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Original Article

Association between trochlear morphology and chondromalacia patella: an MRI study

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ABSTRACT

This study aimed to compare trochlear morphology seen in magnetic resonance imaging between patients with chondromalacia patella and age-matched control patients without cartilage lesion. Trochlear morphology was evaluated using the lateral trochlear inclination, medial trochlear inclination, sulcus angle and trochlear angle on the axial magnetic resonance images. Consequently, an association between abnormal trochlear morphology and chondromalacia patella was identified in women. In particular, women with flattened lateral trochlea are at an increased risk of patellar cartilage structural damage.

1. Introduction

Chondromalacia patella, which is one of the major causes of chronic anterior knee pain, is characterized by the softening or breakdown of the patellar cartilage and is frequently associated with decreased quality of life. Osteoarthritis is generally associated with a progressive loss of articular cartilage [1,2]. Osteoarthritis is a major public health concern and is expected to be the fourth leading cause of disability in the general population by 2020 because of increases in life expectancy and the size of the geriatric population [3,4].

Factors that contribute to the development of chondromalacia patella include knee trauma, structural abnormalities of the tibiofemoral and patellofemoral joints, and vascular insufficiency within the subchondral bone. These structural abnormalities may lead to an overload of the patellar cartilage and subsequently result in the development of cartilage defects [1,5–7].

Arthroscopy is the standard criterion for diagnosing chondromalacia patella but is a highly invasive procedure, and surgical treatment of chondromalacia patella is only indicated in a small minority of patients. Magnetic resonance imaging (MRI) help can visualize joint structure directly and noninvasively and is recognized as a valid, accurate, and reproducible tool to measure articular cartilage lesions. Several authors have reported that the sensitivity of MRI is considerably higher for detecting severe (Grade 3 or 4) cartilage defects. Cross-sectional imaging modalities are the most sensitive noninvasive techniques for demonstrating trochlear morphology. Furthermore, magnetic resonance (MR) images allow a complete and clear visualization of the entire patellofemoral joint by clearly delineating the proximal portion of the trochlea [5,8–11].

Several studies in the literature have evaluated trochlear morphology and its relationship with chondromalacia patella using MRI in patients. Previous studies have revealed that the measurement of the sulcus angle (SA) is primarily used to assess the morphological features of the trochlea. SA is a representative of the geometry of the entire femoral trochlea; thus, it is a popular measurement for evaluating trochlear surface geometry. However, SA cannot be used to evaluate isolated medial and lateral trochlear geometry, and novel methods for measuring the lateral trochlear inclination (LTI) and trochlear angle (TA) have been reported as alternatives [1,12–15]. These are useful tools to evaluate isolated lateral trochlear geometry.

Women have been reported to have a significantly higher prevalence of patellar cartilage defects. However, to the best of our knowledge, there is no study analyzing the association between trochlear morphology and chondromalacia patella exclusively in women.

Therefore, this study aimed to identify morphological measurements of the trochlea associated with chondromalacia patella in women. We hypothesized that the individuals with a flat lateral trochlear facet are more prone to articular cartilage structural damage for which LTI is a determinant.

2. Materials and methods

2.1. Patients

One hundred fifty patients who were diagnosed with Grade 3–4 patellar chondromalacia on the basis of MRI evaluation between January

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2015 and October 2015 were retrospectively evaluated. The exclusion criteria were any history of knee surgery or knee trauma and an imaging finding of a patellar dislocation, inflammatory arthritis, any diagnosis of space-occupying knee lesion, and age <40 or>65 years. Thus, a total of 115 patients were included in the present study. The control group comprised an age-matched cohort of 115 women who had no patellar cartilage lesion as confirmed by MRI and underwent MRI with the indication of anterior knee pain. The present study was approved by the institutional review board (Ankara Numune Education and Research Hospital).

2.2. MRI evaluation

The MR images (Optima, GE Medical System, Milwaukee, WI, USA) of patients were taken with a 1.5-T unit using an extremity coil in the supine position with the knee in full extension. A standardized MRI examination protocol was used, and the following five sequences were performed for each patient: sagittal fast spin-echo T1-weighted [repetition time (TR)/echo time (TE): 500/10 ms, matrix: 288×224, field of view (FOV): 18×18 cm, slice thickness: 4 mm]; sagittal fat-suppressed proton density-weighted (TR/TE: 3000/40 ms, matrix: 256×192, FOV: 18×18 cm, slice thickness: 4 mm); coronal fast spin-echo T1-weighted (TR/TE: 700/20 ms, matrix: 288×224, FOV: 20×20 cm, slice thickness: 4 mm); coronal fat-suppressed proton density-weighted (TR/TE: 2500/50 ms, matrix: 288×224, FOV: 20×20 cm, slice thickness: 4 mm); and axial fat-suppressed proton density-weighted (TR/TE: 3000/40 ms, matrix: 288×224, FOV: 18×18 cm, slice thickness: 3 mm).

