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Original Article

The Relationship Between Patellar Chondromalacia and Patellofemoral Joint Anatomical Variations

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Abstract

Objective: To analyze the relationship between lateral patellar tilt angle, lateral patella-femoral angle, patella–patellar tendon angle, and lateral trochlear inclination angle.

Methods: Cases with knee magnetic resonance imaging between June and October 2022 were analyzed retrospectively. Two groups of 50 each with and without patella chondromalacia were formed. lateral patellar tilt angle, lateral patella-femoral angle, patella–patellar tendon angle, and lateral trochlear inclination angle values were measured on the knee magnetic resonance imaging. Chondromalacia was evaluated and graded. The differences in age, gender, and measurement variables between the groups chondromalacia were analyzed.

Results: There were 58 women and 42 men. Seventeen (34%) patients had low-grade and 33 (66%) patients had high-grade chondromalacia. The median age was 49 (interquartile range: 61) in the chondromalacia group and 37.5 (interquartile range: 38) in the normal group ($P < .001$). The median lateral patellar tilt angle was 6.76 (interquartile range: 15.15) in the chondromalacia group and 6.92 (interquartile range: 19.25) in the normal group ($P = .610$). The median lateral patella-femoral angle was 7.86 (interquartile range: 41.86) in the chondromalacia group and 7.90 (interquartile range: 17.37) in the normal group ($P = 0.471$). Median patella–patellar tendon angle was 142.96 (interquartile range: 32.14) in the chondromalacia group and 145.87 (interquartile range: 27.77) in the normal group ($P = .006$). The median lateral trochlear inclination angle was 19.11 (interquartile range: 19.30) in the chondromalacia group and 20.39 (interquartile range: 20.16) in the normal group ($P = .127$).

Conclusion: The knee joint morphological variations may differ in between the groups with and without patellar chondromalacia. Older age and lower patella–patellar tendon angle were more frequent in the patellar chondromalacia group.

Keywords: anatomic variation, chondromalacia, knee, magnetic resonance imaging, patella

INTRODUCTION

The knee joint consists of the tibiofemoral and patellofemoral (PF) joints. Several soft tissue structures such as collateral ligaments, cruciate ligaments, patellar retinaculum, and menisci support their stability due to the articulation of anatomically incompatible bones. The diversity of these structures gives rise to morphological variations that are different in each person. These variations may be the cause of various pathologies in the knee, mostly in the PF joint.[1]

One of the most common pathologies of the PF joint and an important cause of knee pain is patellar chondromalacia. Magnetic resonance imaging (MRI) is successful in assessing cartilage status with its high contrast resolution.[1] The presence of patellar chondromalacia can be detected and graded with MRI. It has been shown that anatomical variations in the PF joint can be successfully measured with MRI.[2] The lateral patellar tilt angle (LPTA), lateral patella-femoral angle (LPFA), patella–patellar tendon angle (PPTA), and lateral trochlear inclination angle (LTI) are the most important anatomical measurements in the PF joint. The relationship of each of them with patellar chondromalacia was examined in separate studies, and different results were obtained.[2-6] However, the number of studies evaluating the relationship between these measurements and patellar chondromalacia is not sufficient.

Therefore, we hypothesized that anatomical variations involving the PF joint are associated with patellar chondromalacia. With this hypothesis, we aimed to analyze the relationship between patellar chondromalacia and LPTA, LPFA, PPTA, and LTI.

