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ORIGINAL ARTICLE

A new indirect magnetic resonance imaging finding in anterior cruciate ligament injuries: Medial and lateral meniscus posterior base angle

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ABSTRACT

Objectives: This study aimed to define the medial meniscus posterior base angle (MMPBA) and the lateral meniscus posterior base angle (LMPBA) measured in the medial and lateral meniscus posterior horns and examine the biomechanical and morphological relationship between anterior cruciate ligament (ACL) injuries and posterior meniscus horns using these parameters.

Patients and methods: The retrospective study was conducted with 32 patients with ACL rupture and 40 control patients, for a total of 72 patients (40 males, 32 females; mean age: 36.3±9.9 years; range, 18 to 57 years), between January 2016 and January 2018. The posterior tibial slope (PTS) was measured in standard radiographs, and MMPBA and LMPBA values were assessed by standard knee magnetic resonance imaging. The MMPBA was defined as the angle between the line passing through the medial meniscus' tibial side border and the line passing through the capsular side border in the sagittal section's medial meniscus posterior horn. The LMPBA was defined as the angle between the line passing through the lateral meniscus' tibial side border and the line passing through the capsular side border on the sagittal section's lateral meniscus posterior horn. Groups were compared for PTS, MMPBA, and LMPBA.

Results: When both groups were compared in terms of MMPBA and LMPBA, patients with ACL rupture had significantly higher base angles ($p<0.001$ and $p=0.031$, respectively). The mean MMPBA was 84.27º±12.59º (range, 62º to 106.1º) in patients with ACL rupture, while it was 70.75º±7.85º (range, 55.1º to 88.6º) in the control group. The mean LMPBA was 83.62º±11.4º (range, 62.3º to 105.9º) in patients with ACL rupture, while it was 76.94º±11.46º (range, 30.8º to 96.5º) in the control group. In the receiver operating characteristics curve analysis, the cut-off value of MMPBA was 84.5, and values above this showed a 58.5% sensitivity and a 97.6% specificity for ACL rupture, whereas for LMPBA, the cut-off value was 93.15, and values above this showed a 27.3% sensitivity and a 95.1% specificity for ACL rupture. The PTS and MMPBA were significantly correlated with each other ($p=0.047$). The MMPBA and LMPBA were also significantly correlated with each other ($p=0.011$). However, there was no significant correlation between PTS and LMPBA ($p=0.56$).

Conclusion: Medial meniscus posterior base angle and LMPBA values above 84.5º and 93.15º, respectively, are new indirect magnetic resonance imaging findings of ACL injury.

Keywords: Base angle, meniscus, posterior.

The stability of the knee joint is maintained by static and dynamic structures. While muscles act as dynamic stabilizers, bones, joint capsules, ligaments, and the posterior tibial slope (PTS) act as static stabilizers.[1] The PTS is defined as the angle between the tangent of the line passing over the medial and lateral plateau and the anatomical axis of the tibia on a full lateral radiograph.[2]

Radiographic studies have shown a connection between the PTS and the anterior translation of the tibia during weight bearing. It has been shown that as the PTS increases, anterior translation of the tibia increases in the weight-bearing knee.[3] In addition, it has been demonstrated that increased anterior tibial translation elevates the risk of anterior cruciate ligament (ACL) rupture due to strain on the ACL. It has also been demonstrated that an increased PTS is

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associated with pathologies such as Osgood-Schlatter disease and osteochondritis dissecans.[4-8]

In the evaluation of ACL injuries, indirect magnetic resonance imaging (MRI) findings, such as anterior tibial translation, posterior cruciate ligament flexion, ACL line, ACL angle, and posterior displacement of the lateral meniscus, showing biomechanical failure of the ACL and anteroposterior instability of the knee, have been demonstrated.[9-16] Although these indirect findings have low sensitivity (23-46%), they have high specificity (70-100%).[17] Indirect MRI findings related to changes in the relative positions of the tibia and femur and positional changes in the ligamentous structures and lateral meniscus after ACL rupture have been previously examined. A recent study demonstrated the medial and lateral meniscus inclination (anterior angle) being significantly lower in patients with ACL injuries.[18]

We hypothesized that the decrease in the angle in the anterior of the medial and lateral meniscus posterior horn, which Hohman et al.[18] discussed in their study, is only a part of the anatomical and geometrical changes of the meniscus after ACL rupture. Therefore, this study aimed to define the medial meniscus posterior base angle (MMPBA) and the lateral meniscus posterior base angle (LMPBA) measured in the medial and lateral meniscus posterior horns and examine the relationship between these parameters, ACL injuries, and the PTS.

