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Association between MRI-based anterior tibial translation and patellofemoral cartilage damage one year after anterior cruciate ligament reconstruction

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Abstract

The patellofemoral joint is affected by biomechanical alterations to the knee joint following Anterior cruciate ligament (ACL) reconstruction. This study aimed to investigate the relationship between MRI-based Anterior Tibial Translation (ATT) measurements and patellofemoral joint chondral damage following ACL reconstruction. This retrospective study included 40 patients who underwent ACL reconstruction using an autograft between 2020 and 2024 were included in this study. The mean postoperative MRI acquisition time was 11.97 ± 3.23 months. Patellofemoral cartilage lesions were primarily evaluated using the MRI Osteoarthritis Knee Score (MOAKS) scoring system. Patients were classified into rotation groups according to the difference between their ATT-L and ATT-M values. The ATT-L-ATT-M difference was calculated and rotational groups defined: ± 2 mm, neutral; > 2 mm, internal; and < -2 mm, external rotation. The mean age of the patients was 28.93 ± 9.62 years, with 80% of the patients were male. Patellar cartilage damage was detected in 11 (27.5%) patients. The mean ATT-L was 6.075 ± 5.47 mm, whereas the mean ATT-M was 1.84 ± 4.39 mm. No significant association was observed between patellofemoral cartilage damage and either ATT-L or ATT-M ($p = 0.575$ and $p = 0.228$, respectively). The cartilage damage rate was 17.9% in the internal rotation group, compared to 50.0% in the neutral and external rotation groups. Cartilage damage was observed significantly less frequently in the internal rotation group than in the neutral and external rotation groups ($p = 0.037$). Early patellofemoral cartilage damage may be associated with patellofemoral morphology and tibial rotational profile rather than with isolated medial or lateral ATT measurements one year after ACL reconstruction.

Keywords: Anterior cruciate ligament, anterior tibial translation, reconstruction, cartilage, chondromalacia, rotation

Introduction

Anterior cruciate ligament (ACL) injuries are among the common clinical problems of the knee joint. ACL reconstruction (ACLR) is widely performed in current practice. Meniscal pathology, tibiofemoral cartilage abnormalities and collateral ligament injuries are commonly expected in patients with an ACL rupture. However, patellofemoral cartilage disease are less commonly evaluated than meniscal and femorotibial lesions. Biomechanical alterations to the knee joint following ACLR affect not only the tibiofemoral compartment, but also the patellofemoral joint. This leads to increased stress on the patellofemoral cartilage and altered load distribution. The development of patellofemoral osteoarthritis in a substantial proportion of patients after ACLR has been reported in previous studies, with rates of up to 80% of patients at 10 years and up to 90% at 15 years after surgery [1-3]. Detection of early chondropathy at a potentially reversible stage is crucial for personalised interventions, which is why it is important to be aware of the signs. Research shows patellofemoral cartilage is more often affected than tibiofemoral cartilage after ACLR [3-5].

The etiology of patellar chondromalacia is multifactorial and may include trauma, increased vulnerability of the cartilage, patellofemoral instability, osseous anatomical variations, abnormal patellar kinematics [6]. Although the procedure is

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generally considered successful, mild residual knee laxity may be observed during follow-up after ACLR; however, the overall effect on the patellofemoral joint remains unclear [7].

During the postoperative period, magnetic resonance imaging (MRI) is commonly used to evaluate the condition of the ACL graft, the stability of the knee, and any additional intra-articular pathologies. MRI-based anterior tibial translation (ATT) measurements can also be routinely assessed in this context. While the KT-1000 arthrometer is considered the gold standard for ATT evaluation, device and operator factors may influence the measurements [8]. Persistent anterior tibial translation after ACL reconstruction may alter tibiofemoral kinematics and patellofemoral joint loading, thereby contributing to the development of patellofemoral cartilage damage. Investigating the relationship between ATT measured by MRI and patellofemoral joint pathologies could help with the early prediction and management of patellofemoral chondral damage. We aimed to determine whether MRI-based medial and lateral ATT measurements and the tibial rotational profile derived from their difference are associated with patellofemoral cartilage damage, thereby providing a basis for early risk assessment and targeted preventive strategies.

Material and Methods

Patient selection and study design

This retrospective observational study included patients aged 18–50 years who underwent primary anterior cruciate ligament reconstruction using a hamstring autograft between 2020 and 2024. Patients were eligible if they attended routine postoperative follow-up, underwent knee MRI approximately one year after surgery, and had complete clinical and imaging data available for analysis. Patients who underwent revision ACL reconstruction, had multiligament knee injuries, a history of previous surgery on the affected knee, substantial metal artefacts limiting MRI evaluation, or severe arthrofibrosis were excluded. The mean postoperative MRI acquisition time was 11.97 ± 3.23 months.

