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ORIGINAL ARTICLE

Factors Affecting the Femoral Cartilage Thickness After Anterior Cruciate Ligament Reconstruction

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Abstract

Background This study aimed to evaluate the changes in the distal femoral cartilage thickness in patients that underwent anterior cruciate ligament reconstruction (ACLR) and to analyze their association with concomitant meniscal surgery, knee muscle strength, kinesophobia, and physical activity level.

Methods The demographic characteristics and surgical data of 47 male patients that underwent unilateral ACLR (mean, 27.55 ± 5.63; range, 18–40 years) were evaluated. The patients were assessed in three groups depending on surgery: isolated ACLR ($n = 15$), ACLR + partial medial meniscus resection (ACLR&M) ($n = 16$), and ACLR + medial meniscus repair (ACLR&MR) ($n = 16$). The medial (MCCT), intercondylar (ICCT), and lateral (LCCT) femoral cartilage thicknesses on both limbs were measured using ultrasonography. The extensor and flexor muscles strength of the knees was assessed using an isokinetic dynamometer at 60°/s. The physical activity level was evaluated by the International Physical Activity Questionnaire (IPAQ) short form and Tegner Activity Scale (TAS). The fear of movement was assessed by the Tampa Scale for Kinesiophobia Questionnaire (TSKQ).

Results The postoperative mean follow-up duration was 32.24 ± 9.17 months. MCCT and LCCT were significantly decreased in the ACLR&M group ($p < 0.001$ and $p = 0.019$, respectively). MCCT, ICCT and LCCT were significantly decreased in the ACLR&MR group ($p = 0.017$, $p = 0.011$, and $p = 0.004$, respectively). No significant change was found in the ACLR group. Cartilage thickness changes were not significantly correlated with the knee muscle strength, IPAQ, TAS and TSKQ scores in all groups ($p > 0.05$).

Conclusion The results showed partial meniscectomy and meniscus repair at the time of ACLR as important risk factors for decreased chondral thickness.

Keywords Anterior cruciate ligament reconstruction · Femoral cartilage thickness · Ultrasonography · Meniscal surgery

Introduction

Anterior cruciate ligament (ACL) injuries are common, particularly in physically active young populations. ACL is a major stabilizer of the knee since it resists anterior tibial translation and rotational loads. ACL reconstruction (ACLR) is performed to restore knee biomechanics and allow patients to recover their pre-injury activity levels [1, 2].

Although some studies have been reported satisfactory short- and mid-term results, the protective effects of ACLR on the cartilage structure of the knee are contradictory [1–4]. Wipfler et al. reported their long-term results with a mean follow-up of 8.8 years in patients with ACLR and noted no difference of articular cartilage and meniscal degeneration between the operated and healthy knees [3]. However, Ichiba and Kishimoto found increased cartilage degeneration risk in patients that had undergone ACLR and presented with cartilage or meniscal injury [5].

An ultrasound examination has been reported to be useful for the evaluation of distal femoral cartilage echogenicity and femoral cartilage size, which cannot be detected by X-ray [6]. Although there are conflicting results in the

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literature concerning the effects of ACLR on cartilage degenerative changes [3, 4], patient age, choice of surgical technique including grafts, concomitant injuries of the knee, residual instability after surgery, and quadriceps muscle dysfunction are generally considered as risk factors for developing OA after ACLR [7–9].

Accompanying meniscal injury has been the most commonly reported risk factor for OA development following ACLR [1]. Evaluating articular cartilage changes after a 2-year follow-up in patients who underwent arthroscopic ACLR with or without concomitant meniscal surgery, Michalitsis et al. reported more chondral defects in the group that underwent partial meniscectomy at the time of arthroscopic ACLR [10].

ACL injuries can disrupt complex interactions within the neuromuscular system, leading to disruption in kinesthesia and proprioception, abnormal muscle activation, and dynamic knee joint stability [8]. Pamukoff et al. showed that greater quadriceps strength was associated with thicker cartilage and larger cartilage cross-sectional areas after ACLR [11]. In previous studies, kinesiophobia (fear of movement/reinjury) was indicated as a potential reason that led to a decreased physical activity level. High levels of kinesiophobia have been related to worse knee function and a lower return-to-sport rate after ACLR. Thus, kinesiophobia is an important psychosocial factor in ACL rehabilitation [12, 13].

