tears, complex tears, radial tears and root tears [7-9]. MMS has also been correlated with chondral lesions [9]. However, most of these previous studies lacked arthroscopic findings and did not control for possible confounders. The purpose of this study was to explore factors associated with MMS in patients with MMT using multivariate logistic regression analysis. We hypothesized that body mass index (BMI), the type of MMT and chondral lesions involving the ipsilateral medial compartment were factors associated with MMS.

Methods

Sample selection and grouping

We retrospectively evaluated the magnetic resonance (MR) images and clinical data of 218 patients who underwent MR imaging examinations and arthroscopic surgeries for MMT from June 2014 to May 2020. Patients with isolated MMT were selected for the study. The exclusion criteria were as follows: MMT combined with ligament injuries, lateral meniscal tears, rheumatoid arthritis, septic arthritis or tumors; a previous history of knee surgery; and unavailability of MR images of sufficient quality. All arthroscopic surgeries were performed within two weeks of the MR imaging examination. Patients were divided into an MMS group and a control group on the basis of whether MMS was present on MR images.

MR imaging protocol and measurement

All patients underwent MR imaging examinations in the supine position. MR imaging examinations were performed with a 3T MR imaging unit (MAGNETOM Skyra, Siemens Healthcare, Erlangen, Germany) using a quadrature extremity coil. The MR imaging protocol incorporated the following sequences: a T1-weighted turbo spin-echo (TSE) sequence in the sagittal plane (FOV: 160 mm, slice thickness: 4 mm, interslice gap: 0.5 mm, TR: 800 ms, TE: 12 ms, matrix: 256 x 256 mm) and a proton density-weighted TSE sequence with fat saturation in the coronal, sagittal and transversal planes (FOV: 160 mm, slice thickness: 4 mm, interslice gap: 0.5 mm, TR: 3300-3600 ms, TE: 48 ms, matrix: 256 x 256 mm).

The MME distance was measured using the General Electric Healthcare PACS program (GE, Centricity Universal Viewer Zero Footprint, version 5.0 sp7.1). The MME distance was quantified in millimeters (mm) on a coronal MR image obtained at the midpoint of the medial femoral condyle. Two vertical lines were drawn that intersected the outer edge of the medial meniscus and the outer margin of the medial tibial plateau. The distance between the two lines was defined as the MME distance (**Fig. 1**). Osteophytes were excluded when determining the medial margin of the tibial plateau.

Fig. 1 Measurement of medial meniscal extrusion on an MR image

Measurement of medial meniscal extrusion: Using a mid-coronal MR image, the first vertical line was drawn to intersect the medial edge of the medial tibial plateau (dotted line a), and the second vertical line was drawn to intersect the medial edge of the medial meniscus (solid line b). The distance between the two lines (arrow line c) was defined as the medial meniscal extrusion distance.

Two trained surgeons who were blinded to the study design, clinical information and radiological reports measured the MME distance. The mean distance was used in the assessment. An MME distance ≥3 mm was considered to indicate MMS. The interobserver reliability of the measurements between the two surgeons was analyzed using the intraclass correlation coefficient (ICC), with an ICC of 0.40 indicating poor reproducibility, an ICC of 0.40–0.75 indicating fair to good reproducibility, and an ICC greater than 0.75 indicating excellent reproducibility [15]. The ICC was 0.887 (range: 0.841–0.921).

Demographic and clinical data

Demographic and clinical data included sex, age, BMI, the side of the affected knee, the duration of symptoms, the severity of chondral lesions involving the ipsilateral medial compartment and the type of MMT. The duration of symptoms was defined as the length of time with knee pain before the operation was performed. The severity of chondral lesions involving the ipsilateral medial compartment was described according to the Outerbridge classification: Grade 0 signified normal cartilage; Grade I lesion referred to cartilage with softening and swelling; Grade II lesion described a partial-thickness defect with fissures not exceeding 0.5 inches in diameter or reaching subchondral bone; Grade III lesion was characterized by chondral fissures with a diameter >0.5 inches with an area reaching subchondral bone; and Grade IV indicated erosion of the articular cartilage that exposed subchondral bone [16]. The types of MMT were categorized as horizontal tears, longitudinal tears, bucket-handle tears, radial tears, posterior medial meniscus root tears (PMMRT), and complex tears [17]. Because bucket-handle tears were defined as a subgroup of longitudinal tears with an attached fragment displaced away from the periphery of the meniscus, we classified bucket-handle tears as longitudinal tears in this study [18, 19]. The above data were collected as variates for analysis.