To evaluate the presence and size of patellar cartilage defects in addition to determining the trochlear measurements, we used axial fat-suppressed proton density-weighted sequences. A patellar cartilage defect was identified as present if there was irregularity on the cartilage surface with a loss of cartilage thickness on at least two consecutive slices. The severity of the cartilage defect was determined according to the International Cartilage Repair Society Classification system using the lesion depth [5,12]. A loss of >50% of the cartilage thickness without exposed bone and full-thickness cartilage loss with exposed bone were defined as Grade 3 and 4 chondromalacia, respectively (Fig. 1a, b). To evaluate intraobserver reliability, cartilage defects were regraded by the same author (S.D.) 1 month after the first evaluation. The intraclass correlation coefficient for intraobserver reliability was 0.90 for cartilage defects.

2.3. Trochlear morphology assessment

We evaluated the morphological features of the trochlea using LTI, medial trochlear inclination (MTI), TA, and SA. These measurements were taken from the axial MR images in which the largest posterior femoral condyle was observed (i.e., the slice above and below demonstrated a small posterior femoral condyle).

SA is defined as the angle between the medial and lateral trochlear facets (Fig. 2a) [2,4].

LTI is defined as the angle between a line drawn along the lateral trochlear facet surface and a tangential line drawn through the posterior femoral condyle (Fig. 2b) [12–14].

MTI is defined as the angle between a line drawn along the medial trochlear facet surface and a tangential line drawn through the posterior femoral condyle (Fig. 2c) [13,14].

TA is defined as the angle between a line passing along the most anterior margins of the medial and lateral trochlear facets and a tangential line drawn through the posterior femoral condyle (Fig. 2d) [13,14].

All measurements were taken by two observers using electronic calipers. The images were analyzed on a picture archiving and communications system.

2.4. Reliability assessment

All measurements of trochlear morphology were repeated at 2-week intervals by the first author (S.D.). A second author (O.K.), who was blinded with respect to all subject information, took all measurements in 75 knees randomly selected from 230 knees. Inter- and intraobserver intraclass correlation coefficients for all measurements were 0.88 and 0.90, respectively.

2.5. Statistical analysis

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) (Version 20.0; SPSS Inc., Chicago, IL, USA). The distribution between the groups was normal with the Kolmogorov–Smirnov test. The test data were shown to be homogeneously distributed by Levene's test, and parametric tests were used for intergroup comparisons. The results of SA, LTI, MTI and TA between the chondromalacia patella and control groups were analyzed using Student's *t* test. A *P* value of <.05 was considered statistically significant.

A post-hoc power analysis was performed using G Power 3.1 software. To estimate the power analysis, the sample size of each group and the alpha and effect size d values were used. The alpha error probability, effect size d value and statistical power of the study (1-beta) were 0.05, 0.8 and 0.9, respectively.

3. Results

The characteristics of the study patients are presented in Table 1. The SA, LTI, MTI and TA comparisons between groups are given in Table 2.

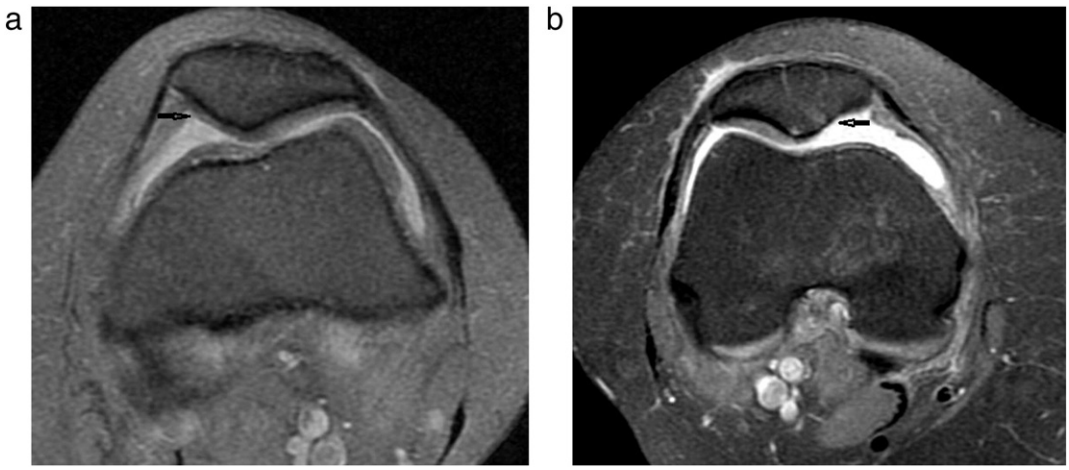

Fig. 1. Axial proton density-weighted fat-suppressed MR images of the knee showing (a) Grade 3 chondromalacia and (b) Grade 4 chondromalacia in the facet of the patella (arrows).