OA following ACLR is multifactorial, and the facilitating factors of this condition have not yet been completely understood. In this study, we hypothesized that concomitant meniscal injury with ACLR was the most affecting factor leading to femoral cartilage lose among all the risk factors mentioned above. Accordingly, this study aimed to evaluate the distal femoral cartilage thickness changes in patients that had undergone ACLR and to analyze their association with concomitant meniscal surgery, knee muscle strength, kinesophobia, and physical activity level.

Materials and Methods

Participants

Patients who had been operated on with the same technique (arthroscopic anatomic single-bundle ACLR with a hamstring tendon autograft) for each type of surgery by the same orthopedic surgeon and referred to our rehabilitation clinic between October 2017 and June 2018 in İstanbul Medipol University were included in the study. Forty-seven male patients (mean age 27.55 ± 5.63; range 18–40 years) met the eligibility criteria and were recruited for the study. Demographic characteristics (age, gender, body height and weight), preoperative symptom duration, postoperative duration, dominant extremity, and operated knee side were recorded. Body mass index (BMI) was calculated (kg/m^2). The inclusion criteria were as follows: (1) volunteered to participate in this study, (2) full range of motion and stable knees under Lachman and pivot-shift examinations, (3)age above 18 and under 40 years, and (4) at least 1 year after the operation. The exclusion criteria were as follows: (1) any type of inflammatory or septic arthritis, (2) history of traumatic injury or surgery of lower limb joints except for the operated knee, (3) restricted range of motion in any lower limb joint, (4) history of osteochondral lesion in the knees, (5) more than one surgery in the operated knee, (6) multiple traumas or mechanical axis deviation in any lower limb, (7) neurologic disorders that could result in lower extremity motor paresis, and (8) psychiatric disorders that could affect communication.

Study Design

The study used a cross-sectional design. Forty-seven male patients were divided into three groups according to the types of surgery they had undergone: ACLR alone ($n = 15$), ACLR + partial medial meniscus resection (ACLR&M) ($n = 16$), and ACLR and medial meniscus repair (ACLR&MR) ($n = 16$).

The study protocol was approved by the Local Ethics Committee of İstanbul Medipol University (Date: November 8, 2019, number: 10840098–604.01.01-E.60984), and written informed consent was obtained from all patients. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Ultrasonographic Assessment

The distal femoral cartilage thickness was measured using ultrasonography (US) in both knees using a commercially available US system with a 12–5-MHz multifrequency linear transducer (Logiq E9, GE Medical Systems, Wauwatosa, WI, USA). Previous studies had found a good inter- and intraobserver agreement when measuring cartilage thickness with US [11, 14]. The participants were instructed to avoid exercise the day before and on the day of the US examination. Before the US measurements, the participants were allowed to rest in a supine position with the knee in full extension for 30 min on the treatment table to unload the articular cartilage and to minimize the effects of any preceding weight-bearing activity on the cartilage. For the US measurement, the patient's knee was placed in 140° of flexion using a handheld goniometer. This position was selected because it allows for the clear visualization of the femoral articular cartilage without interference of surrounding soft tissue structures [11]. The probe was placed anteriorly over the distal femoral cartilage of the medial and lateral femoral condyles in the transverse plane, and the superior border of the patella. The intercondylar notch was centered on the screen using a transparent grid that was overlaid on the ultrasound screen. Each image was captured and measured twice independently by two physiatrists, and the inter-rater and intra-rater reliability values of the measurements were determined. For the intra-observer reliability, the measurements were repeated in two sessions at an interval of at least 2 hours. The grand mean was used for the analysis. Cartilage thicknesses were measured from the midpoints of the medial condyle, intercondylar area, and the lateral condyle by drawing a vertical line between the cartilage–bone and synovial space–cartilage surfaces (Fig. 1). The difference in the cartilage thickness between the healthy and operated sides was calculated from the three regions. The mean values of three successive measurements for each site were noted. Both physiatrists who performed the US examinations were blinded to the patients' groups.

