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Ultrasonographic assessment of knee joint in patients with diabetes mellitus: comparison of sonographic changes in distal femoral cartilage and tendon structures with non-diabetics patients

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Abstract. – OBJECTIVE: The aim of this study was to evaluate the adverse effects of diabetes mellitus on the knee joint by using ultrasonography.

PATIENTS AND METHODS: One hundred and two subjects with diabetes for 5 years and more were compared prospectively with 93 age and sex-matched healthy subjects. Individuals in both groups were aged between 40-55, had a body mass index below 30 kg/m², and had no knee joint complaints. Femoral cartilage thickness, cartilage surface, quadriceps and patellar tendon thickness in both knees were assessed by ultrasonography using a 5-12 mHz linear transducer.

RESULTS: According to ultrasonographic findings, thin and irregular femoral cartilage was more common in diabetic patients than in healthy controls ($p<0.05$). Diabetic patients had thinner quadriceps tendons compared to the control group ($p<0.001$). No statistically significant difference was recorded in patellar tendon thickness (right knee $p=0.697$, left knee $p=0.639$). The presence of effusion in the suprapatellar recess of the right knee was more common in diabetics than non-diabetics ($p=0.006$).

CONCLUSIONS: Irregularity and thinning of the distal femoral cartilage in diabetics may indicate cartilage degeneration. In addition, the decrease in the thickness of the quadriceps tendon may lead to instability and adversely affect the knee joint. These sonographic findings may indicate early knee joint degeneration, so ultrasonography may help determine the possible risk of osteoarthritis in diabetic patients.

Key Words:
Diabetes, Ultrasonography, Knee joint, Cartilage, Tendon.

Introduction

Diabetes mellitus (DM) is a systemic metabolic disorder characterized by persistent hyperglycemia[1,2]. It has many complications like nephropathy, retinopathy, neuropathy, and articular tissue changes secondary to the factors such as microangiopathy, neural loss, and weight[2]. Because of these complications, it requires lifelong follow-up and treatment.

Most diabetic patients have some form of arthritis[3]. Peripheral neuropathy leads to muscle weakness and joint laxity. In addition, hyperglycemia causes microvascular damage, and glycosylation end products accumulate at the tendon-bone interface, so induces changes in cartilage and tendons[3]. Retraction in musculotendinous unit and stiffness in articular connective tissues occur. Cartilage degeneration, chondrocyte dysfunction, and subchondral bone destruction accelerate[4,5]. Osteoarthritis (OA) and DM are frequently associated diseases[6]. DM has adverse effects on the repair of tendons and articular cartilage and hemostasis; therefore, it may induce the formation and development of OA and reduce the response to OA treatment[6].

The detection of early cartilage damage is necessary for the treatment of reversible changes; so, imaging modalities are mainly used in diabetic patients. In previous studies[7-11], cartilage composition, and cartilage changes were investigated using magnetic resonance imaging (MRI), and tendon structures of the knee joint were evaluated with ultrasonography (US) in diabetic patients. US is a widespread, radiation-free imaging modality, easy to perform and low-cost compared to MRI. Also, patients are more compliant during US examinations.

The aim of this study was to investigate the effects of DM on the asymptomatic knee joint, to reveal the changes in cartilage and tendon structures, and to determine whether diabetes increases knee joint changes compared to nondiabetic individuals by using the US.

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Patients and Methods

Study Population

Between 2019 and 2022, patients with DM for five years and more were referred to the Radiology Department from the Endocrinology Department. The study design was prospective. The study was conducted according to the Declaration of Helsinki guidelines and was approved by the Local Institutional Ethics Committee. Informed consent was obtained from all individuals included in the study. To rule out age-related knee joint findings, participants in both diabetes and control groups were between the ages of 40-55.

In the diabetic patient group, inclusion criteria were (a) diagnosis of DM for five years and more, (b) aged between 40-55 years, (c) body mass index (BMI) less than 30 kg/m^2; exclusion criteria were (a) symptomatic knee joint, knee trauma-surgery or inflammation, (b) history of rheumatological disease, (c) osteophyte detection during ultrasonography, (d) smokers (Figure 1).

