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# Evaluation of the relationship between trochlear and patellar morphology and patellar chondromalacia with magnetic resonance imaging

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**It was aimed to investigate the relationship between magnetic resonance imaging (MRI) measurements of trochlear and patellar morphology and grade 3-4 patellar chondromalacia. Grade 3-4 patellar chondromalacia group, and an age- and sex-matched control group with normal patellar joint cartilage were comprised. For trochlear morphology evaluation in MRI; sulcus angle, trochlear angle, lateral trochlear inclination angle and medial trochlear inclination angle were measured. For patellar morphology evaluation; patella trochlear ratio, insall-salvati ratio, modified Insall-Salvati ratio and Blackburne-Peel ratio were measured. Obtained measurements were statistically analyzed according to demographic characteristics. One hundred and twenty-five patients with chondromalacia and 125 controls participated. The sulcus angle and the trochlear angle were significantly higher in the patellar chondromalacia group ($p<0.05$). The lateral trochlear inclination angle was significantly less in the patellar chondromalacia group ($p=0.011$). There was no significant difference between the groups in terms of medial trochlear inclination angle ($p=0.520$). There was no significant difference between the groups in terms of patella-trochlear ratio ($p=0.617$). Insall-Salvati ratio was significantly higher in the patellar chondromalacia group ($p=0.003$). Modified Insall-Salvati ratio was significantly lower in the patellar chondromalacia group ($p=0.001$). The rate of Blackburne-Peel was significantly higher in the patellar chondromalacia group ($p=0.004$). Measurements of sulcus angle, trochlear angle, lateral trochlear inclination angle, Insall-Salvati ratio, modified Insall-Salvati ratio, Blackburne-Peel ratio have diagnostic value for grade 3-4 chondromalacia**.

**Keywords:** Chondromalacia patellae, magnetic resonance imaging, trochlea, morphology.

## INTRODUCTION

Patellar chondromalacia is a disease that causes anterior knee pain and progresses with softening of the cartilage, edema, chondral defects and subchondral erosive changes. It was first described by Aleman in 1928[1]. In its etiology, biomechanics such as chondral or subchondral fracture, direct trauma to the patella, patella fracture, recurrent subluxation or dislocation of the patella, increased Q angle, quadriceps muscle imbalance, patella alta, posttraumatic axis disorder, excessive lateral compression syndrome, meniscus injury, reflex sympathetic dystrophy and biochemical causes such as rheumatoid arthritis, recurrent hemarthrosis, alkaptonuria, peripheral synovitis, sepsis and adhesions, iatrogenic, intra-articular steroid injection, prolonged immobilization, primary osteoarthritis play a role[2].

Arthroscopy is the gold standard for the diagnosis of patellar chondromalacia, but it is an invasive procedure. Magnetic resonance imaging (MRI) is a valuable non-invasive diagnostic method that shows the articular cartilage of the knee. The position of the patellar bone, the presence of bone marrow edema or subchondral changes, the relationship of the patella with the trochlear groove, patellar cartilage and trochlear cartilage thicknesses, signal intensities, integrity and intensities of the quadriceps and patellar tendon, intensities of the fat pads around the patella are evaluated with MRI[3].

Patellar chondromalacia is classified as 4 grades according to Modified Outerbridge grading of chondromalacia[2]. Grade 1 changes include minimal joint cartilage changes. There is softening in a localized area, the fissure is either absent or minimal. Grade 2 changes include irregularity of the cartilage surface, fibrillation, and fissure formation. Grade 3 changes include fibrillation, fissure formation up to the subchondral bone. In Grade 4, the joint cartilage is no longer present and the subchondral bone is eroded[2].

Many studies in the literature have evaluated trochlear morphology and its relationship with chondromalacia patella using MRI[4-10]. Unlike the literature, we aimed to investigate the relationship between MRI measurements of both trochlear and patellar morphology and grade 3-4 patellar chondromalacia in our study.