Muscle Strength Measurements

The bilateral knee extension and flexion muscle strength measurements of the patients were evaluated using a Humac Norm Cybex isokinetic dynamometer at a rate of five repetitions at 60°/s. The patients were seated with the hip joint at 85° of flexion and attached to the dynamometer chair with Velcro straps to ensure stability during maximal contractions [15]. The arm of the dynamometer that gives the knee flexion extension movement is fixed to the distal end of the tibia. First, the muscle strength of the operated knee side was measured. After 2 min of rest, the measurements were undertaken on the healthy knee side. The peak torque was recorded as Newton meter/kilogram (Nm/kg). Knee extension and flexion muscle strength deficits were calculated as percentages. The peak torques of the knee extension and the flexion muscle strength ratio for the operated limbs were also calculated.

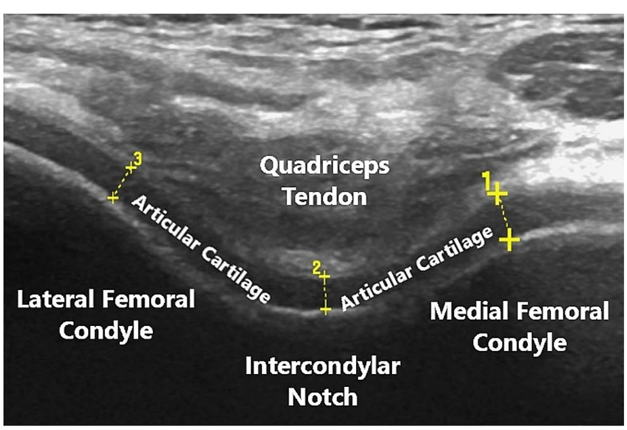

Fig. 1 Ultrasonographic image of femoral cartilage: femoral cartilage thickness was measured as the length of the straight line drawn from the cartilage–bone interface to the synovial space–cartilage interface. 1. Medial femoral cartilage thickness, 2. intercondylar cartilage thickness, and 3. lateral femoral cartilage thickness

Physical Activity Levels and Kinesiophobia Scores

The general physical activity level was assessed according to the International Physical Activity Questionnaire (IPAQ). The short form of IPAQ consists of seven items that determine the frequency (times per week) and duration (minutes or hours per day) of different levels of physical activity (walking, moderate activity, and vigorous activity) performed in the past 7 days. The physical activity level was determined based on the time dedicated to each activity multiplied by the specific metabolic equivalent of task (MET) score of that activity. Accordingly, vigorous-intensity physical activity was assigned a value of 8.0 METs, moderate physical activity 4.0 METs, and walking 3.3 METs. The total physical activity score was obtained by summing these three scores (MET-min/week). The scores were presented as MET-minutes per week (IPAQ-total) and categorized into three categories as low (< 600 MET-minute/week), moderate (> 600–3000 MET-minute/week) and high (> 3000 MET-min/week) physical activity [16]. The knee-specific physical activity level was assessed according to the Tegner Activity Scale (TAS) [17]. A 17-item Turkish version of the self-reported Tampa Scale for Kinesiophobia Questionnaire (TSKQ) was used to assess the fear of movement. Each item was scored using a four-point Likert scale ranging from 1 (strongly disagree) and 4 (strongly agree). The total score was calculated by adding the scores of the individual items (range 17–68) with higher scores indicating a greater degree of kinesiophobia. A score of 37 or over was considered as a high score, while those below this value were considered as low scores [18].

Statistical Analysis

Data were analyzed using IBM SPSS for Windows version 23.0 software (IBM Corp. Armonk, NY, USA). The Shapiro–Wilk test was used to evaluate the normality of data. Frequency, percentage, mean and standard deviation values were used for descriptive statistics. For group comparisons, one-way analysis of variance and paired samples t test were used for continuous data if the variables were normally distributed, and the Kruskal–Wallis test was conducted in the remaining cases. Correlations were evaluated using Pearson's rank correlation analyses. A p value of < 0.05 was considered statistically significant.