PATIENTS AND METHODS

The retrospective study was conducted with 72 patients (40 males, 32 females; mean age: 36.3±9.9 years; range, 18 to 57 years) at Necmettin Erbakan University Meram Medicine Faculty, Department of Orthopedics and Traumatology between January 2016 and January 2018. Of the participants, 32 were patients with an ACL rupture who underwent knee arthroscopy. Patients with a lateral or medial meniscal tear, previous lower extremity surgery, neuromuscular or hematological disease, lower extremity malalignment (differences in leg length, coronal and sagittal plane deformities, and patellar instability), or degenerative arthritis (Kellgren-Lawrence grades 2, 3, and 4) and participants under 18 and over 60 years of age were excluded. Fifty-one age-and sex-matched healthy individuals were evaluated for eligibility. Eleven patients were excluded as their radiographs or MRI scans were not suitable for measurements. Forty who did not have any knee pathology in MRI were included in the control group.

In our study, complete lateral radiographs containing the tibia and exposed femoral condyles were used to measure the PTS. The anatomical tibia axis was determined by joining the midpoints of the lines between the anterior and posterior cortex, 5 and 15 cm distal to the joint. The PTS was obtained by measuring the angle between the horizontal line drawn perpendicular to the anatomical tibia axis and the line tangent to the anterior and posterior of the tibia medial plateau (Figure 1).

Posterior horns of the medial and lateral menisci were measured made from sagittal sections. Reference lines passing through the middle of the medial and lateral tibial plateau in the coronal plane were used to determine the sagittal sections, where measurements were made in the posterior of the medial and lateral menisci (Figures 2 and 3). The MMPBA was defined as the angle between the line passing through the medial

FIGURE 1. Measurement of the PTS.

PTS: Posterior tibial slope; L1: Line showing the anatomical axis of the tibia; L2: Line drawn perpendicular to the anatomical axis of the tibia; L3: Line tangent to the anterior and posterior of the medial tibial plateau; α: Angle between L2 and L3 that gives the PTS value.

meniscus' tibial side border and the line passing through the capsular side border in the sagittal section's medial meniscus posterior horn (Figure 2). The LMPBA was defined as the angle between the line passing through the lateral meniscus' tibial side border and the line passing through the capsular side border on the sagittal section's lateral meniscus posterior horn (Figure 3).

Statistical analysis

Post hoc power calculations were performed using the G*Power version 3.1.9.4 software (Heinrich-Heine Universität, Düsseldorf, Düsseldorf Germany). Measurements were made on 72 patients by two different observers in two separate sessions blinded to each other. Data analysis was performed using the IBM SPSS version 22.0 software (IBM Corp., Armonk, NY, USA). Mean values of the four measurements with confidence intervals (CIs) were presented. Descriptive statistics and frequency analysis were used. The reliability of the measurements was analyzed by two blind observers in two separate sessions using the intraclass correlation coefficient. The normal distribution of the data was analyzed with the Shapiro-Wilk test. The Mann-Whitney U test and the independent samples t-test were used to compare independent variables. Receiver operating characteristics (ROC) curve analysis was used to determine the sensitivity, specificity, and cut-off values. A p value of <0.05 was considered statistically significant.

RESULTS

The intraclass correlation coefficient ranged from 0.85 to 0.91 for all measurements, indicating high within-observation reliability.

The mean age of patients with an ACL rupture was 37.0±9.4 years (range, 22 to 57), whereas the mean age of the control group was 35.9±10.2 years (range, 18 to 57), and there was no significant age difference between the two groups. Demographic information is summarized in Table I.