METHODS

The İzmir Democracy University Buca Seyfi Demirsoy Training and Research Hospital Ethics Committee approved this study and waived the requirement for informed consent (Date: December 28, 2022, No.:2022/12-124). Cases who underwent knee MRI for any reason between June and October 2022 were analyzed retrospectively. Between these dates, a total of 100 cases, 50 with and 50 without patellar chondromalacia, were

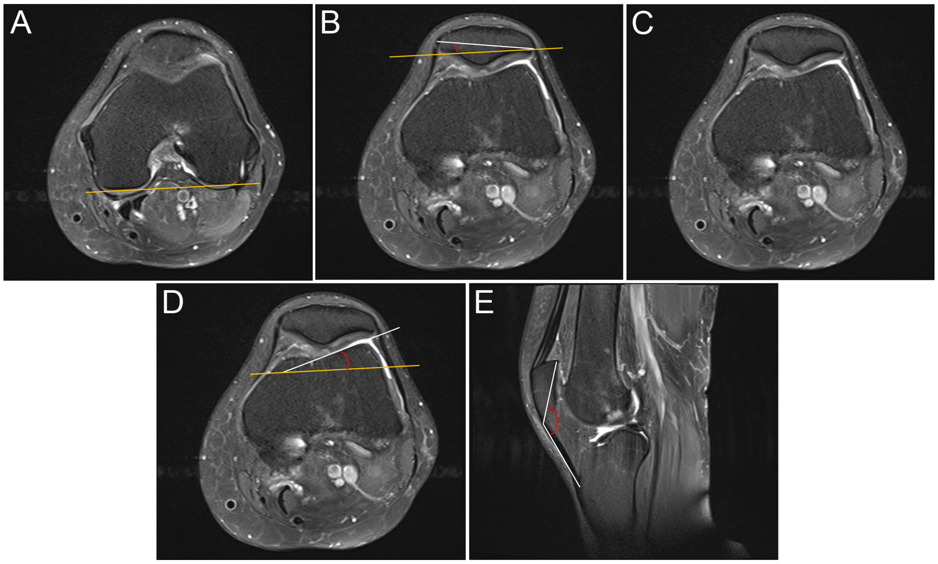

Figure 1. Patellofemoral joint anatomical variations. (A) The line tangent to the posterior femoral condyles. (B) The lateral patellar tilt angle between the line tangent to the subchondral bone in the posterior femoral condyle and the line forming the transverse axis of the patella. (C) The lateral patellofemoral angle is the angle between the line parallel to the tip of the anterior condyles and the lateral patellar facet. (D) The lateral trochlear inclination is the angle between the line tangent to the subchondral bone in the posterior femoral condyle and the line drawn parallel to the lateral trochlear facet subchondral bone. (E) The patella–patellar tendon angle is the angle between the line connects of the upper and lower poles of the patella and the line connects of the lower pole of the patella and the tibial tuberosity.

included in the study. Cases with a history of knee surgery, arthroscopy, moderate- or high-grade joint degeneration (e.g., Kellgren–Lawrence types 3 and 4), ligament/meniscus tear, joint effusion, and high-energy trauma were excluded (n=32). Since the etiology of ligament and meniscal tears and patellar chondromalacia may be similar (e.g., osteoarthritis), it is aimed to exclude factors other than anatomical variation and to be limited to ligament and meniscal tears in the etiology of patellar chondromalacia.

Magnetic resonance imaging was performed with 1.5T scanner (Magnetom Altea, Siemens Healthcare, Erlangen, Germany). The MRI protocol included fat-suppressed proton density sequence (coronal, axial, and sagittal) and T1-weighted sequence (coronal). The LPTA, LPFA, PPTA, and LTI values were measured on the knee MRIs of the patients (Figure 1). Chondromalacia was evaluated according to the modified Outerbridge classification.[7] Cases with grades 1 and 2 chondromalacia were included to the low-grade subgroup, the cases with grades 3 and 4 were chondromalacia were included to the high-grade chondromalacia subgroup (Figure 2, Table 1).

The LPTA was measured on axial slices. The angle between the line tangent to the posterior femoral condyles and the transverse axis of the patella was considered as LPTA. As described in the literature,[2] for the transverse axis of the patella, the axial slice where the patella appears to be the widest, and for the line that is tangent to the posterior of the femoral condyles, the axial slice where the condyles have the most posterior extension was selected. The angle between the line tangent to the posterior femoral condyles and the line drawn parallel to the lateral trochlear facet were considered as the LTI. The LPFA was measured between the line tangent to the tip of the anterior femoral condyles and the lateral patellar facet. The PPTA was measured between the line connects of the upper and lower points of the patella and the line connects of the lower point of the patella and the tibial tuberosity. The PPTA measurement was performed on the midsagittal slice.