Statistical analysis

Statistical analysis was performed with SPSS software (version 25, SPSS, Chicago, IL). The normality of continuous data distributions was assessed using the Kolmogorov-Smirnov test. Normally distributed data were expressed as the mean (±standard deviation), and the median (interquartile range) was used to express data with a skewed distribution. Categorical data were presented as frequencies and percentages. Univariate analysis was performed using the chi-squared test for categorical data, the independent-sample t-test for continuous data with a normal distribution, and the Mann-Whitney U test for continuous data that were not normally distributed. Variates identified by univariate analysis (P value < 0.1) were then inputted into unadjusted and age- and BMI-adjusted multivariate logistic regression analysis. The enter method was used. A P value less than 0.05 was considered statistically significant. The odds ratio (OR) and 95% confidence interval (CI) were calculated as an approximate index of the relative risks.

Goodness of fit was evaluated using the Hosmer and Lemeshow test, where a P value >0.05 indicated good fit of the model. Multicollinearity was assessed by the tolerance and the variance inflation factor (VIF), where a tolerance value <0.1 and a VIF value ≧10 indicated a multicollinearity problem. Influential observations were detected using the leverage value (LEV), and an LEV >0.2 indicated a potential influential point.

According to an empirical formula for sample size estimation, the sample size needed to be equal to 5- to 10-times the number of observed variables [20]. Eight variables, including the types of MMT, were inputted into the age- and BMI-adjusted logistic regression analysis; therefore, a sample size of eighty patients was required in the study.

Results

A total of 115 patients were enrolled in the study, including 66 male patients and 49 female patients with a median age of 53 years (interquartile range: 39–61 years), a mean BMI of 26.1 (±3.3), and a median MME distance of 2.80 mm (interquartile range: 1.70–3.50 mm).

The MMS group consisted of 55 knees in 55 patients with a median age of 55 years (interquartile range: 40–62 years) and a mean BMI of 26.4 (±3.2). The control group consisted of 60 knees in 60 patients with a median age of 51 years (interquartile range: 39–61 years) and a mean BMI of 25.9 (±3.5). The MME distance was significantly higher in the MMS group (median distance: 3.5 mm, interquartile range: 3.3–4.1 mm) than in the control group (median distance: 1.8 mm, interquartile range: 1.3–2.3 mm, P<0.001). Summaries of the demographic data and arthroscopic findings of the patients in the two groups are presented in **Table 1** and **Table 2,** respectively. No significant differences in sex (P=0.085), age (P=0.182), BMI (P=0.405), the side of affected knee (P=0.217), or the duration of symptoms (P=0.890) were noted between the two groups. The Outerbridge classification (P=0.002) and the type of MMT (P<0.001) were significantly different between the MMS group and the control group.

Table 1 Demographic data of the patients in the MMS group and control group

Demographic data	Control group (n=60)	MMS group (n=55)	P
Sex (n (%))			0.085
Female	21 (18.3 %)	28 (24.3%)	
Male	39 (33.9 %)	27 (23.5 %)	
Age (years)	51 (39-61)	55 (40-62)	0.182
BMI	25.9 (±3.5)	26.4 (±3.2)	0.405
Side of affected knee (n (%))			0.217
Left	32 (27.8 %)	23 (20.0 %)	
Right	28 (24.3 %)	32 (27.8 %)	
Duration of symptoms (n (%))			0.890
<3 months	18 (15.7 %)	17 (14.8 %)	
≥3 months, <12 months	21 (18.3 %)	17 (14.8 %)	
≥12 months	21 (19.2 %)	21 (18.3 %)	

MMS, medial meniscal subluxation; BMI, body mass index; the duration of symptoms was defined as the length of time with knee pain before the operation was performed.