When both groups were compared for MMPBA, patients with an ACL rupture had significantly higher values (p<0.001, power: 99.3%). The mean MMPBA was 84.27°±12.59° (range, 62° to 106.1°; 95% CI: 88.63-79.91) in patients with an ACL rupture, while it was 70.75°±7.85° (range, 55.1° to 88.6°; 95% CI: 73.18-68.32) in the control group (Table II). In ROC curve analysis, the best cut-off value was 84.5°, and values above this displayed 58.5% sensitivity and 97.6% specificity for ACL ruptures.

When both groups were compared regarding LMPBA, patients with an ACL rupture had significantly higher a PTS value (p=0.031,

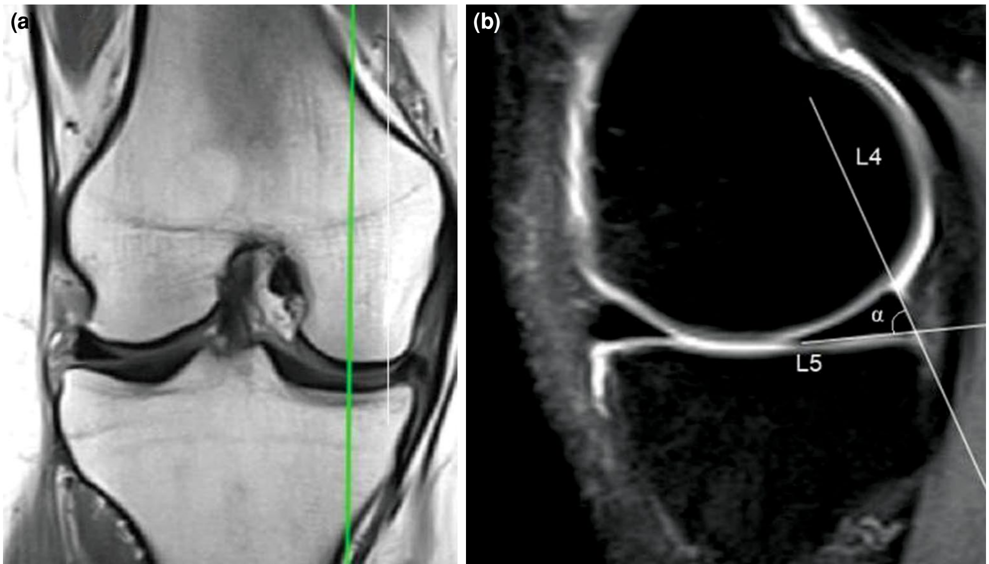

FIGURE 2. Medial meniscus posterior base angle measurement: **(a)** Coronal section used to determine the sagittal section where the measurement will be made (green line determines the sagittal section). **(b)** Measurement of the angle (α) between the line (L5) passing through the tibial border of the meniscus and the line (L4) passing through the posterior border of the meniscus in the sagittal section's posterior horn of the medial meniscus.