Preoperative MRI examinations of all patients were reviewed to assess the baseline patellofemoral cartilage status. Patients were classified as having postoperative chondral damage if new patellofemoral chondral damage developed or if the grade of a pre-existing lesion was higher on postoperative MRI than on the preoperative examination.

MRI-Based Measurement

MRI was performed including sagittal, coronal and axial proton-density-weighted/T1-weighted sequences. Patients were arranged to maintain the supine position, and the knee was fully extended in the neutral position. The slice thickness was 3 mm for all sequences. Anterior tibial translation was measured in both the medial and lateral compartments.

Patellofemoral cartilage lesions were primarily evaluated using the MRI Osteoarthritis Knee Score (MOAKS) cartilage scoring system [9]. MOAKS was chosen as the main classification method due to its MRI-based semi-quantitative structure and its capacity to evaluate cartilage alterations in specific anatomical regions. The modified Outerbridge classification was also used in addition to this [10,11]. Similar results were obtained using both classification systems.

The MOAKS method is used to divide the knee into 14 articular subregions for the purpose of scoring cartilage lesions [9]. Cartilage lesions were scored from 0 to 3. This was based on size. The size was calculated as a percentage of the surface area. This percentage was relative to each subregion. The subregions were: 0 = none, 1 = < 33%, 2 = 33% – 66%, and 3 = > 66%. The size was also based on depth. The depth was calculated as a percentage of the lesion that is full thickness. The percentages were: 0 = no full thickness loss, 1 = < 10%, 2 = 10% – 75%, and 3 = > 75%. The Patellofemoral joint comprises four subregions (medial/lateral patella and medial/lateral femoral trochlea). For statistical analyses, patellofemoral cartilage damage was considered present when a MOAKS cartilage score greater than 0 was identified in at least one of the four patellofemoral subregions; otherwise, patients were classified as having no patellofemoral cartilage damage.

Lateral Anterior tibial translation (ATT-L) was evaluated using sagittal, fat-suppressed, proton-density-weighted images taken at the level of the mid-lateral femoral condyle. Two perpendicular reference lines were drawn: one along the posterior contour of the lateral tibial plateau, and one along the posterior aspect of the lateral femoral condyle. The distance between these two lines was measured in millimeters [12,13]. Medial tibial translation (ATT-M) was assessed using the same technique at the corresponding level of the medial femoral condyle. All measurements were performed by an experienced radiologist (Figure 1).

Subgroup analyses were performed based on patient measurements. In some patients, the ATT-L and ATT-M values were similar, whereas marked differences were observed in others. Patients were classified into rotation groups according to the difference between their lateral and medial tibial translation values. A study-specific threshold of ± 2 mm was defined to distinguish comparable medial and lateral translation from rotational asymmetry. Patients with an ATT-L–ATT-M difference within this range were classified as neutral. Patients outside the neutral position were assigned to the internal rotation group if their ATT-L was greater than their ATT-M, and to the external rotation group if their ATT-M was greater than their ATT-L.

Patellar and patellar tendon measurements were obtained on the sagittal slice demonstrating the longest patellar length. Patellar length was measured from the proximal margin to the distal anterior tip, excluding osteophytes and enthesophytes. Patellar tendon length and its anteroposterior (AP), mediolateral (ML), and craniocaudal (CC) dimensions were recorded (Figure 2). The Insall–Salvati index was calculated using patellar length and patellar tendon length, and patellar tendon volume was estimated using the ellipsoid formula: $\pi/6 \times ML \times AP \times CC$.

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Trochlear measurements were performed on axial proton density fat-suppressed images at the level of the anterior physeal line (Figure 2). Trochlear depth, trochlear facet asymmetry, and trochlear sulcus angle were measured using osseous landmarks only, excluding articular cartilage. Trochlear depth was defined as the maximum perpendicular distance from the deepest point of the trochlear groove to the line connecting the medial and lateral trochlear facets. Facet asymmetry was calculated as the medial-to-lateral facet length ratio, and the angle between the medial and lateral facets was recorded as the trochlear sulcus angle [14].