Table 2 Arthroscopic findings of the patients in the MMS group and control group

Arthroscopic findings	Control group (n=60)	MMS group (n=55)	P
Outerbridge classification (n (%))			0.002*
Grade 0 - II	50 (43.5 %)	31 (27.0 %)	
Grade III - IV	10 (8.7 %)	24 (20.9 %)	
Type of MMT (n (%))			0.000*
Horizontal tears	35 (30.4%)	12 (10.4 %)	
Longitudinal tears	6 (5.2 %)	3 (2.6 %)	
Radial tears	4 (3.5 %)	11 (9.6 %)	
PMMRT	2 (1.7 %)	9 (7.8 %)	
Complex tears	13 (11.3 %)	20 (17.4 %)	

MMS, medial meniscal subluxation; MMT, medial meniscus tears; PMMRT, posterior medial meniscus root tears.

* Statistically significant ($P<0.05$)

The variates, including sex, Outerbridge classification and the type of MMT, were input into the unadjusted and the age- and BMI-adjusted multivariate logistic regression analysis. The results showed that the type of MMT was an independent factor associated with MMS in both models. Compared with horizontal tears, radial tears, PMMRT and complex tears had approximately 6-fold (adjusted OR 6.468, 95% CI 1.509–27.718, P=0.012), 10-fold (adjusted OR 10.324, 95% CI 1.719–61.989, P=0.011) and 4-fold (adjusted OR 4.458, 95% CI 1.602–12.408, P=0.004) higher associations with MMS, respectively (**Table 3**).

Table 3 Multivariate logistic regression analysis of factors associated with MMS

Variates	Model 1[a]			Model 2[b]		
	Unadjusted OR	95% CI	P	adjusted OR	95% CI	P
Outerbridge classification						
Grade 0 - II	1.00 (Reference)	-	-	1.00 (Reference)	-	-
Grade III - IV	2.043	0.757-5.514	0.158	2.338	0.820-6.666	0.112
Type of MMT			0.016*			0.013*
Horizontal tears	1.00 (Reference)	-	-	1.00 (Reference)	-	-
Longitudinal tears	1.666	0.352-7.882	0.520	1.595	0.333-7.648	0.560
Radial tears	5.467	1.359-21.999	0.017*	6.468	1.509-27.718	0.012*
PMMRT	8.638	1.526-48.890	0.015*	10.324	1.719-61.989	0.011*
Complex tears	4.030	1.495-10.863	0.006*	4.458	1.602-12.408	0.004*
Sex						
Female	1.00 (Reference)	-	-	1.00 (Reference)	-	-
Male	0.606	0.260-1.413	0.246	0.552	0.229-1.330	0.186
Age				0.984	0.948-1.022	0.410
BMI				0.966	0.852-1.096	0.594

OR, odds ratio; CI, confidence interval; MMT, medial meniscus tears; PMMRT, posterior medial meniscus root tears; BMI, body mass index.

a Model 1 was unadjusted for age and BMI.

b Model 2 was adjusted for age and BMI.

* Statistically significant (P<0.05)

Non-significance of the Hosmer and Lemeshow test (Model 1: P=0.916; Model 2: P=0.929) showed that the two models had acceptable fitness. The LEVs of the two models ranged from 0.025 to 0.165 and from 0.027 to 0.191, respectively, indicating that no influential point existed. No multicollinearity problems were observed in the two models since all tolerance values were greater than 0.1 and VIF values were less than 10.