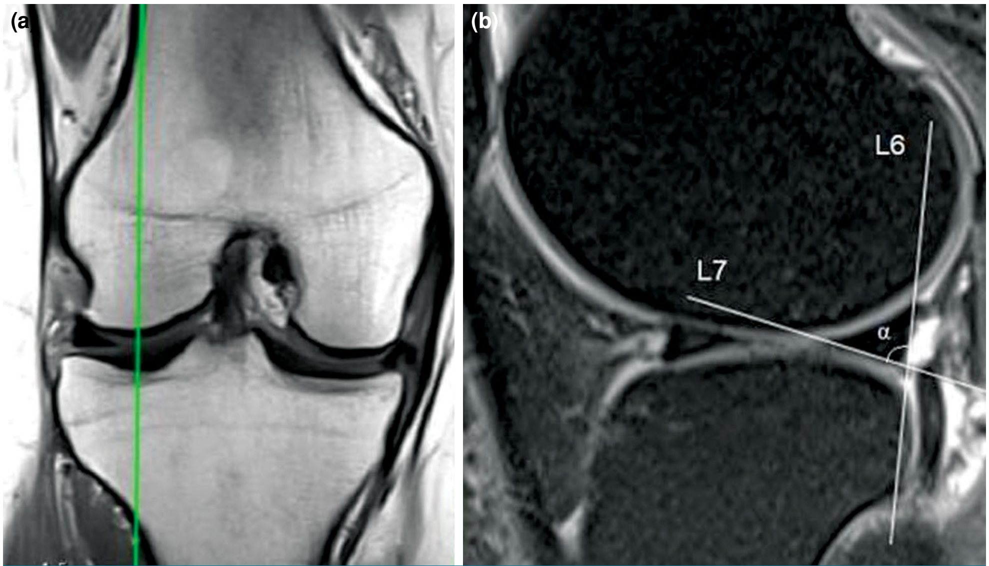

FIGURE 3. Lateral meniscus posterior base angle measurement: **(a)** Coronal section used to determine the sagittal section where the measurement will be made (green line determines the sagittal section). **(b)** Measurement of the angle between the line (L7) passing through the tibial border of the meniscus and the line (L6) passing through the posterior border of the meniscus in the sagittal section's posterior horn of the lateral meniscus.

power: 68.3%). The mean LMPBA was 83.62°±11.4° (range, 62.3° to 105.9°; 95% CI: 87.57-79.67) in patients with an ACL rupture, while it was 76.94°±11.46° (range, 30.8° to 96.5°; 95% CI: 80.49-73.39) in the control group (Table II). In ROC curve analysis, the best cut-off value was 93.15°, and values above this exhibited 27.3% sensitivity and 95.1% specificity for ACL ruptures.

TABLE I
Demographic characteristics of patients

	ACL ruptured (n=32)			ACL intact (n=40)			
	n	Mean±SD	Min-Max	n	Mean±SD	Min-Max	*p*
Mean (year)		37.0±9.4	22-57		35.9±10.2	18-55	0.69
Sex							
Male	19			21			
Female	13			19			

ACL: Anterior cruciate ligament; SD: Standard deviation.

TABLE II
Comparison of patients with ruptured and intact ACLs in terms of MMPBA, LMPBA, and PTS parameters

	ACL ruptured		ACL intact		
Radiological parameter	Mean±SD	95% CI	Mean±SD	95% CI	*p*
MMPBA	84.27°±12.59°	62°-106.1°	70.75°±7.85°	55.1°-88.6°	<0.001*
		88.63-79.91		73.18-68.32	
LMPBA	83.62°±11.4°	62.3°-105.9°	76.94°±11.46°	30.8°-96.5°	=0.031*
		87.57-79.67		80.49-73,39	
PTS	14.23°±3.14°	9°-20.9°	8.32°±2.7°	4.1°-17°	<0.001*
		13.15-15.31		9.15-7.49	

MMPBA: Medial meniscus posterior base angle; LMPBA: Lateral meniscus posterior base angle; PTS: Posterior tibial slope; ACL: Anterior cruciate ligament; SD: Standard deviation.

When both groups were compared concerning PTS, patients with an ACL rupture had significantly higher results ($p<0.001$, power: 99.9%). The mean PTS in patients with ACL rupture was 14.23°±3.14° (range, 9° to 20.9°; 95% CI: 13.15-15.31), while it was 8.32°±2.7° (range, 4.1° to 17°; 95% CI: 9.15-7.49) in the control group (Table II). The PTS and MMPBA were significantly correlated with each other ($p=0.047$). The MMPBA and LMPBA were also significantly correlated with each other ($p=0.011$). However, there was no significant correlation between the PTS and LMPBA ($p=0.56$).