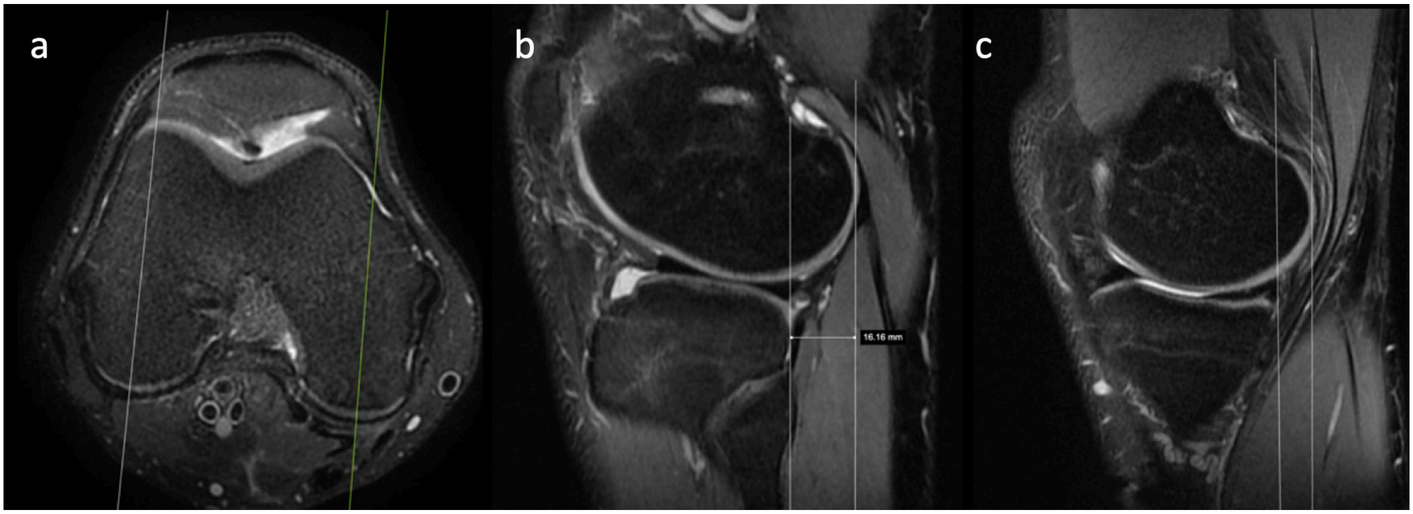

Figure 1. MRI-based ATT measurement technique; (a) Axial image used to identify the femoral condylar level; (b, c) Sagittal images demonstrating lateral and medial ATT measurements