## MATERIALS AND METHODS

In our Radiology Clinic, 1590 patients who underwent knee MRI with any complaint between 01.01.2014-25.04.2018 were scanned retrospectively, starting from the last date. Among individuals between the ages of 18-65 years; Patients with grade 3-4 patellar chondromalacia and a control group whose patellar articular cartilage matched the chondromalacia group in terms of age and gender were included.

*Exclusion criteria:* 1. Those who have undergone trauma and operations that disrupt the morphology of the knee joint, 2. Those who have a benign or malignant mass in the knee joint, 3. Those with arthritis and rheumatological findings in the knee joint, 4. Individuals with a previous fracture involving the knee joint, 5. Patients with known trochlear dysplasia and patellar instability, 6. Patients with incomplete knee MRI images.

All MRI examinations were performed using dual channel SENSE Flex-M coil by 1.5 Tesla (T) MRI systems (Philips Medical Systems, Achieva Release 3.2 Level 2013-10-21, The Netherlands). A standardized MRI examination protocol was used, and the following sequences were performed for all subjects: coronal fat suppressed (Short T1 Inversion Recovery = STIR) T2-weighted images (TR ms/ TE ms; 3648/30, "field of view" (FOV) 160x160 mm and matrix 264x216 mm), axial fat suppressed (Spectral Attenuated Inversion Recovery = SPAIR) T2-weighted images (TR ms/ TE ms; 3515/30, "field of view" (FOV) 160x160 mm and matrix 240x190 mm), sagittal (dual) T2-weighted images (TR ms/ TE ms; 2252/110, "field of view" (FOV) 160x160 mm and matrix 208x160 mm), sagittal (dual) Proton Density (PD) weighted images (TR ms/ TE ms; 2252/7.1, "field of view" (FOV) 160x160 mm and matrix 208x160 mm), sagittal T1-weighted images (TR ms/ TE ms; 450/20, "field of view" (FOV) 160x160 mm and matrix 268x210 mm), sagittal fat suppressed (SPAIR) T2-weighted images (TR ms/ TE ms; 3130/30, "field of view" (FOV) 160x160 mm and matrix 244x180 mm) obtained using a 3-mm slice thickness and 1-mm intersection gap, and 26-34 sections were obtained.

In our study, trochlear and patellar morphologies were evaluated with the following parameters in knee MRIs of patients with grade 3-4 patellar chondromalacia and controls. Trochlear and patellar parameters were then compared between groups.

*Evaluation of trochlear morphology;*

– Sulcus angle (Figure 1): It is the angle between the lateral facet of the trochlea and the medial facet. For trochlear dysplasia which can result in patellofemoral instability, the angle must be ≥145°[11].

– Trochlear angle (Figure 2): It is the angle between a line passing through the highest points of the medial and lateral trochlear facets and a line passing through the posterior of the femoral condyles. With a cutoff value of 8°, the sensitivity is 81% and the specificity is 79%[12].

– Lateral trochlear inclination angle (Figure 3): It is the angle between the line that passes posterior to the femoral condyles and the line drawn along the lateral facet. The mean value of the lateral trochlear slope is 16.9° in the knee without trochlear dysplasia. It is 6.1° in patients with patellar instability. When the threshold value for trochlear dysplasia is taken as <11°, it makes the diagnosis with 93% sensitivity and 87% specificity[4].

– Medial trochlear inclination angle (Figure 4): It is the angle between the medial trochlear facet surface line and the line passing through the posterior of the femoral condyles[13].