Results

A total of 47 male patients (mean age, 27.55 ± 5.63 years, range, 18–40 years) were enrolled in the study. The mean BMI was 25.39 ± 2.83 (range, 20.06–30.37) kg/m^2. The preoperative symptom duration was 2.55 ± 3.92 (range, 2.55 ± 3.92) months. The postoperative mean follow-up duration was 32.24 ± 9.17 (range, 17.1–51.8) months. No significant difference was found between the groups in terms of the demographic and clinical features and the TAS, TAMPA and IPAQ scores (Table 1). Levene's test was used to assess variance between three groups and we ensured that all participants of three groups came from similar population. The medial and lateral condyle cartilage thicknesses were significantly decreased in the ACLR&M group ($p < 0.001$ and $p = 0.019$, respectively). The intercondylar, medial and lateral condyle cartilage thicknesses were significantly decreased in the ACLR&MR group ($p = 0.011$, $p = 0.017$, and $p = 0.004$, respectively). However, no significant change was found in the ACLR group (Table 2).

Table 1 Demographic and clinical features of the participants

	Total (*n* = 47)	ACLR Group (*n* = 15)	ACLR&M Group (*n* = 16)	ACLR&MR Group (*n* = 16)	*p*
Age, years*	27.55 ± 5.63	26.47 ± 6.16	27.19 ± 5.69	27.55 ± 5.63	0.461[1]
Body mass index (kg/m^2)*	25.39 ± 2.83	24.64 ± 2.92	25.02 ± 3.07	25.39 ± 2.83	0.164[1]
Preoperative symptom duration, months*	2.55 ± 3.92	1.82 ± 2.0	2.44 ± 3.67	2.55 ± 3.92	0.920[1]
Postoperative duration, months*	32.24 ± 9.17	33.69 ± 8.6	32.66 ± 8.76	32.24 ± 9.17	0.616[1]
Operated knee side, *n* (%)					
Right	27 (57.4)	9 (60)	8 (50)	10 (62.5)	0.752[2]
Left	20 (42.6)	6 (40)	8 (50)	6 (37.5)	
Dominant	30 (63.8)	11 (73.3)	10 62.5)	9 (56.3)	0.607[2]
Non-dominant	17 (36.2)	4 (26.7)	6 (37.5)	7 (43.8)	
Tegner Activity Scale score**	5 (4–7)	6 (5–7)	6 (4–7)	4 (3.75–6)	0.050[3]
IPAQ score**	4080 (2772–5079)	4692 (3712.5–5283)	4039.5 (2764–5346.75)	3066 (1722.75–4126.5)	0.078[3]
Tampa Scale score**	28 (18–43)	34 (18–40.5)	20 (17–32.5)	30 (21.25–46)	0.332[3]

ACLR Anterior cruciate ligament reconstruction, *ACLR&M* Anterior cruciate ligament reconstruction with partial meniscectomy, *ACLR&MR* Anterior cruciate ligament reconstruction and meniscus repair, *IPAQ* International physical activity questionnaire, *n* number of patients

*Mean ± SD

**Median (IQR)

[1]One-way ANOVA test

[2]Pearson Chi-Squared Test

[3]Kruskal–Wallis test

Table 2 Comparison of the ultrasound measurements of the distal femoral cartilage thickness

Group	Measurement area	Healthy knee (mm)	Operated knee (mm)	Difference	*p
ACLR	Intercondylar	2.89 ± 0.67	2.86 ± 0.81	0.03 ± 0.63	0.840
	Lateral condyle	2.73 ± 0.57	2.55 ± 0.46	0.18 ± 0.61	0.271
	Medial condyle	2.7 ± 0.55	2.43 ± 0.48	0.27 ± 0.66	0.138
ACLR&M	Intercondylar	3.3 ± 0.75	2.97 ± 0.47	0.33 ± 0.64	0.061
	Lateral condyle	2.86 ± 0.6	2.5 ± 0.55	0.36 ± 0.54	**0.019**
	Medial condyle	2.99 ± 0.48	2.62 ± 0.43	0.37 ± 0.32	**< 0.001**
ACLR&MR	Intercondylar	3.15 ± 0.47	2.71 ± 0.62	0.44 ± 0.61	**0.011**
	Lateral condyle	2.78 ± 0.63	2.21 ± 0.59	0.57 ± 0.69	**0.004**
	Medial condyle	2.77 ± 0.41	2.35 ± 0.52	0.42 ± 0.63	**0.017**

Data are expressed as mean ± SD

Statistically significant differences are marked in bold

ACLR Anterior cruciate ligament reconstruction, *ACLR&M* Anterior cruciate ligament reconstruction with partial meniscectomy, *ACLR&MR* Anterior cruciate ligament reconstruction and meniscus repair

*Paired samples *t* test, statistically significant at $p < 0.05$

İnterrater reliability was good with ICC values between 0.85 and 0.89.