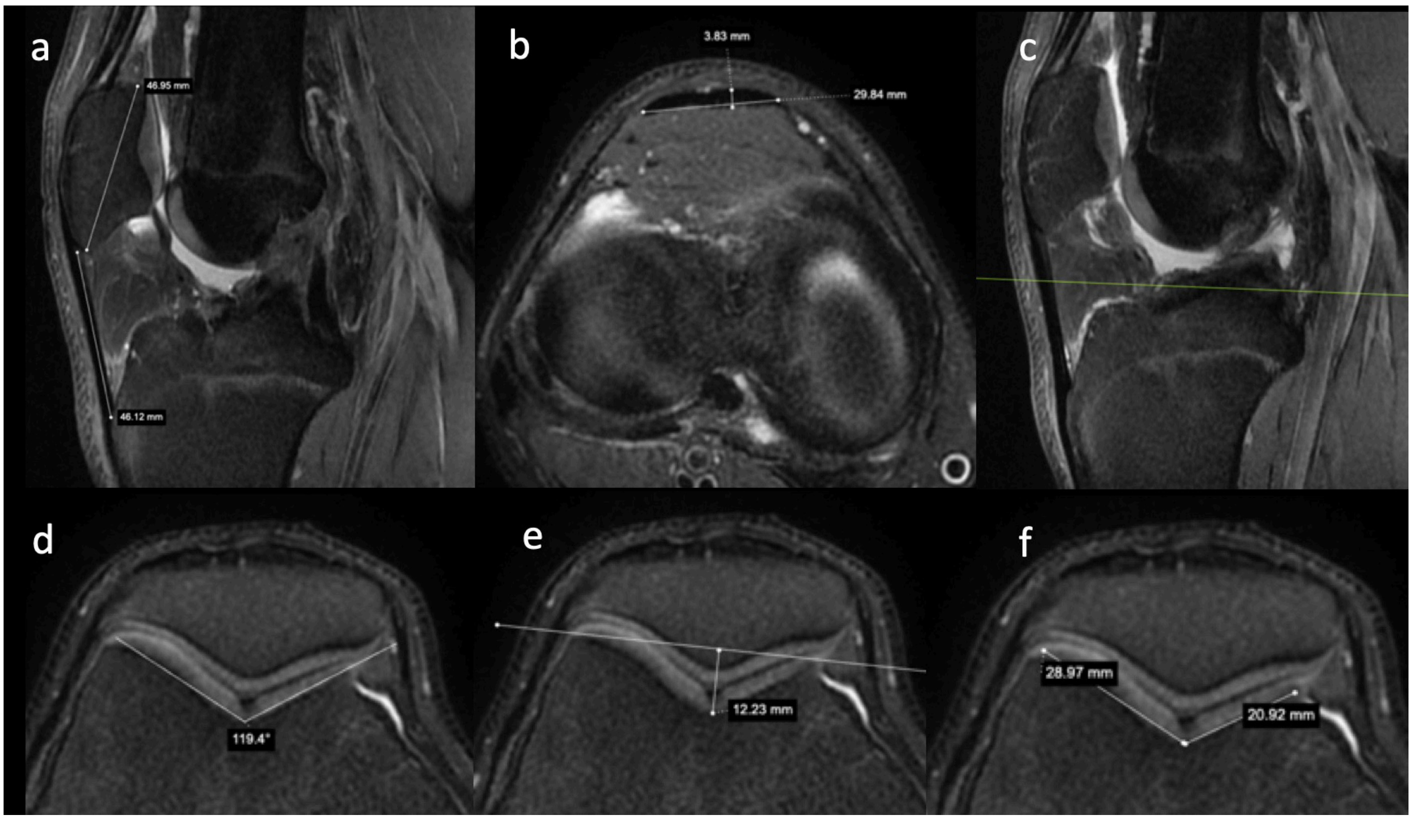

Figure 2. MRI-Based patellofemoral anatomical measurements; (a) Patellar tendon length and patellar bone craniocaudal length; (b, c) Patellar tendon anteroposterior thickness and mediolateral width; (d–f) Trochlear sulcus angle, trochlear height, and medial/lateral trochlear measurements

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The mean values of lateral and medial ATT, as well as the differences between these measurements, were included in the statistical analysis. In addition, other parameters potentially associated with the development of patellofemoral cartilage lesions were also analyzed.

Statistical analyses

Statistical analyses were performed using SPSS version 26.0. Continuous variables were presented as mean ± standard deviation, and categorical variables as number and percentage. Continuous variables were compared using the independent samples t-test, and categorical variables using the chi-square test. Effect size was calculated using Cohen's d. A p value < 0.05 was considered statistically significant.

Ethics Statement

This study was approved by the Samsun University Non-Interventional Clinical Research Ethics Committee (Approval No: GOKAEK 2025/23/8, Date: 03.12.2025) and conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants.

Results

The study included a total of 40 patients who had undergone ACLR. The mean age of the patients was 28.93 ± 9.62 years, with 80% of patients were male. The right knee was affected in 19 patients (47.5%), while the left knee was affected in 21 patients (52.5%). The overall demographic and clinical characteristics of the patients, including age, sex, body mass index (BMI), operated side, time from injury to surgery, preoperative and postoperative International Knee Documentation Committee (IKDC) scores, time to return to sport, and follow-up duration, are presented in Table 1.

Table 1. Demographics and clinical characteristics

Variables		Mean ± SD (n = 40)
Age in years		28.93 ± 9.62
Gender	**Men**	32 (80%)
	Women	8 (20%)
BMI in kg/m²	**Men**	24 ± 3
	Women	23 ± 2
Side	**Right**	17 (42%)
	Left	23 (58%)
Time to from surgery in months		6 ± 1.2
Pre-op IKDC score		50.2 ± 8.1
Post-op IKDC score		91.2 ± 8.1
Return to sport time in months		6.9 ± 1.1
Follow-up time in months		12 ± 1.2

Patellofemoral cartilage damage was detected in 11 patients, while no defects were observed in the remaining 29 patients. According to the modified Outerbridge classification, grade 1–2 chondromalacia was identified in 8 patients and grade 3–4 in 3 patients. The MOAKS method revealed cartilage damage affecting all four patellofemoral articular surfaces in one patient. Combined medial and lateral patellar cartilage damage were present in three patients, and combined lateral patellar and lateral trochlear cartilage damage were present in one patient. Six patients had isolated cartilage damage involving a single patellofemoral articular surface. Of these, lateral patellar cartilage damage was present in two patients, medial patellar cartilage damage in three patients and a medial trochlear cartilage damage in one patient (Figure 3).