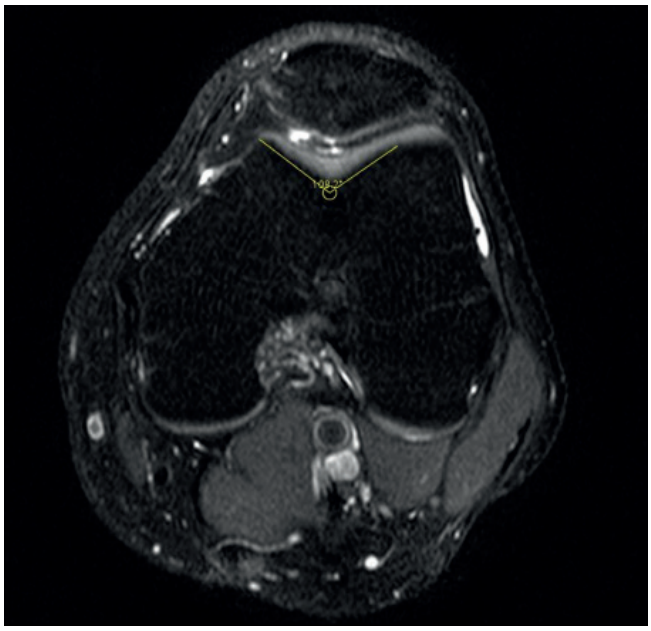

*Figure 1 — Axial T2 weighted fat-suppressed image, measurement of sulcus angle.*

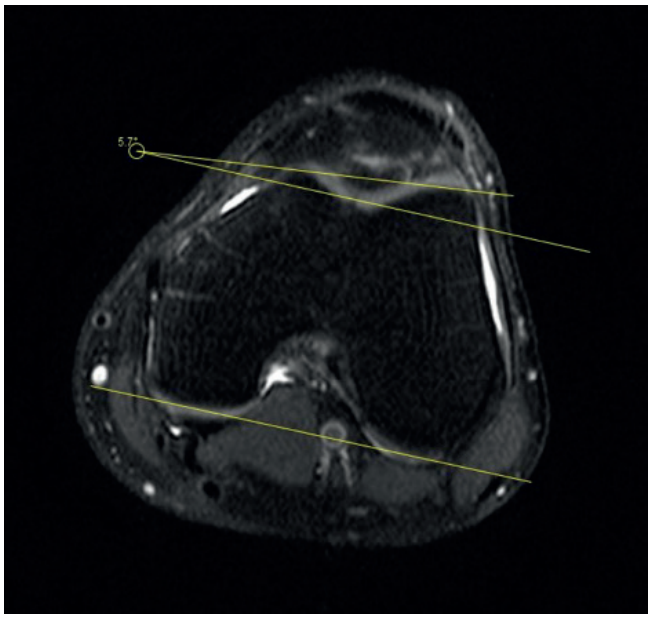

*Figure 2 — Axial T2 weighted fat-suppressed image, measurement of trochlear angle.*

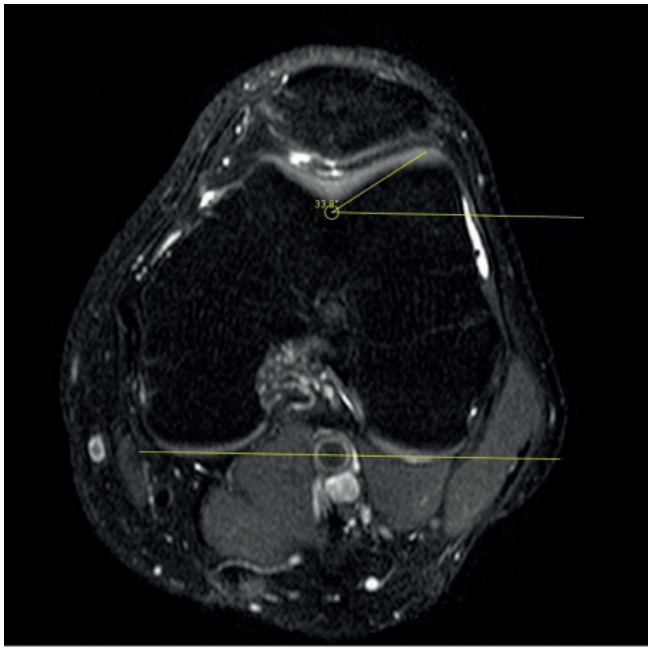

*Figure 3 — Axial T2 weighted fat-suppressed image, measurement of lateral trochlear inclination angle.*