MAIN POINTS

- Magnetic resonance imaging can be used for evaluating the knee joint anatomical variations.
- The patella–patellar tendon angle is lower, and age is higher in the patients with patellar chondromalacia.
- Anatomical variations can cause patellar chondromalacia.

Statistical analysis was done with IBM SPSS Statistics version 25.0 software (Armonk, NY, USA). Since our study population does not have a normal distribution, the difference in age and measurement variables between the groups with and without chondromalacia were examined with the Mann–Whitney *U*-test. The difference in gender

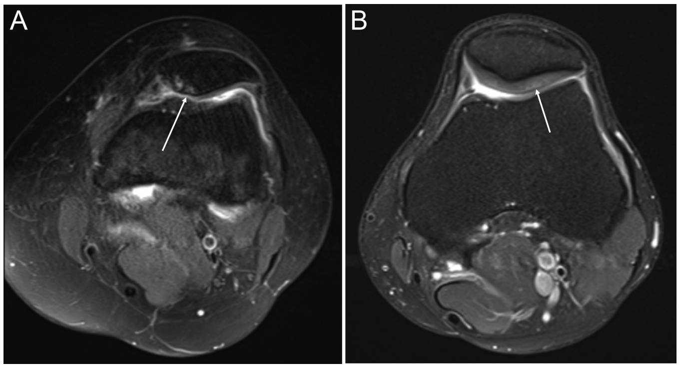

Figure 2. Two different axial fat-suppressed proton density images patients with high-grade chondromalacia (A) and low-grade chondromalacia (B). In Figure 2A, near-full-thickness cartilage loss (arrow) with underlying bone reactive changes is consistent with high-grade chondromalacia. In Figure 2B, focal areas of hyperintensity (arrow) without fraying/ or cartilage loss is seen.

Table 1. Modified Outerbridge Classification for MRI

Grade	MRI Findings
1	Focal areas of hyperintensity with normal contour
2	Blister-like swelling/fraying of articular cartilage extending to surface
3	Partial-thickness cartilage loss with focal ulceration
4	Full-thickness cartilage loss with underlying bone reactive changes

MRI, magnetic resonance imaging.

between the normal and chondromalacia groups was evaluated with the continuity corrected chi-square test. The distribution of parameters in the groups was given as median and interquartile range (IQR). A value of $P < .05$ was accepted as statistically significant.

RESULTS

The median age of the patients included in the study was 45 (IQR: 18.5). There were 58 women and 42 men. The median age was 49 (IQR: 61) in the group with patellar chondromalacia and 37.5 (IQR: 38) in the normal patellar cartilage group ($P < .001$). There was no statistically significant difference in gender distribution between the groups with patellar chondromalacia (25 females and 25 males) and those without (33 females and 17 males) ($P = .156$).

The median LPTA was 6.76 (IQR: 15.15) in the chondromalacia group and 6.92 (IQR: 19.25) in the normal patellar cartilage group ($P = .610$). The median LPFA was 7.86 (IQR: 41.86) in the chondromalacia group and 7.90 (IQR: 17.37) in the normal patellar cartilage group ($P = .471$). Median PPTA was 142.96 (IQR: 32.14) in the chondromalacia group and 145.87 (IQR: 27.77) in the normal patellar cartilage group ($P = .006$). The median LTI was 19.11 (IQR: 19.30) in the chondromalacia group and 20.39 (IQR: 20.16) in the normal patellar cartilage group ($P = .127$).