In the nondiabetic control group, inclusion criteria were (a) no known history of DM, (b) aged between 40-55 years, (c) BMI less than 30 kg/m^2; exclusion criteria were (a) symptomatic knee joint, knee trauma-surgery or inflammation, (b) the participants who had a first-degree relative with diabetes, (c) history of rheumatological disease, (d) osteophyte detection during ultrasonography, (e) smokers (Figure 2).

The endocrinologist referred 109 diabetic individuals and 95 healthy individuals who met the eligibility requirements to the Radiology Department for ultrasonographic evaluation. Nine of all individuals were excluded because of osteophyte detection during ultrasonography by the radiologist. Finally, 102 patients with DM and 93 healthy volunteers (control group) were included in the study. Sonographic findings of a total of 390 knee joints were evaluated.

US Protocol

US of each participant's bilateral knee joints was performed with a linear transducer (5-12

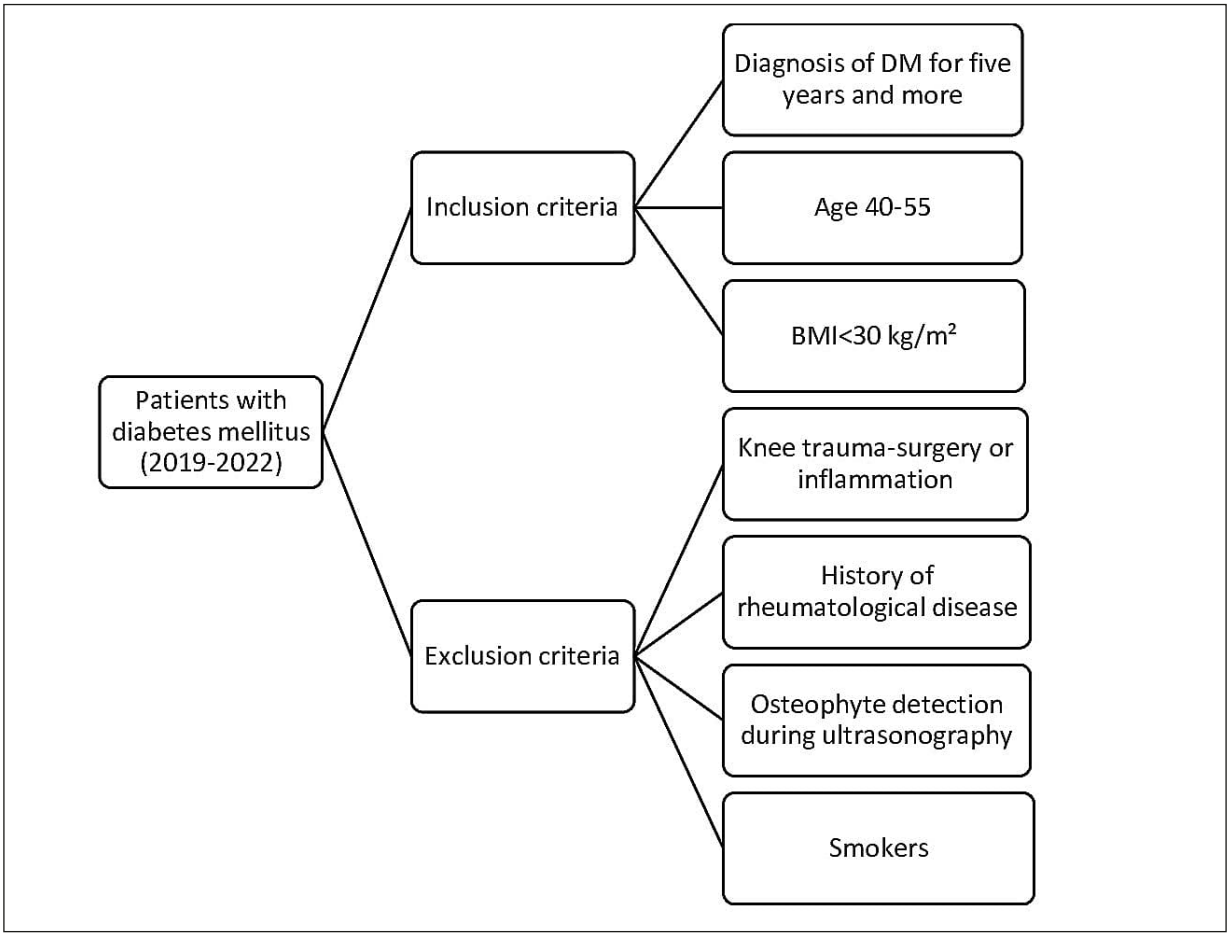

Figure 1. Inclusion and exclusion criteria in the diabetic patient group.

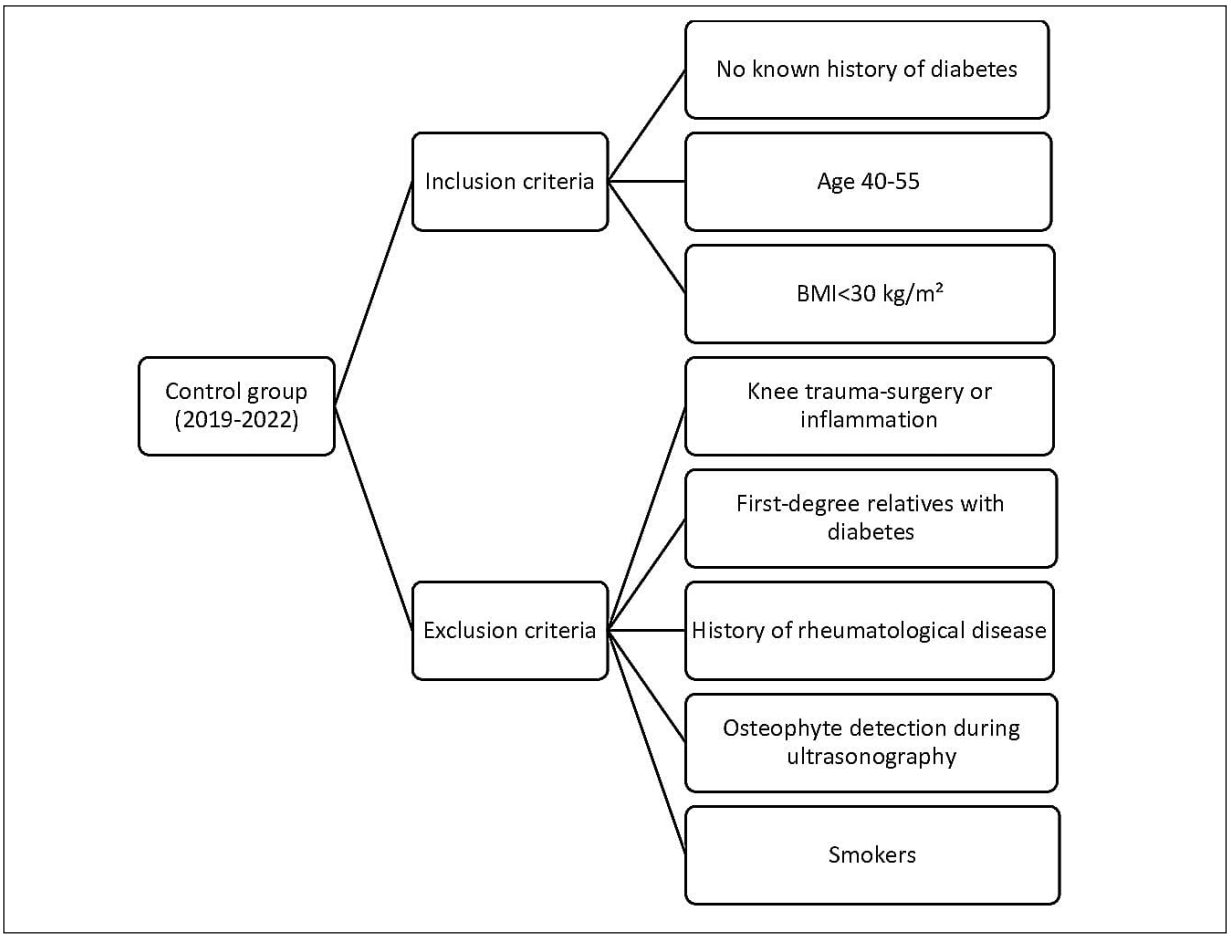

Figure 2. Inclusion and exclusion criteria in the nondiabetic control group.