DISCUSSION

The most significant feature of this study is the newly defined medial and lateral meniscus posterior base angles, which revealed new indirect MRI findings in ACL injury. Gentili et al.[12] compared the amount of posterior lateral meniscus displacement in patients with ACL injuries in their study involving 89 patients. When they accepted the cut-off value as 3.5 mm in the posterior meniscus displacement, they showed that this parameter had a 44% sensitivity and a 94% specificity for ACL ruptures. When they accepted the cut-off value as 5 mm, sensitivity decreased to 20%, and specificity increased to 100%. The LMPBA we defined in our study showed a 27.3% sensitivity and a 95.1% specificity. In our study, the results of the previous studies on LMPBA measurements and the amount of lateral meniscus posterior displacement were similar.[12,19] The medial meniscus is connected to the medial collateral ligament, but the lateral meniscus does not connect to the lateral collateral ligament. Therefore, the lateral meniscus is more mobile than the medial meniscus.[20] After an ACL injury, an anteroposterior instability occurs, making the lateral meniscus more mobile. In addition, factors such as knee rotation during MRI affect the lateral meniscus position more than the medial. Thus, the specificity of the measurements related to the lateral meniscus is low. Anterior tibial translation in ACL injury has the effects of posteriorly displacing the lateral meniscus and increasing LMPBA. We think that the overall effect of anterior tibial translation on the posterior horn of the lateral meniscus is shared between the amount of posterior displacement and the change in the LMPBA. However, we do not know the direction and amount of this change. Further radiological measurement studies are needed to evaluate the amount of lateral meniscus posterior displacement and changes in the anatomy of the lateral meniscus posterior horn (LMPBA and anterior angle of the lateral meniscus posterior horn). Since the possibility of posterior mobilization of the lateral meniscus due to anterior tibial translation in ACL rupture is higher than the medial meniscus, studies in the literature have mainly focused on the mobilization of the lateral meniscus.[12,18,19] The MMPBA we defined in our study showed a sensitivity of 58.5% and a specificity of 97.6%, and these values are higher compared to the LMPBA and the studies on lateral meniscus posterior displacement in the literature. Since the medial meniscus is more immobile than the lateral meniscus, the effect of anterior tibial translation on the medial meniscus may be in favor of increasing the meniscus posterior base angle rather than the posterior displacement effect, which may be the reason why MMPBA is more sensitive and specific than LMPBA. To the best of our knowledge, our study is the first in the literature describing the medial and lateral meniscus posterior base angles and examining their relationship with ACL injuries.

Elmansori et al.[21] compared meniscal slopes in medial and lateral midsagittal MRI sections in patients with ACL ruptures and a control group. They showed that the meniscal slope and the PTS were increased in patients with an ACL rupture. The meniscal slope measured in this study is affected only by the highest points of the anterior and posterior horns of the meniscus, and since this meniscal slope is measured using the anatomical axis of the tibia, it is not just a meniscal slope but a combined slope that includes the bone curve. Therefore, it does not show the relationship between bone slope and isolated meniscus slope, and thus, it differs from our study. The meniscal slope measured by Elmansori et al.[21] does not provide any information about a specific geometrical change in the anterior or posterior horns of the medial and lateral menisci in patients with ACL ruptures. The MMPBA we defined in our study is a measurement that only concerns the posterior medial meniscus, it is not affected by changes in other anatomical parts of the meniscus, and it can give an idea about the ACL rupture independent of the PTS. We believe that MMPBA and LMPBA are superior to the meniscal slope measured by Elmansori et al.,[21] specifically in terms of providing the change of the anatomy of the posterior horns of the meniscus. Elmansori et al.'s[21] and our study support each other in that PTS is significantly higher in patients with an ACL injury.

Hudek et al.[22] used the anterior and posterior horns of the medial and lateral meniscus to calculate the meniscus slopes and showed that the anterior horns had no stabilizing effect in preventing anterior tibial translation. In the same study, they mentioned the possibility that anterior tibial translation may be more prominent in case the posterior secondary stabilizers that prevent anterior tibial translation lose their function. Guess and Razu[23] used finite element analysis and found increased contact forces and hoop tension in the medial meniscus posterior horn in patients with ruptured ACLs without any change in the anterior horn. They revealed in their study that the posterior horn of the medial meniscus is a physical barrier that limits anterior tibial translation. In our study, the significant increase in MMPBA in patients with an ACL rupture may indicate a biomechanical and morphological change in the posterior horn of the medial meniscus, which is a more stable structure than the lateral meniscus, to prevent anterior tibial translation due to its anatomical relationship with the MCL. To the best of our knowledge, our study is the first in the literature in this aspect.