When the whole sample was evaluated, the knee extension and flexion muscle strength was significantly lower on the operated knee side than on the healthy side ($p = 0.002$ and $p = 0.012$, respectively). The extensor muscle strength of the operated knee was found to be significantly decreased only in the ACLR&M group ($p = 0.04$). The flexor muscle strength of the operated knee was significantly decreased only in the ACLR&MR group ($p = 0.015$) (Table 3). There was no significant correlation between decreased cartilage thickness and operated knee extension and flexion muscle strength, knee extension and flexion muscle deficits and operated knee extension/flexion ratio, IPAQ-total, TAS and TSKQ scores ($p > 0.05$) (Table 4).

When grouped according to physical activity level and kinesophobia scores, the decreased in the cartilage thickness in the operated knee was not statistically significant among those with high and moderate levels of physical activity and among the groups with high and low kinesophobia scores. And there was no correlation between the decreased in cartilage thickness in the operated knee and physical activity level and kinesophobia scores within the groups (Table 5).

Discussion

In this study, first, we evaluated the changes in the distal femoral cartilage thickness in patients that had undergone ACLR and analyzed their association with concomitant meniscal surgery, knee muscle strength, kinesophobia, and physical activity level. To prevent or slow down the development of OA after ACL injury, it is very important to determine the risk factors before advanced disease develops [19]. Our study findings showed that the individuals that undergone ACLR and concomitant meniscal surgery had a thinner femoral cartilage in the operated knee than in the healthy knee. Furthermore, the isokinetic knee extension–flexion

Table 3 PT values of the extensor and flexor muscles of the operated and healthy knees according to surgery groups

Group	Knee extensors PT (N/m)			Knee flexors PT (N/m)		
	Healthy knee	Operated knee	*p	Healthy knee	Operated knee	*p
ACLR	225.13 ± 41.68	212.27 ± 38.92	0.070	119.33 ± 31.62	109.87 ± 26.29	0.090
ACLR&M	242.81 ± 34.43	215.06 ± 44.88	**0.040**	134.75 ± 20.89	130.56 ± 32.89	0.601
ACLR&MR	205.37 ± 57.13	179.0 ± 47.89	0.090	116.13 ± 29.49	101.75 ± 24.07	**0.015**
TOTAL	224.43 ± 47.15	201.89 ± 46.30	**0.002**	123.49 ± 28.26	114.15 ± 30.09	**0.012**

Data are expressed as mean ± SD

Statistically significant differences are marked in bold

PT peak torque, *ACLR* Anterior cruciate ligament reconstruction, *ACLR&M* Anterior cruciate ligament reconstruction with meniscectomy, *ACLR&MR* Anterior cruciate ligament and meniscus reconstruction

*Paired samples *t* test, statistically significant at $p < 0.05$

Table 4 Correlation between decreased cartilage thickness and investigated variables

	ICCT		LCCT		MCCT	
	r	*p**	*r*	*p**	*r*	*p**
Age	0.017	0.911	0.096	0.521	− 0.098	0.510
Body mass index	− 0.051	0.733	− 0.047	0.752	− 0.177	0.233
Preoperative symptom duration	− 0.029	0.845	− 0.105	0.481	− 0.203	0.170
Postoperative symptom duration	0.110	0.461	0.037	0.803	0.037	0.803
Operated knee extension muscle peak torque	− 0.233	0.114	− 0.011	0.943	0.022	0.881
Operated knee flexion muscle peak torque	− 0.049	0.742	0.065	0.665	0.063	0.672
Knee extension muscle strength deficit	0.155	0.297	0.045	0.761	0.141	0.343
Knee flexion muscle strength deficit	0.154	0.301	0.094	0.531	0.164	0.269
Extension–flexion muscle strength ratio of the operated knee	− 0.222	0.134	− 0.182	0.22	− 0.202	0.173
Tegner Activity Scale score	− 0.025	0.866	− 0.041	0.783	0.169	0.255
IPAQ total score	− 0.259	0.079	− 0.084	0.576	− 0.126	0.397
Tampa Scale Score	0.161	0.281	0.073	0.627	0.111	0.457