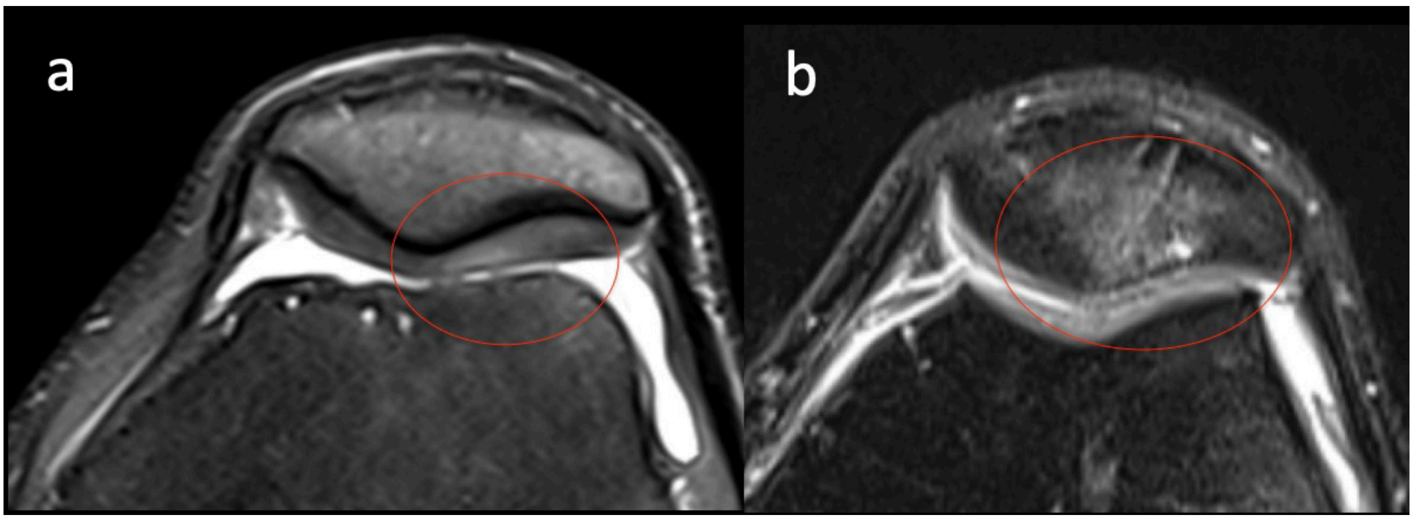

Figure 3. Proton density-weighted axial MRI findings of patellofemoral cartilage damage; (a) Increased lateral patellar cartilage signal intensity; (b) Lateral patellofemoral cartilage damage with subchondral bone marrow edema and degenerative subchondral cyst formation

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The mean lateral anterior tibial translation (ATT-L) as measured by MRI was 6.075 ± 5.47 mm, whereas the mean medial anterior tibial translation (ATT-M) was 1.84 ± 4.39 mm. No significant association was observed between patellofemoral cartilage damage and either ATT-L or ATT-M ($p = 0.575$ and $p = 0.228$, respectively). Patients with cartilage defects exhibited a significantly higher patellar tendon-to-patella ratio (Insall–Salvati index) ($p = 0.038$, ES = 0.759) and a higher trochlear sulcus angle ($p = 0.049$, ES = 0.716). These large effect sizes indicate that increased patellar height and trochlear shallowing may be clinically relevant markers in the development of cartilage lesions. Although statistical significance was not reached, moderate effect sizes were observed for trochlear height ($p = 0.110$, ES = 0.580) and medial trochlear length ($p = 0.152$, ES = 0.518), suggesting that these anatomical variations may reflect clinically relevant trends. A comparative analysis of patients with and without cartilage defects is presented in detail in Table 2.

Table 2. Comparison of ATT and patellofemoral measurements by cartilage damage status