In the patellar chondromalacia group, 17 (34%) patients had low-grade chondromalacia and 33 (66%) patients had high-grade chondromalacia. The median age was 42 (IQR: 20.5) in the low-grade patellar chondromalacia group and 52 (IQR: 17.5) in the high-grade patellar chondromalacia group ($P = .005$). There were 11 women (65%) and 6 men (35%) in the low-grade chondromalacia group, and 22 women (66.7%) and 11 men (33.3%) in the high-grade chondromalacia group ($P < .001$). The median LPTA was 6.21 (IQR: 6.43) in the low-grade patellar chondromalacia group and 7.19 (IQR: 5.4) in the high-grade patellar chondromalacia group ($P = .384$). The median LPFA was 6.93 (IQR: 8.94) in the low-grade patellar chondromalacia group and 8.1 (IQR: 8.67) in the high-grade patellar chondromalacia group ($P = .224$). Median PPTA was 143.16 (IQR: 8.64) in the low-grade patellar chondromalacia group and 142.76 (IQR: 7.37) in the high-grade patellar chondromalacia group ($P = .467$). The median LTI was 16.45 (IQR: 5.33) in the low-grade patellar chondromalacia group and 19.47 (IQR: 8.2) in the high-grade patellar chondromalacia group ($P = .407$).

Table 2 and Figure 3 summarize the results of the groups with and without chondromalacia, and Table 3 and Figure 4 summarize the results of the groups of high-grade and low-grade patellar chondromalacia.

DISCUSSION

The PF joint helps the quadriceps muscle to extend the knee with less force and is an essential component of the extensor mechanism. The load on the knee joint is distributed more homogeneously during extension with the PF joint. It has been described that anatomical

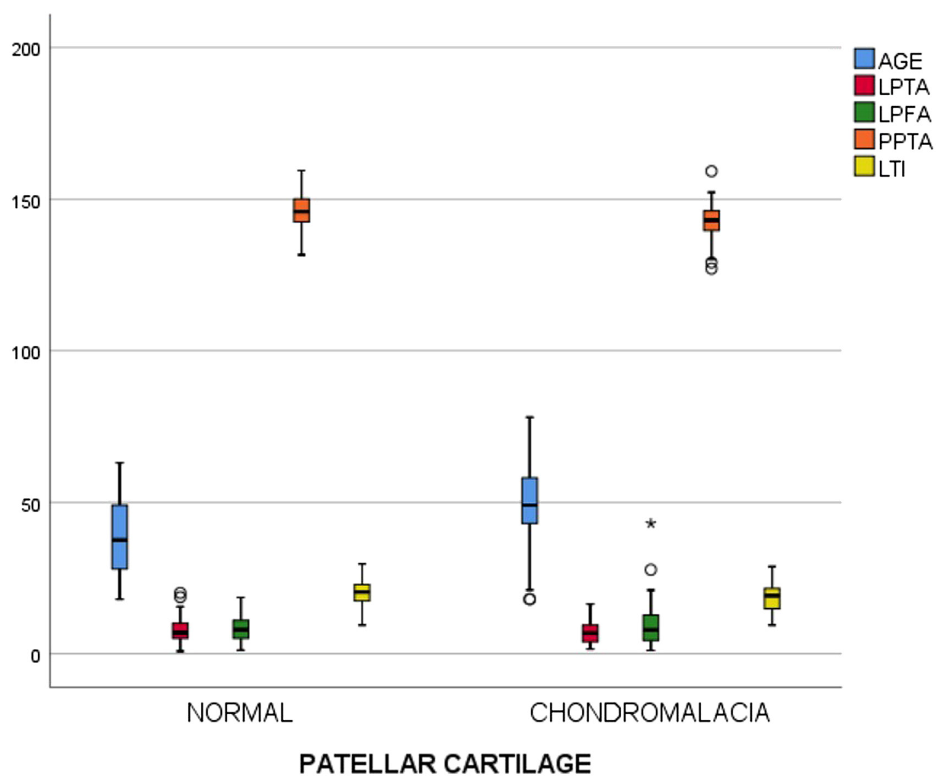

Figure 3. Box blot analyses of age and anatomical measurements between groups with and without patellar chondromalacia. LPFA, lateral patella-femoral angle; LPTA, lateral patellar tilt angle; LTI, lateral trochlear inclination angle; PPTA, patella–patellar tendon angle.