ICCT intercondylar cartilage thickness, *LCCT* lateral condylar cartilage thickness, *MCCT* medial condylar cartilage thickness, *IPAQ* International Physical Activity Questionnaire

*Pearson's correlation analyses; *r* correlation coefficient; statistically significant at $p < 0.05$

Table 5 Comparison and correlation between femoral cartilage thickness decrease and physical activity and kinesiophobia level in groups

	Femoral cartilage thickness decrease, mm					
	Intercondylar		Lateral condylar		Medial condylar	
	r	**p*	*r*	**p*	*r*	**p*
High Physical Activity Level ($n=32$)	− 0.187	0.304	0.031	0.867	0.022	0.907
Moderate Physical Activity Level ($n=15$)	− 0.348	0.204	− 0.151	0.590	− 0.192	0.494
High Tampa Scale Score ($n=16$)	− 0.255	0.340	− 0.079	0.772	− 0.068	0.803
Low Tampa Scale Score ($n=31$)	0.176	0.344	0.164	0.379	0.020	0.917
High Physical Activity Level ($n=32$)	0.19 ± 0.63		0.33 ± 0.61		0.32 ± 0.53	
Moderate Physical Activity Level ($n=15$)	0.45 ± 0.64		0.47 ± 0.66		0.42 ± 0.58	
***p*	0.195		0.484		0.571	
High Tampa Scale Score ($n=16$)	0.36 ± 0.48		0.41 ± 0.67		0.43 ± 0.62	
Low Tampa Scale Score ($n=31$)	0.23 ± 0.70		0.35 ± 0.61		0.31 ± 0.51	
***p*	0.510		0.792		0.487	

Data are expressed as mean ± SD

n number of patients, *mm* millimetre

*Pearson's correlation analyses; *r* correlation coefficient

**Paired samples *t* test, Statistically significant at $p < 0.05$

muscle strength on the operated side was less than that of the healthy side in this patient group.

US and magnetic resonance imaging (MRI) are valid and reliable imaging modalities for assessing femoral cartilage thickness. The advantages of MRI include excellent soft tissue contrast, high-resolution imaging, and multiplanar imaging capabilities. However, MRI is expensive, time-consuming and not widely available for routine use. In this study, we assessed distal femoral cartilage thickness with US which is an accurate, inexpensive, readily accepted by patients, and noninvasive method [20].

After ACL injury and reconstruction, aberrant joint loading and alterations in joint metabolism occur. As a result, it is considered that knee-joint tissue homeostasis is impaired, leading to a decline in articular cartilage health and the possible development of OA [2]. The risk factors for the development of OA after ACLR include demographic features (advanced age at the time of injury and reconstruction, and high BMI), concomitant meniscal or articular cartilage damage at the time of injury, preoperative symptom duration, choice of graft and surgical technique, and quadriceps weakness [5, 11, 19, 21].

Age and high BMI have been indicated as demographic risk factors for the development of OA after ACLR [21]. In individuals with ACLR, every 10 years of age is proposed as a significant predictor of OA development with an OR of 1.7 and every increment of BMI is reported to be associated with an OR of 1.2 risk for OA progression [22]. In our study, there was no significant correlation between decreased cartilage thickness and age and BMI. This may be because the study population was under the age of 40 years and only one person was obese (BMI > 30 kg/m^2).