mHz Philips Affiniti 70G, Phillips Healthcare, Amsterdam, the Netherlands) by the same physician. The physician was a 10-year experienced radiologist and was blind to whether the participant was in the diabetic group or the healthy group. US was performed with the participant in the supine position, the knee flexed approximately 20-30 degrees and was supported with a pillow. In this position, suprapatellar effusion, quadriceps tendon, and patellar tendon were evaluated. For suprapatellar recess, the transducer was positioned longitudinally above the patella. The effusion was considered positive when it was 5 mm or more. The thickness of the tendons was measured when the transducer was parallel to the longitudinal axis of the tendons. Anteroposterior thickness was measured at three points (proximal, central, distal) for each tendon in each knee. And the mean values were noted.

Distal femoral cartilage thickness was measured. When the individuals were in the supine position with their knees at maximum flexion, the transducer was placed axially on the suprapatellar region. Measurements were taken from the medial femoral condyle (MFC), intercondylar area (ICA), and lateral femoral condyle (LFC) midpoints for each knee. For cartilage thickness, the distance between the hyperechoic line at the synovial border and the hyperechoic line at the bone border was measured[12,13] (Figure 3). The cartilage surface was evaluated by ultrasonography. If the cartilage border was unclear and serrated, and the thin hyperechoic line at the synovial border was distorted, it was defined as irregular; if the cartilage border was clear, and the thin hyperechoic line at the synovial border was sharply edged, it was termed smooth (Figure 4).

Statistical Analysis

Statistical analysis was performed using SPSS 26.0 (IBM Corp., Armonk, NY, USA) software. The normality of the distribution of data was

assessed with the Kolmogorov-Smirnov test. Descriptive statistics of continuous variables were reported using mean±standard deviation (SD) together with median (min-max) depending on the data distribution. Categorical variables were presented as numbers (n) and percentages (%). In the comparison of numerical variables between two independent groups, *t*-test (student's *t*-test) was used for normally distributed data, and Mann-Whitney U test was used for data not normally distributed. Ratio comparisons between categorical variables were done using the Chi-square test. The statistical significance was set at the $p<0.05$ level.

Results

Ultrasonographic findings of 195 individuals (102 diabetic patients, 93 nondiabetic participants) who met the inclusion criteria were evaluated. Demographic characteristics are illustrated in Table I. The mean age was 48.13±3.87 in the diabetic group and 48.12±3.01 in the control group. Gender distribution was 72 females-30 males in the diabetic group and 71 females-22 males in the control group. The mean BMI (kg/m^2) was 26.93±1.45 in the diabetic group and 26.59±2.23 in the control group. Gender ratios, BMI values, and mean age were statistically similarly distributed between the two groups ($p>0.05$). Two hundred and four knee joints in the diabetic and 186 knee joints in the nondiabetic group were evaluated with US.

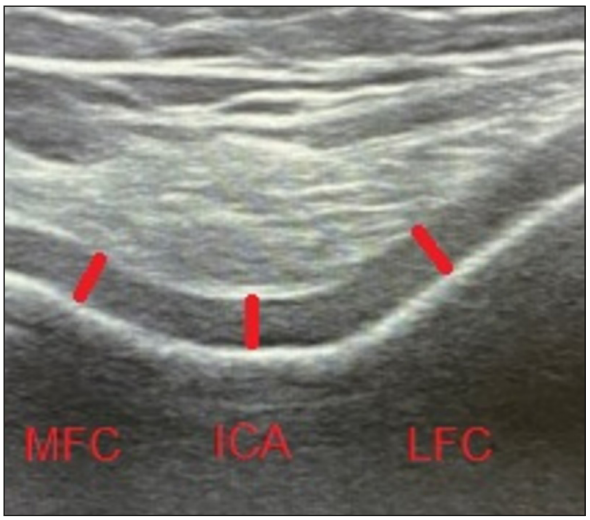

Figure 3. Ultrasonographic appearance of left knee femoral cartilage with normal thickness and smooth surface, from 45 years old female nondiabetic. (MFC: medial femoral condyle, ICA: intercondylar area, LFC: lateral femoral condyle).