Table 2. Results of the Normal Patellar Cartilage Group and Patellar Chondromalacia Group

	Normal Group, median (Minimum–Maximum)	Chondromalacia Group, median (Minimum–Maximum)	*P*
Age (years)	37.5 (18-63)	49 (18-78)	< .001
Lateral patellar tilt angle	6.92 (0.82-20.07)	6.76 (1.25-16.4)	=.610
Lateral patellofemoral angle	7.90 (1.2-18.57)	7.86 (1.11-42.97)	=.471
Patella patellar tendon angle	145.87 (131.66-159.43)	142.96 (127.08-159.2)	=.006
Lateral trochlear inclination angle	20.39 (9.46-29.62)	19.11 (9.45-28.75)	=.127

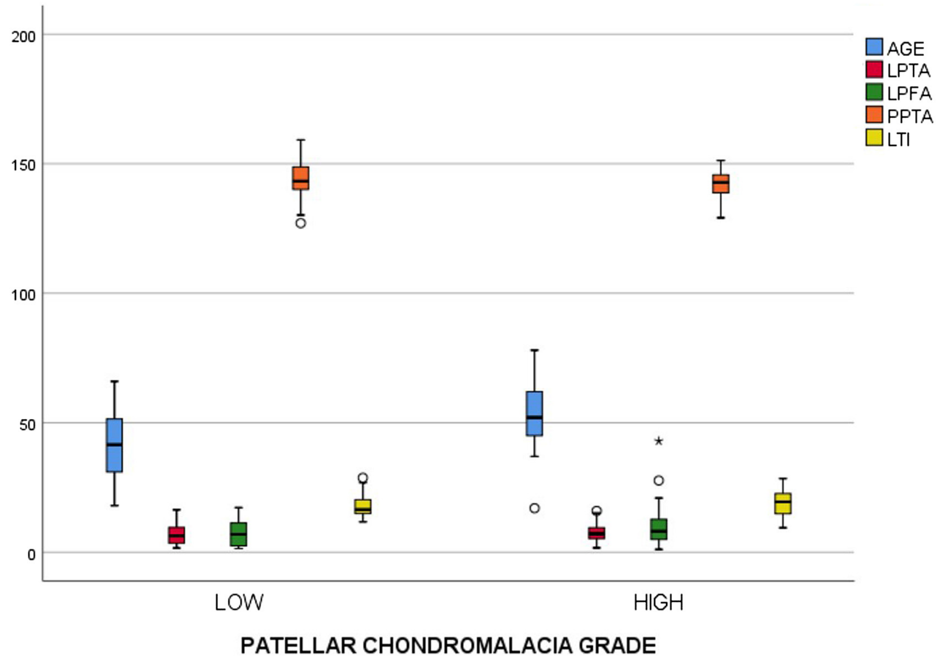

Figure 4. Box blot analyzes of age and anatomical measurements between groups low-grade and high-grade patellar chondromalacia. LPFA, lateral patella-femoral angle; LPTA, lateral patellar tilt angle; LTI, lateral trochlear inclination angle; PPTA, patella–patellar tendon angle.

differences in the PF joint can cause damage to the patellar cartilage by affecting the load distribution.[2-6] In this study, we aimed to reveal whether anatomical variations affect the patellar cartilage. We found a significant difference between the patellar chondromalacia and normal patellar cartilage groups in terms of PPTA. Other anatomical variations examined did not differ significantly between the 2 groups. The patellar chondromalacia group was significantly older than the normal patellar cartilage group. In addition, patients with high-grade chondromalacia in the patellar chondromalacia group were found to be significantly older than those with low grade.