Variables	Non-cartilage damage	Cartilage damage	t	p	95% CI		
	Mean ± SD	Mean ± SD			ES	LB	UB
ATT (mm)							
ATT-L	5.77 ± 5.66	6.88 ± 5.13	-0.565	0.575	0.203	-0.894	0.497
ATT-M	1.31 ± 4.24	3.21 ± 4.70	-1.225	0.228	0.432	-1.132	0.270
ATT-Mean	3.54 ± 4.41	5.04 ± 3.97	-0.985	0.331	0.349	-1.045	0.352
ATT- Δ	4.45 ± 4.71	3.66 ± 5.81	0.443	0.660	0.157	-0.539	0.851
Patellar datas (mm)							
P-CC	44.78 ± 3.68	42.72 ± 3.97	1.548	0.130	0.548	-0.160	1.249
PT-CC	44.94 ± 5.95	48.06 ± 5.74	-1.493	0.144	0.529	-1.229	0.179
PT/P	1.01 ± 0.16	1.14 ± 0.20	-2.144	**0.038***	0.759	-1.469	-0.040
PT-ML	28.01 ± 2.49	26.78 ± 2.60	1.380	0.176	0.489	-0.217	1.188
PT-AP	4.65 ± 1.01	4.53 ± 0.54	0.396	0.694	0.140	-0.555	0.834
PT Volume (cm^3)	3.06 ± 0.88	3.03 ± 0.56	0.129	0.898	0.046	-0.543	0.617
Trochlear datas							
TR-A	136.62 ± 13.05	142.65 ± 11.26	-2.023	**0.049***	0.716	-1.424	-0.021
TR-H	6.14 ± 2.20	4.93 ± 1.70	1.637	0.110	0.580	-0.130	1.282
TR-M	16.52 ± 2.47	15.22 ± 2.60	1.463	0.152	0.518	-0.189	1.218
TR-L	23.75 ± 2.69	22.66 ± 3.33	1.073	0.290	0.400	-0.322	1.077
TR-M/TR-L (%)	70.09 ± 10.75	68.28 ± 13.73	0.441	0.662	0.156	-0.540	0.850

Compared using the independent samples t-test; SD: standard deviation, ES: Cohen's d effect size, LB: lower bound, UB: upper bound, ATT: Anterior tibial translation, L: Lateral, M: Medial, Mean: Mean of ATT-M and ATT-L, Δ: Difference of ATT-L and ATT-M, P-CC: patella craniocaudal measure, PT: Patellar tendon, PT/P: InsallSalvati, PT-CC: Patellar tendon craniocaudal measure, PT-ML: Patellar tendon mediolateral measure, PT-AP: Patellar tendon anteroposterior measure, PT Volume: Patellar tendon volume, TR: Trochlea, TR-A: Trochlear Angle, TR-H: Trochlear Height, TR-M: Trochlea medial measure, TR-L: Trochlea lateral measure, TR-M/TR-L: Trochlea Medial/Trochlea Lateral*100

Based on ATT measurement data, 28 patients were classified as exhibiting internal rotation, nine as exhibiting a neutral position, and three as exhibiting external rotation (Figure 4). The cartilage damage rate was 17.9% in the internal rotation group, compared to 50.0% in the neutral and external rotation groups. Cartilage damage was observed significantly less frequently in the internal rotation group than in the neutral and external rotation groups ($p = 0.037$) (Table 3).

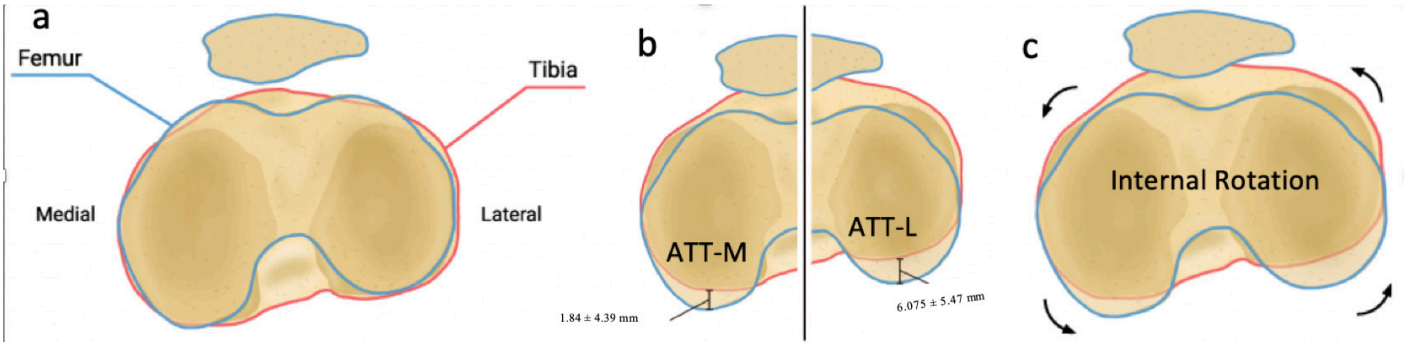

Figure 4. Anterior tibial translation measurement; (a) Normal relationship between the femur and tibia; (b) Mean values of medial and lateral anterior tibial translation; (c) Internal rotation pattern, defined as ATT-L greater than ATT-M