US Findings

Mean femoral cartilage thickness, cartilage surface, quadriceps, and patellar tendon thickness, the presence of suprapatellar effusion are presented in Table II. Femoral cartilage thickness in LFC, ICA, and MFC of both knees was

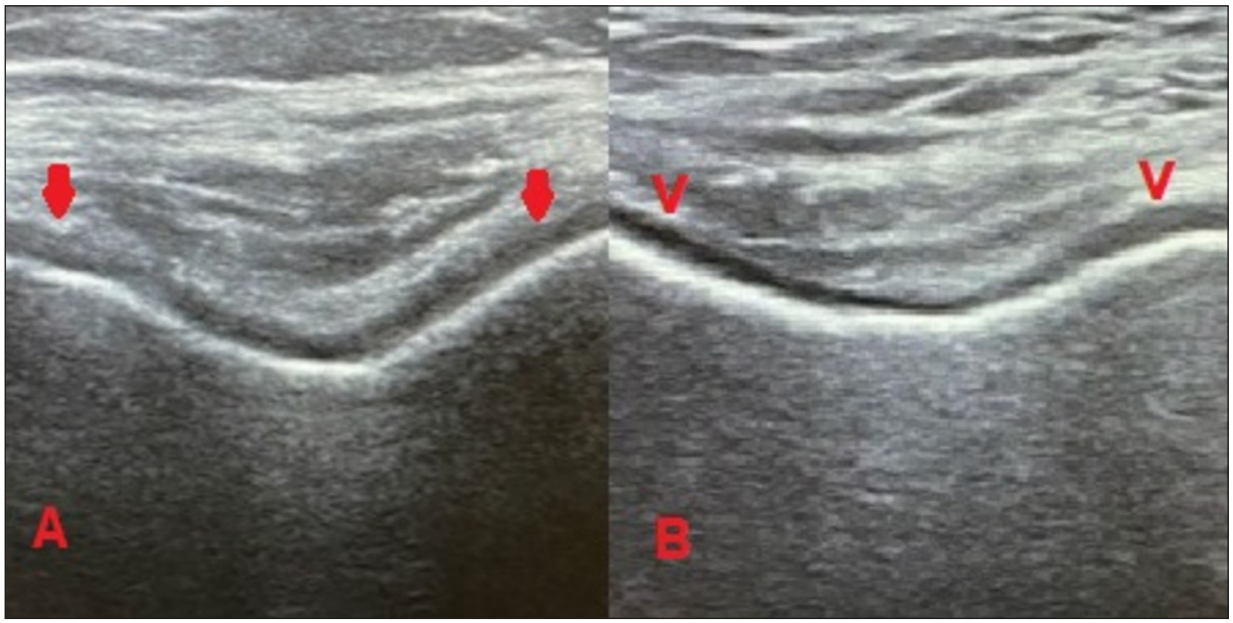

Figure 4. Ultrasonographic images of knee cartilage in diabetics. **A**, Thin cartilage with an irregular surface in a 42-year-old male diabetic (arrows). **B**, Thin cartilage with a smooth surface in a 47-year-old female diabetic (arrowheads).

Table I. Participant demographics, mean±SD.