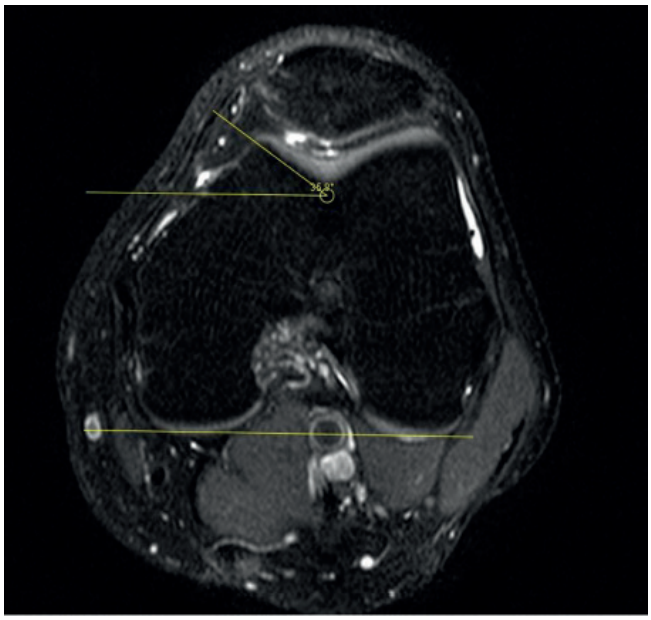

*Figure 4 — Axial T2 weighted fat-suppressed image, measurement of medial trochlear inclination angle.*

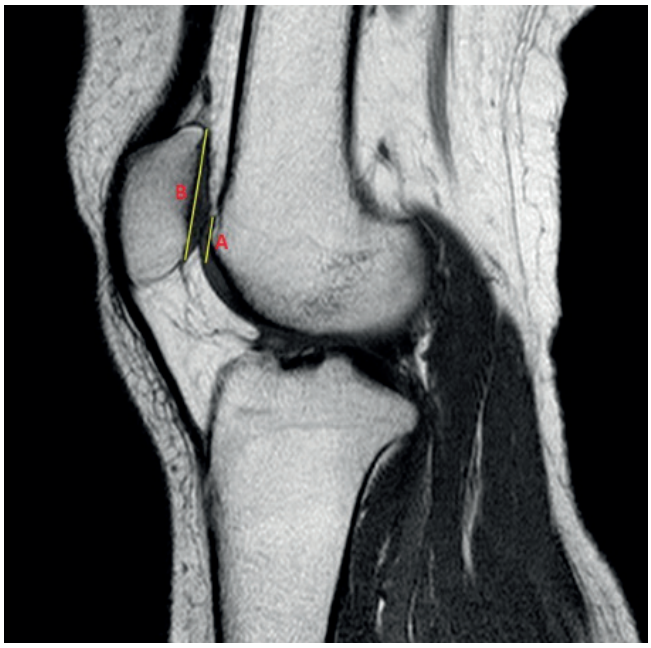


*Figure 5 — Sagittal T1 weighted image, patella-trochlear ratio (A/B).*

*Evaluation of patellar morphology;*

– Patella-trochlear ratio (Figure 5): It is the ratio of the trochlear articular surface length to the patellar articular surface length. The threshold value is >%50 for patella baja and <%12.5 for patella alta[14].

– Insall-Salvati ratio (Figure 6): It is the ratio of the patellar tendon length to the maximum diagonal length of the patella[16]. Insall-Salvati ratio below 0.8 is the threshold value for patella baja and above 1.2 for patella alta diagnosis[16].

– Modified Insall-Salvati ratio (Figure 7): It is the ratio of the distance from the lower edge of the patellar joint surface to the patellar tendon insertion point to the length of the patellar joint surface. The threshold value was accepted as >1 for patella alta[17].