Table 3. Association between rotational pattern and cartilage damage

Rotational pattern		Non-cartilage damage	Cartilage damage	Total	p value
Internal rotation	**N (%)**	23 (82.1)	5 (17.9)	28 (100.0)	
Neutral and external rotation	**N (%)**	6 (50.0)	6 (50.0)	12 (100.0)	
Total	**N (%)**	29 (72.5)	11 (27.5)	40 (100.0)	**p = 0.037***

*P values were calculated using the chi-square test

Discussion

This study evaluated the relationship between ATT, patellofemoral alignment parameters and patellofemoral cartilage damage in patients undergoing ACL reconstruction. Our main findings were that increased patellar height (PT/T ratio) and trochlear morphology (trochlear sulcus angle) were significantly associated with cartilage damage. However, ATT parameters did not demonstrate a significant association with cartilage damage when considered individually.

However, when the distribution of ATT between the medial and lateral compartments was considered, a significant relationship emerged. Patients with a relative internal rotational profile, characterised by higher lateral ATT than medial ATT, had a significantly lower prevalence of cartilage damage than those with neutral or external rotational patterns. These findings suggest that the distribution of tibial translation between compartments may play a critical role in patellofemoral joint degeneration, in addition to its magnitude.

Although structural changes in the patellofemoral joint after ACLR have received less attention than those in the tibiofemoral compartment, current evidence suggests that the patellofemoral joint is at least as important as the tibiofemoral joint in terms of early degenerative processes [15,16]. Schache et al. [15] demonstrated that patellofemoral osteoarthritis is prevalent following ACLR and may be related to altered joint loading. They also reported that early patellofemoral osteoarthritis, detected within the first year, as well as progression of the condition between one and five years after surgery, was associated with lower patellofemoral joint contact pressure. These findings suggest that cartilage degeneration after ACLR may be caused not only by mechanical overload, but also by insufficient or altered loading patterns [15,16]. Similarly, Wang et al. [16] reported an increase in patellar cartilage volume 2.5–4.5 years after surgery in patients who underwent either isolated ACLR or surgery for concomitant meniscal pathology. This finding may reflect an early hypertrophic response of the patellar cartilage. In the same study, the positive correlation between the baseline patellar cartilage damage score and the subsequent increase in cartilage volume over the following two years suggests that early morphological changes may be linked to later degenerative responses [16].

Conversely, a T2 mapping-based assessment by Zagaria et al. [3] detected mild patellofemoral chondropathy in a significant proportion of patients at a median of 54 months after ACLR. However, no significant difference was observed in the development of early chondropathy between bone–patellar tendon–bone and hamstring tendon grafts [3]. These results imply that the patellofemoral degenerative process is not fully explained by graft choice alone, but rather by a combination of biomechanical loading characteristics, reduced activity status, and early biochemical alterations in the articular cartilage [15,16].

In addition, Zagaria et al. [3] reported significant agreement between the Knee Injury and Osteoarthritis Outcome Score (KOOS) and Tegner–Lysholm scores and chondropathy grading.

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However, no significant relationship was observed between T2 mapping subsegmental analyses and functional scales. This suggests that early patellofemoral cartilage changes may not always be accompanied by overt clinical symptoms, and that early detection through imaging may complement clinical assessment.

An important arthroscopic study by Oksman et al. [17] found that patellar chondral lesions were present in 28.8% of the 250 patients examined for chronic ACL insufficiency. Most of the lesions were superficial and predominantly affected the lateral facet. Additionally, a significant worsening of the International Cartilage Repair Society (ICRS) grade was observed with increasing laxity duration. These results suggest that patellofemoral cartilage damage is a dynamic process that can worsen over time and that the patellofemoral compartment should not be considered of secondary importance in cases of knee pathology related to the ACL [17].

The studies suggest that degenerative changes to the patellofemoral joint following ACLR can occur at the biochemical and morphological levels during the early stages. These changes may also progress structurally over time and are often related to changes in joint loading [15-17].

Therefore, when investigating the development of patellofemoral chondromalacia or osteoarthritis after ACLR, a more comprehensive pathophysiological interpretation can be achieved by considering not only static structural findings, but also joint biomechanics, the stage of cartilage response and concomitant meniscal factors [15,16].