Discussion

The menisci are crescent-shaped wedges of fibrocartilage that are anchored to the tibia by anterior and posterior root attachments. They consist of a sparse cell population and dense extracellular matrix composed primarily of water (72 %) and collagen (22 %), with other constituents including glycosaminoglycans, DNA, adhesion glycoproteins and elastin [21, 22]. Collagen is the major fibrillar component of the menisci. The main collagen fiber bundles predominantly exhibit a circumferential orientation [8]. During weight-bearing, the compressive force applied on the wedge-shaped meniscus results in hoop strain, which stretches the collagen bundles in a radial direction [8, 23]. However, the meniscus mainly responds to loading by compressing rather than extruding because the tensile strength of the meniscus, which depends on the circumferential collagen fiber bundles and the anatomical insertions of the anchoring horns (anterior and posterior root attachments), counteracts extrusion [21]. Hence, disruption of either the circumferential collagen fiber bundles or the meniscal root attachments can result in MME [7].

Costa et al. reviewed one hundred and five knee MR images and found that an MME distance >3 mm was associated with severe meniscal degeneration, extensive tears, complex tears, large radial tears and root tears [8]. Lerer et al. concluded that MMS was associated with moderate and large medial compartment marginal osteophytes, moderate to severe medial compartment cartilage loss, radial tears and root pathology by evaluating 205 consecutive knee MR images of patients with knee pain [7]. However, these two reports lacked arthroscopic findings, which are the gold standard for diagnosing the type of MMT and for evaluating the severity of chondral lesions. Choi et al. analyzed 248 patients with MMT who underwent arthroscopic meniscectomy and found that MMS was significantly correlated with root tears, and that the severity of chondral lesions involving the medial femoral condyle depended on the arthroscopic findings [9]. However, these studies could not identify the most relevant factors associated with MMS because confounders were not controlled.

In this study, we found that the type of MMT was an independent factor associated with MMS. Compared with horizontal tears, radial tears, PMMRT and complex tears had approximately 6-fold, 10-fold and 4-fold higher associations with MMS, which was consistent with the histological and anatomical morphology of the menisci. Radial tears perpendicular to the long axis of the circumferential collagen fiber bundles completely disrupt the ability to resist hoop strain and lead to major extrusion [8, 23]. Meniscal root tears impair the attachments of the menisci, which are anchored to the tibial plateau, and most tears occurring at or near the meniscal roots are radial tears [24, 25]. Complex tears significantly alter hoop strain resistance because of extensive structural disruption of more than one cleavage plane through the collagen fiber bundles [8]. Horizontal tears and longitudinal tears oriented parallel to the circumferential collagen fiber bundles cause minor impairment and thus are not associated with extensive MME [8, 10].

We found ten knees (16.7 %) with an Outerbridge classification of grade III–IV among 60 knees in the control group versus 24 (43.6 %) of 55 knees in the MMT group. The severity of chondral lesions involving the ipsilateral medial compartment was significantly different between the two groups. These results are similar to those of previous studies [7, 9]. Because our study was cross-sectional, we could not verify a causal relationship between MMS and chondral lesions. Choi et al. performed a longitudinal observational study including forty patients who showed MMS on MR images without cartilage degeneration. After two years of follow-up, cartilage degeneration on the ipsilateral medial femoral condyle was observed in twenty-five patients (62.5 %), and the amount of MMS was related to the degree of progression of cartilage degeneration [14]. Therefore, MMS is more likely to precede the development of chondral lesions, and abnormal stress distribution patterns of the knee joint caused by MMS lead to increased focal loading on articular cartilage and subsequent chondral loss.

In a longitudinal study, BMI was reported to be a risk factor for the development of MME (OR 3.04, 95% CI 1.04–8.93) [26], but we found that BMI was not associated with MMS. In our study, patients were in a supine non-weight-bearing position when MR imaging was performed; therefore, BMI might have little influence on MME. The results may be altered when patients are in a weight-bearing position.