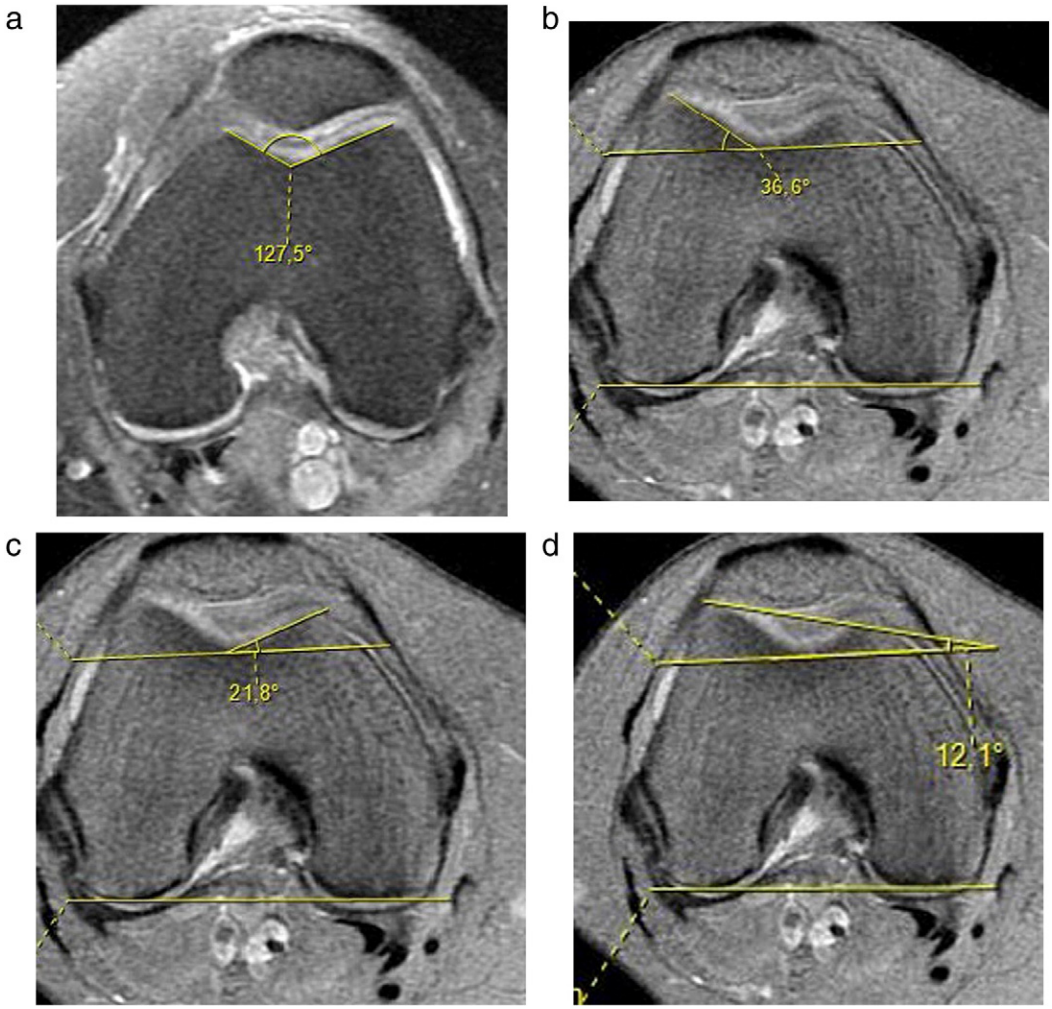

Fig. 2. Measurement of SA (a), LTI (b), MTI (c) and TA (d) in a patient on MRI.

The mean LTI (P=.01) and TA (P=.001) were significantly lower in the chondromalacia patella group than those in the normal group. The mean SA was significantly higher in patients with chondromalacia patella than in control patients (P=.01). No statistically significant difference was found in MTI between the two groups (P=.55).

4. Discussion

The results of the present study revealed an association between patellar cartilage structural damage and trochlear morphology. Patellar cartilage defects are observed more frequently in knees with a low LTI than in those with a high LTI. This finding supports our hypothesis that knees with flattened lateral trochlea are more prone to patellar cartilage structural damage.

Osteoarthritis is a progressive degenerative disease characterized by a gradual loss of articular cartilage. The geometry of the femoral trochlea is becoming more influential in determining chondromalacia patella. Previous studies that investigated the association between trochlear morphology and patellar cartilage defects involved both genders [1,5,13]. When considering gender-specific differences in trochlear morphology, to the best of our knowledge, the literature contains no study analyzing those relationships exclusively in women.