*Figure 6 — Sagittal T1 weighted image, insall-salvati ratio (A/B).*

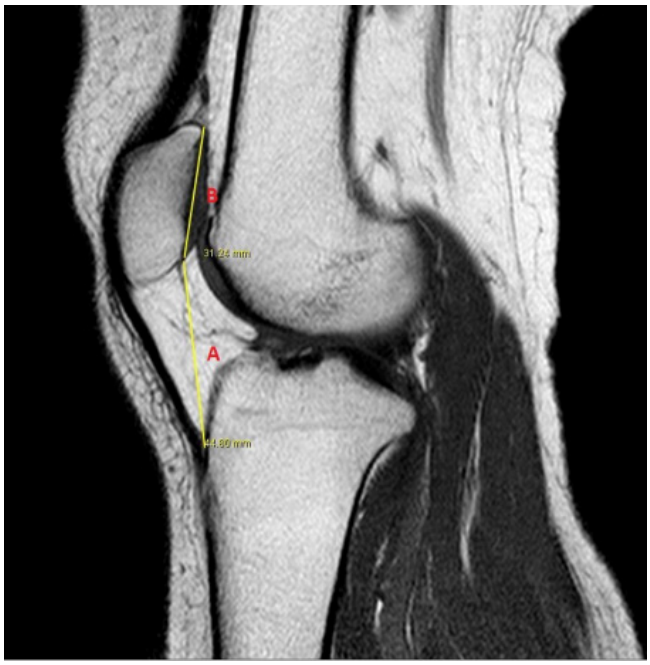


*Figure 7 — Sagittal T1 weighted image, modified insall-salvati ratio (A/B).*

– Blackburne-peel ratio (Figure 8): It is the ratio of the distance from the lower edge of the patellar joint surface to the line extended forward along the tibial plateau to the length of the patellar joint surface. The threshold value is >1 for patella alta and <0.8 for patella baja[18].

All measurements were made from optimal images, after Workstation processing by a radiologist (M.D.).

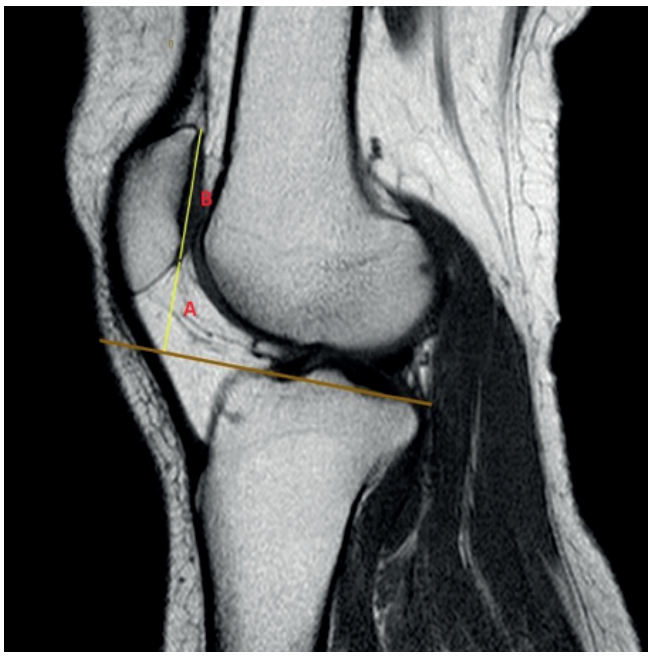


*Figure 8 — Sagittal T1 weighted image Blackburne-Peel ratio (A/B).*

Descriptive statistics were given as mean and standard deviation. Shapiro-Wilks test and histograms were used to investigate the normal distribution. The t-test was used in independent groups to compare the variables with normal distribution, and the Mann-Whitney U test was used to compare variables that did not fit the normal distribution. The cut-off value for statistical significance was $p<0.05$.

## RESULTS

One hundred twenty five patients with grade 3-4 patellar chondromalacia and 125 controls participated in our study. The mean age of the patellar chondromalacia group was 48.8±8.7(SD) and the mean age of the control group was 48.2±6.5(SD). There was no significant age difference between the study groups (p=0.090). There was no significant difference between the study groups in terms of gender (p=0.303). There was no significant difference between the study groups in terms of direction (p=0.206), (Table I).