Our study found that the difference in the frequency of patellofemoral cartilage damage among groups defined by internal rotation group suggests that alterations in patellofemoral joint biomechanics after ACLR may be associated with cartilage degeneration. The lower rate of chondromalacia observed in the internal rotation group, coupled with the higher rates evident in the neutral and external rotation groups, highlights the importance of evaluating load transfer across the patellofemoral joint in terms of both the magnitude and spatial distribution of translation, as well as the accompanying rotational pattern.

In clinical practice, loading abnormalities and maltracking in the patellofemoral joint tend to be predominantly concentrated on the lateral facet [17]. Due to factors such as trochlear geometry, the direction of quadriceps force, the effect of the Q angle and lateral retinacular tension, the patella is often prone to lateral displacement or increased contact stress on the lateral articular surface. Conversely, internal rotation can lead to medial displacement and tilt of the patella, potentially reducing cartilage damage, particularly on the lateral aspects of the patellofemoral joint [18]. In our study, translational and/or rotational alterations associated with neutral and external rotation patterns contributed to the transition from patellofemoral joint adaptation to degenerative cartilage morphology, as evidenced by the higher frequency of cartilage damage ($p = 0.037$).

In the arthroscopic series reported by Oksman et al. [17], the severity of patellar chondral lesions increased significantly with longer laxity duration in patients with chronic ACL insufficiency. This suggests that the patellofemoral compartment is susceptible to progressive deterioration of the cartilage over time in cases of knee pathology related to the ACL. Our study found that patients with an internal rotation pattern had a lower incidence of early patellar cartilage damage at the first year MRI evaluation. Therefore, this rotational alignment may be associated with a lower risk of early patellofemoral cartilage injury.

Conversely, persistent tibial translational irregularity following ACL reconstruction surgery may contribute to patellofemoral degeneration over time [15,17]. Previous studies have demonstrated that the degenerative process in patellar cartilage can start soon after ACLR and worsen over time [3,16]. Similarly, our findings indicate that MRI-based measurements could be used to predict patellofemoral cartilage damage following ACLR.

The higher Insall–Salvati index and increased trochlear sulcus angle observed in the cartilage damage group indicate an association with patellofemoral cartilage damage. Similar relationships have been reported in previous studies [19-21]. In our study, patellofemoral cartilage damage was significantly associated with both the Insall–Salvati index and the trochlear sulcus angle ($p = 0.049$ and $p = 0.038$, respectively). Although not statistically significant, variables such as trochlear height and medial trochlear length showed moderate effect sizes and may represent additional anatomical measurements that could reveal more clinically relevant associations in larger cohorts.

This study has several limitations. The retrospective design and relatively small sample size may restrict the generalisability of the findings. MRI-based ATT measurements were obtained from static, non-weight-bearing images, which may not accurately reflect dynamic knee instability or patellofemoral loading during activity. Additionally, the rotational classification was based on a threshold specific to this study, derived from the difference between medial and lateral ATT measurements. The small number of patients in some rotational subgroups also limited more detailed analyses. Given the multifactorial nature of patellofemoral cartilage damage, additional clinical, biomechanical and surgical factors may also contribute to the observed relationships. Nevertheless, the study has several strengths. These include evaluating a relatively homogeneous cohort that was treated with a hamstring autograft; conducting a postoperative MRI assessment approximately one year after surgery; taking compartment-specific measurements of medial and lateral ATT; and combining the evaluation of the tibial rotational profile, patellofemoral morphology, and cartilage damage using established MRI-based measurement methods.

Conclusion

In conclusion this study showed that patellofemoral cartilage damage one year after ACLR was not associated with ATT alone. Instead, it was associated with the medial–lateral distribution of

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translation and the accompanying rotational pattern. The lower incidence of patellofemoral cartilage damage in patients with an internal rotation pattern suggests that this rotational alignment may be associated with more favourable patellofemoral cartilage outcomes after ACLR. Additionally, the association between increased Insall–Salvati index and trochlear sulcus angle values and patellofemoral cartilage damage indicates that patellar and trochlear morphology should be considered when evaluating early degenerative changes. Overall, these findings imply that a combined assessment of ATT measurements and patellofemoral anatomical parameters using routine MRI after ACLR may help predict early patellofemoral cartilage damage.

Ethical Approval

This study was approved by the Samsun University Non-Interventional Clinical Research Ethics Committee (Approval No:2025/23/8, Date: 03.12.2025) and conducted in accordance with the Declaration of Helsinki.

Patient Consent

Written informed consent was obtained from all participants.

Conflict of Interest

The authors confirm the absence of any conflicts associated with this work.

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