Patellofemoral osteoarthritis is more prevalent in women than in men, particularly after 50 years of age when the occurrence of the disease becomes more frequent [16]. According to the literature, SA is commonly used for trochlear morphological measurements [1–5,7,13,15,17]. Certain previous studies have reported no significant association between SA and patellofemoral cartilage lesions [2,17,18]. However, Ali et al. [12] demonstrated that a wider SA was associated with severe cartilage defects in patients younger than 40 years, and Stefanik et al. [13] demonstrated an association between a wider SA and patellar cartilage damage in patients aged 50 years and above. The present study evaluating the female population revealed that the mean SA was 143.3° in the chondromalacia patella group and 130° in the group without cartilage lesions. These observations indicate that a

Table 1
Characteristics of the study population (n=230)

Patients	Chondromalacia patella (Grade 3–4)	Control group
Sample size	115	115
Age (year)	54.6±6.7	54.2±6.7
Right/Left	40/75	40/75

(Values are expressed as mean ± standard deviation).

Table 2
Descriptive analyses of trochlear parameters by groups

Measurement method	Chondromalacia patella (Grade 3–4)	Control group	P value
Sulcus angle	143.3±8	130±9.2	.01*
Lateral trochlear inclination	19.5±3	26.3±3.1	.001*
Medial trochlear inclination	23.4±4.2	24.9±4.6	.55
Trochlear angle	6±1	8.1±0.9	.001*

(Values are expressed as mean ± standard deviation).
* Statistical significance.

flat and shallow trochlea may contribute to the development of patellar cartilage defects, which is in accordance with the results of the study by Stefanik et al. [13]. Shallow femoral trochlea can lead to patellar instability with subsequent disproportional load distribution across the patellofemoral joint during knee movement, as reported by previous studies. High mechanical stress on either side of the patellofemoral joint may cause degenerative changes in the articular cartilage [3,4,12].

SA is defined as the angle between the medial and lateral trochlear facets. SA of a knee with a flattened medial facet and normal lateral facet may be similar to that of a knee with a flattened lateral facet and normal medial facet. Therefore, alternative measures of trochlear shape, including LTI and TA, have been reported. Carrillon et al. [9] were the first to describe the use of LTI in MRI. Ali et al. [12] reported no significant association between LTI and patellar cartilage defects in patients older than 40 years. They determined that an abnormal trochlear morphology is a risk factor for the development of cartilage defects only in younger patients. Another study revealed no significant association between LTI and patellar cartilage defects [1]. We found a decreased LTI in the knees with chondromalacia patella (mean=19.5°), whereas this value was considerably greater in the knees with normal cartilage (mean=26.3°). This finding of an association between a lower LTI and patellar cartilage defect is consistent with the results reported by Stefanik et al. [13]. The literature emphasizes the importance of the lateral femoral trochlea in preventing excessive lateral patellar tilt and displacement during quadriceps contraction [7]. When the lateral facet is flattened, the patella is more likely to be laterally displaced due to the lateral force vector acting on the patella as a result of the angle of the pull of the quadriceps muscle. Thus, the contact between the patella and lateral anterior femoral condyle increases as the knee flexes, leading to cartilage defects in the patellofemoral joint [2,10,14].

Here, we demonstrated that TA is decreased in patients with chondromalacia patella, a finding similar to the results reported in patients with patellofemoral osteoarthritic by Stefanik et al. [13].

Previous studies have investigated the association between LTI and patellar cartilage defects [1,12]. To the best of our knowledge, there is no study analyzing the association between medial trochlear geometry and chondromalacia patella. In the present study, we found no association between MTI and patellar articular cartilage damage. These results suggest that the inclination of the medial trochlear facet may not be as important as that of the lateral trochlear facet in articular cartilage structural damage. It has been reported that the medial anterior femoral condyle has less contact with the patella upon quadriceps contraction [7].

The present study evaluated articular cartilage defects by MRI. Early structural changes in the patellar cartilage can be accurately and reliably quantified using MRI. In previous studies, the overall sensitivity and specificity of MRI in the diagnosis of patellar cartilage defects ranged between 83% and 97% [8,15,18].

Our study has some limitations. The study design was retrospective. However, it was not possible to evaluate the clinical findings of patients who had undergone MRI and had chondromalacia patella. In addition, the grading of chondromalacia patella was performed on MRI only, without arthroscopy.

In conclusion, the evaluation of the morphological features of the femoral trochlea plays an important role in the diagnosis of chondromalacia patella. We established an association between abnormal trochlear morphology and patellar articular cartilage defects of the knee in female patients. We specifically demonstrated that the knees with low LTI are at an increased risk of patellar cartilage structural damage. The consideration of LTI during the evaluation of chondromalacia patella may be useful in revealing the etiology. Future randomized prospective studies, including concomitant clinical and radiological evaluations, on this subject are required.

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