Concomitant meniscal injury elevates the prevalence of OA development by two to four times compared to knees with isolated ACL injury [1]. Increased joint contact stress and impaired stability have been found responsible for the increased prevalence of OA [23]. Wang et al. investigated the cartilage morphology among individuals who had undergone ACLR with or without concomitant meniscal injury and healthy controls using MRI, and found more cartilage defects and smaller cartilage volume in the ACLR group with and without simultaneous meniscus injury compared to the healthy individuals. The authors also showed more cartilage defects in the concomitant meniscal injury group than in the isolated ACLR group [1]. These findings suggest that having a meniscus injury accompanying an ACL injury may cause an earlier development of OA and is an important factor that increases the risk of OA in the long term. Early reconstruction provides early stability preventing secondary meniscus injury and returning to active life in a shorter time. A longer interval from injury to reconstruction increases both the risk of OA development and its grade [24]. A previous study that investigated the relationship between reconstruction time and OA in patients that had undergone ACLR found the risk of OA to be six times greater in those who had early surgery (< 1 year after injury) than those who had late surgery (≥ 1 year after injury) [25]. In our study, there was no significant correlation between decreased cartilage thickness and preoperative symptom duration. A possible explanation may be the mean preoperative symptom duration of our patients being too short (2.55 months) for observing the OA development.

Maximizing quadriceps strength with a good rehabilitation program following ACLR is critical to achieving pre-injury physical activity [26]. Weakened eccentric quadriceps muscle strength may lead to biomechanical distortions incorporating more extended knee angles during the initial stance phase of gait when impact loading is highest. This biomechanical change can alter the distribution of compressive loading within the knee joint during the stance phase of gait and may cause abnormal load on the articular cartilage [27]. In a study conducted with 27 patients that had undergone ACLR, joint cartilage was evaluated based on T1ρ MRI relaxation times, and isometric quadriceps strength was assessed using an isokinetic dynamometer during a 6-month follow-up, the authors concluded that maximizing quadriceps strength was critical in maintaining cartilage health following ACLR [26]. In our study, the isokinetic knee extension and flexion muscle strength of the operated side was weaker than that of the healthy side in patients that had undergone ACRL and concomitant meniscal surgery. However, there was no significant correlation between decreased cartilage thickness and isokinetic knee extension and flexion muscle strength or the strength deficits of the operated knee. This might be related to the number of our sample size being too small to determine any significant correlation with these parameters.

The effects of physical activity and specific exercises on the prevention of OA of the lower limbs are well known. Kinesiophobia is associated with the loss of function and decreased physical activity in patients following ACLR [7]. High fear of movement or reinjury after ACLR is also negatively associated with the knee-related quality of life after surgery [28]. Tengman et al. analyzed the relationship between the physical activity level and kinesiophobia in patients with ACL injury and reported a negative relationship between fear of movement-re-injury and knee function [8]. In the current study, although the IPAQ, TAS and TAMPA scores did not significantly differ between the groups, there was a significant decrease in the distal femoral cartilage thickness of all three regions in the ACLR&MR group; thus, increased knee-specific physical activity could be effective in preventing the development of knee OA.

This study has certain limitations. First, we measured the femoral cartilage thickness from three regions using US, but it may have been better to also measure the cross-sectional area. Second, we did not have a healthy control group, and our sample size was very small. Therefore, we were not able to perform a regression analysis to identify the risk factors of OA after ACLR.

In conclusion, we found a significant decrease in the femoral cartilage thickness in patients that had undergone ACLR and concomitant meniscal surgery, suggesting the development of OA after ACLR. US in an easily accessible imaging technique to follow the development of OA after ACLR. All patients should be evaluated according to the risk factors to determine appropriate prevention methods. In the current study, meniscus injury accompanying ACLR was the most affecting factor of decreased femoral cartilage thickness. Therefore, patients should be included in a preoperative rehabilitation program before planning surgery. In addition, patients should be encouraged to increase their physical activity and minimize kinesiophobia level. Further studies that examine the cartilage thickness at regular intervals before and after ACLR are needed to identify the possible risk factors for the OA development. Follow-up US examinations offer a new possibility in monitoring the course of degenerative joint disease in these patients.

Author contributions AÜ: conception and design of the study, analysisand interpretation of data, drafting the article, and approval of the finalversion. ST: acquisition of data and drafting the article.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict ofinterest

Ethical standard statement Ethical consent was obtained from the Local EthicsCommittee of Istanbul Medipol University (Date: 8 November- 2019,number:10840098-604.01.01-E.60984).

Animal/human rights statement All procedures in the study thatinvolved human participants were performed in accordance with theethical standards of the institutional and/or national research committeeand with the 1964 Helsinki declaration and its later amendments orcomparable ethical standards.

Informed consent Informed consent was obtained from all individualparticipants included in the study.

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