The sulcus angle was significantly higher in the patellar chondromalacia group (p<0.001). Trochlear angle was significantly higher in the patellar chondromalacia group (p=0.018). The lateral trochlear inclination angle was significantly less in the patellar chondromalacia group (p=0.011). There was no significant difference between the study groups in terms of medial trochlear inclination angle (p=0.520), (Table II).

**Table I**. — Characteristics of study groups

| Measurements | | Chondromalacia group (n=125) | Control group (n=125) | P value |
|---|---|---|---|---|
| Age (years) | | 48.8±8.7 | 48.2±6.5 | 0.09 |
| Gender | Female | (78) 62.4 % | (70) 56.0 % | 0.303 |
| | Male | (47) 37.6 % | (55) 44.0 % | |
| Direction | Right | (69) 55.2 % | (59) 47.2 % | 0.206 |
| | left | (56) 44.8 % | (66)52.8 % | |
| (Age values are expressed as mean±standard deviation, other values are expressed as percentages and numbers) | | | | |

**Table II.** — Trochlear and patellar parameters in study groups

| Measurements | | Chondromalacia group | Control group | P value* |
|---|---|---|---|---|
| Trochlear | Sulcus angle | 121.4±7.5 | 118.1±7.1 | <0.001** |
| | Trochlear angle | 2.9±1.8 | 2.4±1.5 | 0.018** |
| | Lateral trochlear inclination angle | 25.7±4.6 | 27.3±4.7 | 0.011** |
| | Medial trochlear inclination angle | 30.1±5.4 | 31.2±8.4 | 0.520 |
| Patellar | Patella Trochlear ratio | 34%±45% | 29%±10% | 0.617 |
| | Insall-Salvati ratio | 0.99±0.15 | 0.97±0.09 | 0.003** |
| | Modified Insall-Salvati ratio | 1.49±0.13 | 1.55±0.13 | 0.001** |
| | Blackburne peel ratio | 0.83±0.69 | 0.72±0.11 | 0.004** |
| (Values are expressed as mean±standard deviation). * The independent samples t-test shows the results of the sulcus angle comparison, the Mann-Whitney U test shows the results of other comparisons. ** Statistical significance. | | | | |

**Table III.** — Trochlear and patellar parameters in study groups according to gender

| Measurements | | Chondromalacia group | | Control group | | P values* |
|---|---|---|---|---|---|---|
| | | Female | Male | Female | Male | |
| Trochlear | Sulcus angle | 119.6±7.0 | 124.4±7.4 | 118.4±7.3 | 117.8±6.9 | $p_1$=0.303 $p_2$<0.001** |
| | Trochlear angle | 3.1±2.0 | 2.8±1.6 | 2.5±1.7 | 2.2±1.2 | $p_1$=0.088 $p_2$=0.106 |
| | Lateral trochlear inclination angle | 26.1±4.3 | 25.1±5.0 | 27.0±3.5 | 27.8±5.9 | $p_1$=0.310 $p_2$=0.007** |
| | Medial trochlear inclination angle | 31.2±5.0 | 28.2±5.5 | 31.6±10.5 | 30.6±4.3 | $p_1$=0.546 $p_2$=0.041** |
| Patellar | Patella Trochlear ratio | 31%±14% | 40%±72% | 30%±11% | 28%±10% | $p_1$=0.788 $p_2$=0.717 |
| | Insall-Salvati ratio | 1.00±0.18 | 1.00±0.10 | 1.00±0.09 | 0.94±0.09 | $p_1$=0.631 $p_2$<0.001** |
| | Modified Insall-Salvati ratio | 1.49±0.12 | 1.51±0.15 | 1.56±0.14 | 1.54±0.12 | $p_1$=0.001** $p_2$=0.175 |
| | Blackburne peel ratio | 0.76±0.11 | 0.97±1.11 | 0.73±0.12 | 0.72±0.11 | $p_1$=0.258 $p_2$<0.001** |
| (Values are expressed as mean±standard deviation). * The independent samples t-test shows the results of the sulcus angle comparison, the Mann-Whitney U test shows the results of other comparisons. Comparison of p1 females. Comparison of p2 males. ** Statistical significance. | | | | | | |