Some limitations existed in this study. First, the sample size was relatively small. According to the empirical formula for sample size estimation, a sample size of 115 patients was acceptable. However, the sample size in each subgroup of MMT type was lacking; thus, the results must be validated by studies with larger sample sizes. Second, the nature of the cross-sectional design of this study did not allow us to confirm the temporal order of incidents; therefore, causal relationships between variates and MMS could not be determined. Third, because of a lack of long-leg radiographs, knee malalignment was not assessed in our study. Therefore, longitudinal investigations with larger sample sizes and more variates should be performed to identify risk factors for further study.

Conclusions

Our results demonstrated that the type of MMT was an independent factor associated with MMS in knees with MMT. Radial tears, PMMRT and complex tears were more likely than horizontal tears to result in MMS. The results suggest that MMT combined with MMS should be noted when managing MMT, especially radial tears, PMMRT and complex tears. Moreover, the results indicate that we must not only preserve the meniscus as much as possible but also restore its position to as close to normal as possible.

List Of Abbreviations

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MME Medial meniscal extrusion

MMS Medial meniscal subluxation

MMT Medial meniscus tears

BMI Body mass index

MR Magnetic resonance

ICC Intraclass correlation coefficient

PMMRT Posterior medial meniscus root tears

OR Odds ratio

CI Confidence interval

VIF Variance inflation factor

LEV Leverage value

Declarations

Ethics approval and consent to participate

The study was approved by the Ethical Review Committee of Peking University International Hospital (No. 2019-070). The Ethical Review Committee determined that patient approval and informed consent were not required for reviewing images and records.

Consent for publication

No applicable

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to being used for a diagnostic study but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

XL: Conceptualization, Methodology, Data Curation, Writing - Original Draft. RD: Investigation. BY: Investigation. CL: Data Curation, Supervision. WW: Conceptualization, Methodology, Writing - Review & Editing. All authors have read and approved the final manuscript.

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References

1.Seedhom BB, Dowson D, Wright V: Proceedings: Functions of the menisci. A preliminary study. Ann Rheum Dis. 1974;33(1):111.

2.Walker PS, Erkman MJ: The role of the menisci in force transmission across the knee. Clin Orthop Relat Res. 1975;109:184-92.

3.Bessette GC: The meniscus. Orthopedics. 1992; 15(1):35-42.

4.McBride ID, Reid JG: Biomechanical considerations of the menisci of the knee. Can J Sport Sci. 1988; 13(4):175-87.

5.Zhang F, Kumm J, Svensson F, Turkiewicz A, Frobell R, Englund M: Risk factors for meniscal body extrusion on MRI in subjects free of radiographic knee osteoarthritis: longitudinal data from the Osteoarthritis Initiative. Osteoarthritis Cartilage. 2016; 24(5):801-6.

6.Makris EA, Hadidi P, Athanasiou KA: The knee meniscus: structure-function, pathophysiology, current repair techniques, and prospects for regeneration. Biomaterials. 2011; 32(30):7411-31.

7.Lerer DB, Umans HR, Hu MX, Jones MH: The role of meniscal root pathology and radial meniscal tear in medial meniscal extrusion. Skeletal Radiol. 2004; 33(10):569-74.

8.Costa CR, Morrison WB, Carrino JA: Medial meniscus extrusion on knee MRI: is extent associated with severity of degeneration or type of tear? AJR Am J Roentgenol. 2004; 183(1):17-23.

9.Choi CJ, Choi YJ, Lee JJ, Choi CH: Magnetic resonance imaging evidence of meniscal extrusion in medial meniscus posterior root tear. Arthroscopy. 2010; 26(12):1602-6.

10.Swamy N, Wadhwa V, Bajaj G, Chhabra A, Pandey T: Medial meniscal extrusion: Detection, evaluation and clinical implications. Eur J Radiol. 2018; 102:115-24.

11.Yang A YS, Greif W, Janick PA, Michael R.: Role of meniscal subluxation in degenerative arthritis of the knee: demonstration with coronal MR imaging and the oreo cookie model. Radiol Suppl. 1993;189:380.