Hohman et al.[18] compared patients with an ACL rupture and the control group regarding the inclination (anterior slope) formed between the tibia-facing side of the posterior meniscus horn and the side facing the femoral condyle in midsagittal sections of the medial and lateral menisci. They showed that the midsagittal anterior slope of the medial and lateral menisci was significantly reduced in patients with ACL rupture; however, they did not provide any sensitivity and specificity values. Anterior tibial translation is the reason why MMPBA and LMPBA we defined in our study are significantly higher in patients with an ACL injury and the meniscal slope, defined by Hohman et al.,[18] is significantly lower in patients with an ACL injury. The slope measured by Hohman et al.[18] is between the meniscus' tibial surface and the femoral condyle's surface, and the side of the meniscus facing the femoral condyle is not flat but concave, in harmony with the femoral condyle. However, in MMPBA and LMPBA, the posterior aspect of the meniscus instead of the femoral condyle side is used. Therefore, MMPBA and LMPBA are more reliable measurement techniques since the posterior face is flatter than the femoral condyle face.

The significant correlation between PTS and MMPBA and the absence of a significant correlation with LMPBA suggest that MMPBA is a more reliable parameter than LMPBA. This might be since the lateral meniscus is more mobile than the medial meniscus.

The clinical significance of this basic radiological study is not entirely clear. Although there are many studies on ACL rupture and indirect MRI findings, studies on this subject have focused on the morphological change of the meniscus after ACL rupture and the clinical biomechanical meaning of these changes beyond just indirect findings. In our study, the increase in MMBPA and LMBPA in patients with ACL rupture supports that the posterior horns of the meniscus are associated with a mechanical barrier that prevents anterior tibial translation. Nonetheless, we do not know how much of the total force required to prevent anterior tibial translation is covered by the ACL and how much is supported by posterior structures, such as the medial and lateral meniscus. Whether posterior meniscus horn tears are related to MMPBA and LMPBA in patients with or without ACL rupture should be investigated. With these studies, biomechanical relationships between ACL, posterior meniscus horns, which try to prevent anterior tibial translation, and PTS, which is associated with ACL rupture at high values, can be further clarified. Furthermore, we believe that femoral condyle sizes, femoral condyle radii, tibial plateau sizes, and their ratios to each other, which determine meniscus morphology, will also contribute to this change. Therefore, we think that in the future, in addition to PTS and anterior tibial translation, three-dimensional computed tomography and MRI studies considering femoral condyle sizes, femoral condyle radii, tibial plateau sizes, and their ratios to each other may yield results with higher sensitivity and specificity.

There were some limitations in our study. First, patients with a tear in the medial and lateral meniscus were not included in the study, and the exclusion criteria were broad, leading to a relatively small sample size. In addition, MRI images were taken lying down without weight on the lower extremities. Differences in meniscus anatomy can be observed in MRI images taken while standing compared to the supine position.[21]

In conclusion, MMPBA values above 84.5º (with 58.5% sensitivity and 97.6% specificity) and LMPBA values above 93.15º (with 27.3% sensitivity and 95.1% specificity) are new indirect MRI findings of ACL injury.

Ethics Committee Approval: Ethical approval was obtained from the Necmettin Erbakan University Meram Faculty of Medicine Ethical Committee (IRB number: 2022/3671). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea: H.Y., F.T., M.Ö.; Data collection: H.Y., M.Ö., F.T.; Critical review: M.Ö., F.T.; Writing article: H.Y., M.Ö.