The LPTA describes the lateral angulation of the patella in the axial plane.[8] It causes anterior knee pain by causing patellar chondromalacia or fat-pad edema in some cases.[2-6] We think that the LPTA is generally ignored in daily practice. In our study, we did not find a significant difference for LPTA between groups with and without patellar chondromalacia. We did not evaluate fat-pad edema because it was not the aim of our study, but there are studies in the literature showing a significant relationship between increased LPTA, knee joint fat-pad edema, and anterior knee pain.[2,9-11]

We found a significant difference between the groups with and without patellar chondromalacia in terms of median PPTA and median age. These results are compatible with other data in the literature. The fact that the patellar chondromalacia group was older than the normal group may have been due to degenerative cartilage changes. Although we exclude moderate-severe degeneration cases, degenerative chondromalacia that develops with age might have affected our results. Similarly, Gürsoy et al[4] found the mean age to be significantly higher in the patellar chondromalacia group. We found lower values of PPTA in the patellar chondromalacia group. The angular position of the patella in the sagittal plane may have increased the load on the PF joint, leading to

Table 3. Results of the Low-Grade and High-Grade Patellar Chondromalacia Groups

	Low-Grade Chondromalacia, median (Minimum–Maximum)	High-Grade Chondromalacia, median (Minimum–Maximum)	*P*
Age (years)	42 (18-66)	52 (18-78)	=.005
Lateral patellar tilt angle	6.21 (1.25-16.4)	7.19 (1.68-15.96)	=.384
Lateral patellofemoral angle	6.93 (1.44-17.19)	8.1 (1.11-42.97)	=.224
Patella–patellar tendon angle	143.16 (127.08-159.2)	142.76 (129.1-151.2)	=.467
Lateral trochlear inclination angle	16.45 (11.7-28.75)	19.47 (9.45-28.46)	=.407

cartilage damage. Damgacı et al[12] and Kim et al[13] found the mean PPTA significantly lower in the patients with patellar chondromalacia.

There was no significant difference between the groups for LPTA, LPFA, and LTI. There are studies in the literature with and without significant differences in LPTA and LPFA between groups with and without patellar chondromalacia.[2,4,14] Yeniçeri et al[14] did not find any difference between the groups with and without patellar chondromalacia for LPTA. However, in another study, patellar chondromalacia was found to be associated with increased LPTA.[2] In the study of Gürsoy et al[14] there was no significant difference for LPFA between the groups with and without patellar chondromalacia. These differences in results between studies may be due to body characteristics such as age, gender, and body mass index of the patient population.

One of the limitations of our study is that the study was retrospective, and the cases were not asymptomatic. The causes of chondromalacia might have been developed for another reason. Although we excluded moderate-severe joint degeneration cases, degenerative cartilage changes might have affected our results. The absence of arthroscopic confirmation or the presence of chondromalacia is another limitation. Since the presence of chondromalacia by the radiologist who had made the anatomical measurements could have been evaluated from the MR images, bias might have been developed.

In conclusion, we demonstrated morphological differences between the groups with and without patellar chondromalacia. The PPTA and age were found to be significantly different between these groups. In addition, the median age was higher in patients with high-grade chondromalacia. It should be kept in mind that demographic differences and anatomical variations may be a cause of patellar chondromalacia.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of İzmir Democracy University Buca Seyfi Demirsoy Training and Research Hospital (Date: December 28, 2022, Number: 2022/12-124).

Informed Consent: Due to the retrospective design of the study, informed consent was not taken.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – C.U., A.H.Ç., Ö.T.; Design – C.U., A.H.Ç.; Supervision – B.D.M., Ö.T.; Materials – C.U., A.H.Ç.; Data Collection and/or Processing – C.U.; Analysis and/or Interpretation – A.H.Ç., O.S.; Literature Search – C.U., A.H.Ç., O.S.; Writing Manuscript – C.U., A.H.Ç., O.S., B.D.M., Ö.T.; Critical Review – B.D.M., Ö.T.

Declaration of Interests: The authors declare that they have no competing interest.

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