12.Gokkus K, Atmaca H, Ugur L, Ozkan A, Aydin AT: The relationship between medial meniscal subluxation and stress distribution pattern of the knee joint: Finite element analysis. J Orthop Sci.2016; 21(1):32-7.

13.Wang Y, Wluka AE, Pelletier JP, Martel-Pelletier J, Abram F, Ding C, Cicuttini FM: Meniscal extrusion predicts increases in subchondral bone marrow lesions and bone cysts and expansion of subchondral bone in osteoarthritic knees. Rheumatology (Oxford). 2010; 49(5):997-1004.

14.Choi YR, Kim JH, Chung JH, Lee DH, Ryu KJ, Ha DH, Dan J, Lee SM: The association between meniscal subluxation and cartilage degeneration. Eur J Orthop Surg Traumatol. 2014; 24(1):79-84.

15.Park HJ, Kim SS, Lee SY, Choi YJ, Chung EC, Rho MH, Kwag HJ: Medial meniscal root tears and meniscal extrusion transverse length ratios on MRI. Br J Radiol. 2012; 85(1019):e1032-7.

16.Slattery C, Kweon CY: Classifications in Brief: Outerbridge Classification of Chondral Lesions. Clin Orthop Relat Res. 2018; 476(10):2101-4.

17.Nguyen JC, De Smet AA, Graf BK, Rosas HG: MR imaging-based diagnosis and classification of meniscal tears. Radiographics. 2014; 34(4):981-99.

18.Saltzman BM, Cotter EJ, Wang KC, Rice R, Manning BT, Yanke AB, Forsythe B, Verma NN, Cole BJ: Arthroscopically Repaired Bucket-Handle Meniscus Tears: Patient Demographics, Postoperative Outcomes, and a Comparison of Success and Failure Cases. Cartilage. 2020; 11(1):77-87.

19.Frizziero A, Ferrari R, Giannotti E, Ferroni C, Poli P, Masiero S: The meniscus tear. State of the art of rehabilitation protocols related to surgical procedures. Muscles Ligaments Tendons J. 2012;2(4):295-301.

20.Guo Y, Jia P, Zhang J, Wang X, Jiang H, Jiang W: Prevalence and risk factors of postoperative delirium in elderly hip fracture patients. J Int Med Res. 2016; 44(2):317-27.

21.Aagaard H, Verdonk R: Function of the normal meniscus and consequences of meniscal resection. Scand J Med Sci Sports. 1999; 9(3):134-40.

22.Fox AJ, Wanivenhaus F, Burge AJ, Warren RF, Rodeo SA: The human meniscus: a review of anatomy, function, injury, and advances in treatment. Clin Anat. 2015; 28(2):269-87.

23.Magee T: MR findings of meniscal extrusion correlated with arthroscopy. J Magn Reson Imaging. 2008; 28(2):466-70.

24.Brody JM, Hulstyn MJ, Fleming BC, Tung GA: The meniscal roots: gross anatomic correlation with 3-T MRI findings. AJR Am J Roentgenol. 2007; 188(5):W446-50.

25.Brody JM, Lin HM, Hulstyn MJ, Tung GA: Lateral meniscus root tear and meniscus extrusion with anterior cruciate ligament tear. Radiology. 2006; 239(3):805-10.

26.Englund M, Felson DT, Guermazi A, Roemer FW, Wang K, Crema MD, Lynch JA, Sharma L, Segal NA, Lewis CE et al: Risk factors for medial meniscal pathology on knee MRI in older US adults: a multicentre prospective cohort study. Ann Rheum Dis. 2011; 70(10):1733-39.