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REFERENCES

1. Hohmann E, Bryant A, Reaburn P, Tetsworth K. Is there a correlation between posterior tibial slope and non-contact anterior cruciate ligament injuries? Knee Surg Sports Traumatol Arthrosc 2011;19 Suppl 1:S109-14.
2. Faschingbauer M, Sgroi M, Juchems M, Reichel H, Kappe T. Can the tibial slope be measured on lateral knee radiographs? Knee Surg Sports Traumatol Arthrosc 2014;22:3163-7.
3. Hudek R, Schmutz S, Regenfelder F, Fuchs B, Koch PP. Novel measurement technique of the tibial slope on conventional MRI. Clin Orthop Relat Res 2009;467:2066-72.
4. Dare DM, Fabricant PD, McCarthy MM, Rebolledo BJ, Green DW, Cordasco FA, et al. Increased lateral tibial slope is a risk factor for pediatric anterior cruciate ligament injury: An MRI-based case-control study of 152 patients. Am J Sports Med 2015;43:1632-9.
5. Green DW, Sidharthan S, Schlichte LM, Aitchison AH, Mintz DN. Increased posterior tibial slope in patients with osgood-schlatter disease: A new association. Am J Sports Med 2020;48:642-6.
6. O'Malley MP, Milewski MD, Solomito MJ, Erwteman AS, Nissen CW. The association of tibial slope and anterior cruciate ligament rupture in skeletally immature patients. Arthroscopy 2015;31:77-82.
7. Wechter JF, Sikka RS, Alwan M, Nelson BJ, Tompkins M. Proximal tibial morphology and its correlation with osteochondritis dissecans of the knee. Knee Surg Sports Traumatol Arthrosc 2015;23:3717-22.
8. Zeng C, Yang T, Wu S, Gao SG, Li H, Deng ZH, et al. Is posterior tibial slope associated with noncontact anterior cruciate ligament injury? Knee Surg Sports Traumatol Arthrosc 2016;24:830-7.
9. Boeree NR, Ackroyd CE. Magnetic resonance imaging of anterior cruciate ligament rupture. A new diagnostic sign. J Bone Joint Surg [Br] 1992;74:614-6.
10. Karadağ D, Kaya A, Uçar F. On çapraz bağ yirtiklarinda ön çapraz bağ-medial tibial plato açisinin tanisal değeri. Eklem Hastalik Cerrahisi 2010;21:68-72.
11. Brandser EA, Riley MA, Berbaum KS, el-Khoury GY, Bennett DL. MR imaging of anterior cruciate ligament injury: Independent value of primary and secondary signs. AJR Am J Roentgenol 1996;167:121-6.
12. Gentili A, Seeger LL, Yao L, Do HM. Anterior cruciate ligament tear: Indirect signs at MR imaging. Radiology 1994;193:835-40.
13. Polat A, Acar N, Aybar A, Fidan F, Özden E, Gürkan O. The correlation between posterior cruciate ligament buckling sign and meniscofemoral ligaments: A radiological study. Jt Dis Relat Surg 2021;32:371-6.
14. Robertson PL, Schweitzer ME, Bartolozzi AR, Ugoni A. Anterior cruciate ligament tears: Evaluation of multiple signs with MR imaging. Radiology 1994;193:829-34.
15. Schweitzer ME, Cervilla V, Kursunoglu-Brahme S, Resnick D. The PCL line: An indirect sign of anterior cruciate ligament injury. Clin Imaging 1992;16:43-8.
16. Vahey TN, Hunt JE, Shelbourne KD. Anterior translocation of the tibia at MR imaging: A secondary sign of anterior cruciate ligament tear. Radiology 1993;187:817-9.
17. Horton LK, Jacobson JA, Lin J, Hayes CW. MR imaging of anterior cruciate ligament reconstruction graft. AJR Am J Roentgenol 2000;175:1091-7.
18. Hohmann E, Tetsworth K, Glatt V, Ngcelwane M, Keough N. Increased posterior slope of the medial and lateral meniscus posterior horn is associated with anterior cruciate ligament injuries. Arthroscopy 2022;38:109-18.
19. McCauley TR, Moses M, Kier R, Lynch JK, Barton JW, Jokl P. MR diagnosis of tears of anterior cruciate ligament of the knee: Importance of ancillary findings. AJR Am J Roentgenol 1994;162:115-9.
20. 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;28:269-87.
21. Elmansori A, Lording T, Dumas R, Elmajri K, Neyret P, Lustig S. Proximal tibial bony and meniscal slopes are higher in ACL injured subjects than controls: A comparative MRI study. Knee Surg Sports Traumatol Arthrosc 2017;25:1598-605.
22. Hudek R, Fuchs B, Regenfelder F, Koch PP. Is noncontact ACL injury associated with the posterior tibial and meniscal slope? Clin Orthop Relat Res 2011;469:2377-84.
23. Guess TM, Razu S. Loading of the medial meniscus in the ACL deficient knee: A multibody computational study. Med Eng Phys 2017;41:26-34.