There was no significant difference between the study groups in terms of patella-trochlear ratio (p=0.617). Insall-Salvati ratio was significantly higher in the patellar chondromalacia group (p=0.003). The modified Insall-Salvati ratio was significantly lower in the patellar chondromalacia group (p=0.001). The rate of Blackburne-Peel was significantly higher in the patellar chondromalacia group (p=0.004), (Table II).

The sulcus angle was significantly higher in men in the patellar chondromalacia group than in the control

group (p<0.001). In the patellar chondromalacia group, the lateral trochlear inclination angle was significantly less than in the control group (p=0.007). The medial trochlear inclination angle was significantly lower in men in the patellar chondromalacia group compared to the men in the control group (p=0.041), (Table III).

Insall-Salvati ratio was significantly higher in men in the patellar chondromalacia group compared to men in the control group (p<0.001). The modified Insall-Salvati ratio in women in the patellar chondromalacia group was significantly lower than in women in the control group (p=0.001). Blackburne-Peel ratio was significantly higher in men in the patellar chondromalacia group compared to men in the control group (p<0.001), (Table III).

## DISCUSSION

The results of this study revealed a relationship between patellar cartilage structural damage and trochlear and patellar morphology. In patients with grade 3-4 chondromalacia; sulcus angle, trochlear angle, lateral trochlear inclination angle, Insall-Salvati ratio, modified Insall-Salvati ratio, Blackburne-Peel ratio showed significant differences compared to the control group.

Resorlu et al.[19] investigated the relationship between trochlear morphology and patellar chondro-malacia. Duran et al.[5] compared trochlear measurements in patients with grade 3-4 chondromalacia among women. In both studies, the sulcus angle was significantly higher in the chondromalacia group, similar to our study. Contrary to the study of Duran et al.[5], in our study, the sulcus angle in the female gender was not different in the chondromalacia group compared to the control group. This shows that the significant difference in the sulcus angle in our study is due to the differences in the male gender (Table 3).

There are also studies in the literature that do not reveal a relationship between sulcus angle and chondromalacia. Dowd et al.[20] compared the sulcus angle between chondromalacia patients and the control group and reported that there was no significant difference between the two groups. In the study of Perrild et al.[21] in which they compared the sulcus angle, Insall-Salvati ratio and Blackburne-Peel ratio, it was reported that there was no significant difference between the chondromalacia group and the control group, and the mean sulcus angle values between the two groups.

Tuna et al.[22] in his study, trochlear parameters were compared between chondromalacia and control groups. Later, the chondromalacia group was divided into two groups as grade 1-2 and grade 3-4, and the relationship of parameters with the severity of chondromalacia was investigated. It was reported that the sulcus angle value was significantly higher in the chondromalacia group compared to the control group. In addition, it was reported that it did not show a significant change according to the severity of the disease.

Dong et al.[12] found in their study that trochlear angle is a parameter that increases in case of trochlear dysplasia and progressively increases as the severity of dysplasia increases. In our study, the trochlear angle was found to be significantly higher in the chondromalacia group (Table II).

In our study, the lateral trochlear inclination angle was found to be 25.7˚±4.6˚ in the chondromalacia group and 27.3˚±4.7˚ in the control group. The angle was significantly less in the chondromalacia group (Table II). Ali et al.[23] found that the lateral trochlear inclination angle in patients with grade 3-4 chondro-malacia was lower than the control group, similar to our study.

Duran et al.[5] concluded that the medial trochlear inclination angle did not differ significantly between the chondromalacia group and the control group. Similar results were obtained in our study.

Ali et al.[23] in a similar study, it was found that there was no significant difference in terms of patella-trochlear ratio. In our study, patella-trochlear ratio was found to be 34%±45% in the patellar chondromalacia group and 29±10% in the control group, and there was no significant difference between the study groups in terms of patella-trochlear ratio (Table II).