Figures

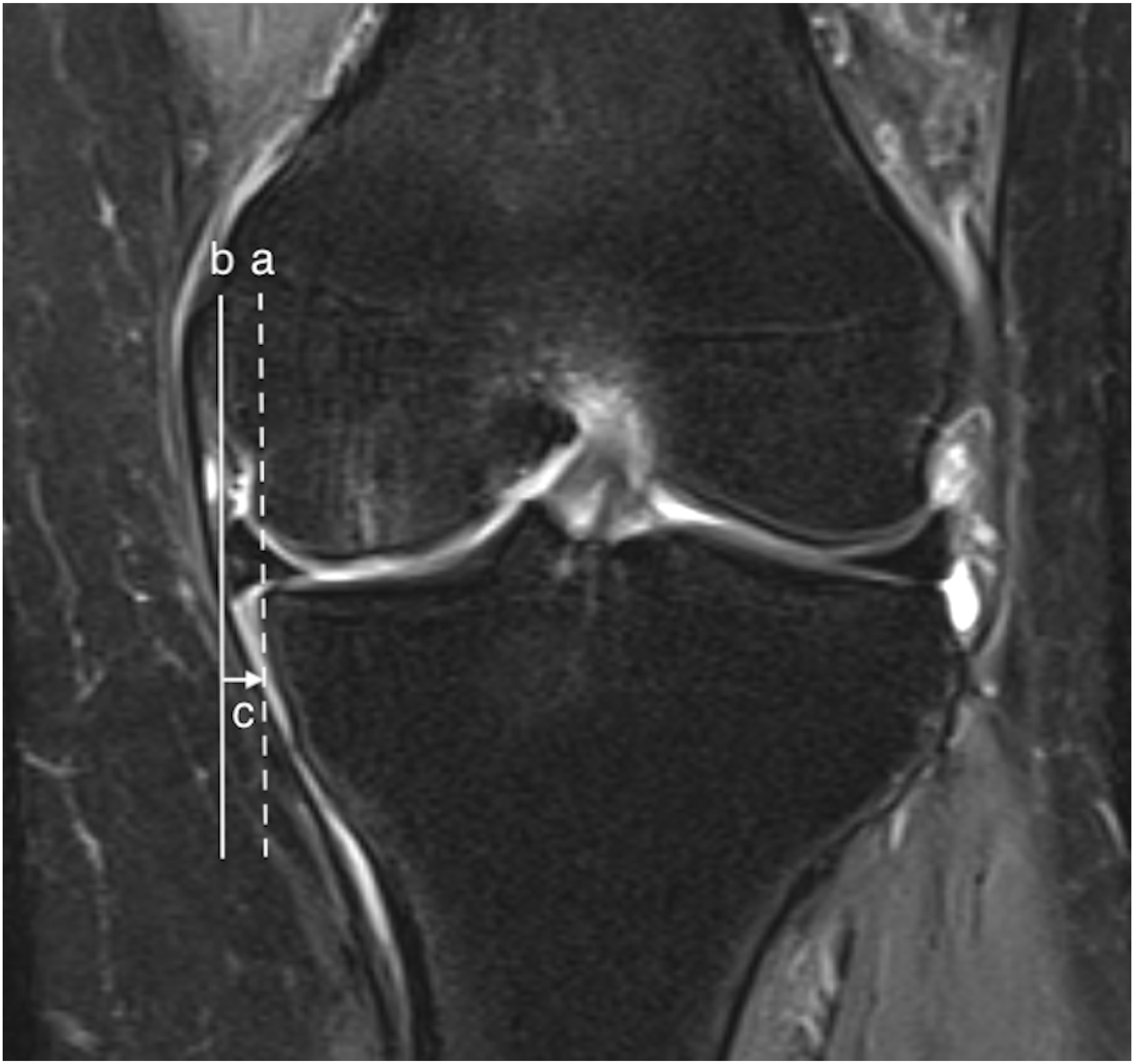

Figure 1

Measurement of medial meniscal extrusion on an MR image Measurement of medial meniscal extrusion: Using a mid-coronal MR image, the first vertical line was drawn to intersect the medial edge of the medial tibial plateau (dotted line a), and the second vertical line was drawn to intersect the medial edge of the medial meniscus (solid line b). The distance between the two lines (arrow line c) was defined as the medial meniscal extrusion distance.