Perrild et al.[21] in his study, Insall-Salvati ratio was significantly higher in the chondromalacia group. Similarly, it was found to be significantly higher in the chondromalacia group in our study. However, there are also studies in the literature that contradict the findings of these two studies. Endo et al.[24] in the study in which they compared patellar measurements in the chondromalacia group and the control group, the rate was found to be 0.96±0.14 in the chondromalacia group and 0.92±0.14 in the control group, and it was reported that there was no significant difference between the two groups.

Blackburne-Peel ratio, another parameter measuring patella height, was found to be 0.83±0.69 in the chondromalacia group and 0.72±0.11 in the control group in our study (Table II). The rate was significantly higher in the chondromalacia group. Perrild et al.[21] is the only study we have accessed that compares the Blackburne-Peel ratio between patients with patellar chondromalacia and the control group. Perrild et al.[21]

reported that, unlike our study, there was no significant difference between the chondromalacia and control groups. However, there are differences in the design of the two studies. In our study, the exclusion criterion for the control group was surgery that disrupted the knee morphology. Whereas, Perrild et al.[21], the control group consisted of patients who had undergone meniscal surgery.

Insall-Salvati ratio below 0.8 indicates patella baja and above 1.2 indicates patella alta. Blackburne-Peel ratio below 0.8 indicates patella baja and above 1.0 indicates patella alta. Patella alta is known to be a risk factor for chondromalacia[25,26]. In our study, Insall-Salvati ratio and Blackburne-Peel ratio were significantly higher in the chondromalacia group than in the control group (Table II).

The Insall-Salvati ratio is the most commonly used patellar height measurement method. However, this method has some disadvantages. One of these is an incorrect measurement of the ratio due to variations in patellar morphology. Researchers have shown that in the case of a long distal facet, the Insall-Salvati ratio can be measured incorrectly[17]. To avoid this possible error, a method called the modified Insall-Salvati ratio has been developed to be used with the Insall-Salvati ratio. For this ratio, patella alta was accepted as the lower threshold value of >2[17]. In our study, the modified Insall-Salvati ratio was also measured along with the Insall-Salvati ratio. The modified Insall-Salvati ratio was 1.49±0.13 in the patellar chondromalacia group and 1.55±0.13 in the control group, and the value was significantly lower in the chondromalacia group (Table II). Unusual patellar shapes, longer articulated facet of the patella may explain this lowness in the patellar chondromalacia group. To our knowledge, our study is the first to investigate the modified Insall-Salvati ratio in patients with chondromalacia.

The limitations of our study, first, are that the patients included in the study were diagnosed with grade 3-4 chondromalacia by MRI without arthroscopy. Second, since the measurements were made by a single radiologist at one time, no intra-observer and inter-observer comparisons were made. Third, since it is a retrospective cross-sectional study, it cannot be demonstrated whether the parameters worsen over time. Fourth, the study could not be generalized to the whole population because it was single-centered and performed in a tertiary healthcare institution. However, our study is important because it included a relatively large number of patients with chondromalacia and most of the patellar and trochlear parameters were investigated in these patients.

## CONCLUSION

Sulcus angle, trochlear angle, lateral trochlear inclination angle, Insall-Salvati ratio, modified Insall-Salvati ratio, Blackburne-Peel ratio differ significantly in patients with chondromalacia compared to the control group. Our results show that trochlear dysplasia and patella alta are predisposing risk factors of grade 3-4 patellar chondromalacia, apart from the known association with patellofemoral instability.

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*Conflict of Interest:* The author has no conflicts of interest to declare.

*Ethics Committee Approval:* This retrospective study was conducted at Kırıkkale University, Medical Faculty, Department of Radiology. This study was approved by Kırıkkale University Clinical Researches Ethics Committee (Decision Number: 15/21, Date:01.10.2018) and conducted according to the Declaration of Helsinki.

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