	Diabetics (n=102)	Diabetes-free controls (n=93)	*p*-values
Age (years)	48.13±3.87	48.12±3.01	0.556
Female [n (%)]	72 (70.6%)	71 (76.3%)	0.364
Male [n (%)]	30 (29.4%)	22 (23.7%)	0.364
BMI (kg/m^2)	26.93±1.45	26.59±2.23	0.636

(BMI: Body mass index, n: number, SD: Standard deviation).

significantly thinner in the diabetic group than in the nondiabetic group (p<0.05). The femoral cartilage surface of both knees was significantly irregular in diabetic patients compared to the control group (p<0.001). The presence of suprapatellar effusion in the right knee was more common in participants with DM than in those without DM (right knee p=0.006, left knee p=0.109). Quadriceps and patellar tendon thicknesses were measured. Compared with the control group, diabetic patients had thinner quadriceps tendons in both knees (p<0.001) (Figure 5). Patellar tendon thickness did not differ between diabetics and nondiabetic subjects (right knee p=0.697, left knee p=0.639).

Discussion

In this study, the knee joint was evaluated in diabetic patients with US, which is a low-cost, reliable, and useful imaging method in evaluating the musculoskeletal system. In the literature, there are some studies[12-15] evaluating the femoral cartilage thickness with ultrasonography in various diseases. We think that it is one of the few studies in the literature using the US on the effects of diabetes on the knee joint. The primary finding of our study was the difference in femoral cartilage thickness between diabetic individuals and the control group. The distal femoral cartilage thickness in diabetic patients was statistically thinner in both the left and right knees compared to the control group. In addition, the femoral cartilage surface of both knees was significantly more irregular in diabetics than in nondiabetics. Bedewi et al[16] measured the mean femoral cartilage thickness with US, and unlike our study, they revealed no significant statistical difference between patients with DM and healthy subjects; however, their patient group and the control group did not match in terms of age, BMI, and gender; also, their sample size was relatively small (34 diabetic patients, 36 healthy individuals). In our study, the sample size was larger in both diabetes and control groups, and there was no significant difference between the two groups in terms of demographic characteristics (age, gender, BMI). We think that these factors increase the reliability of our results.

In diabetes mellitus, hyperglycemia causes microvascular damage and glycosylation of proteins in multiple organ systems. Advanced glycosylation end products (AGEs) have a central role in the inflammatory and degenerative process in OA[17]. The most extensive accumulation of AGEs occurs in tissues containing collagen-like proteins such

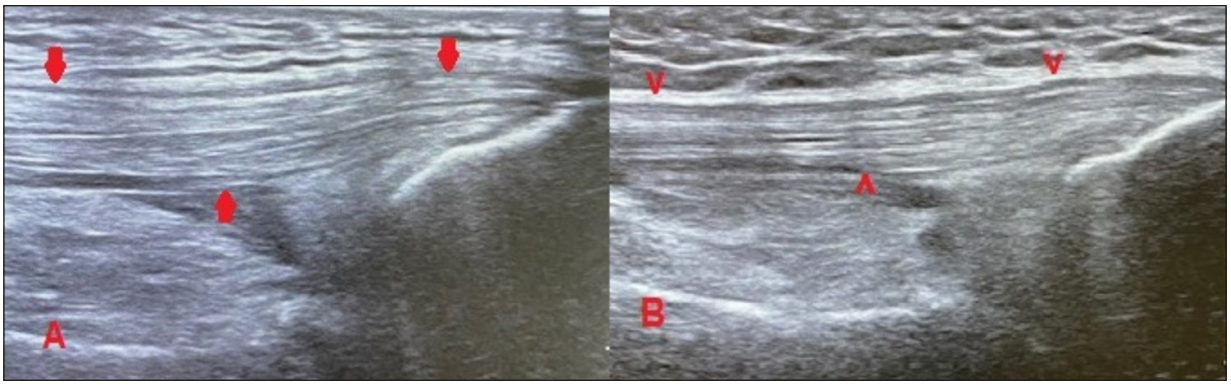

Figure 5. Ultrasonographic images of quadriceps tendon thickness, sonographic view of the longitudinal axis. **A**, 45-year-old male nondiabetic, quadriceps tendon with a normal thickness (arrows). **B**, 46-year-old male diabetic, thin quadriceps tendon (arrowheads).

Table II. Comparison of knee joint ultrasonographic findings between the diabetics and nondiabetic group.

	Diabetics (n=102)	Diabetes-free controls (n=93)	*p*-values
Femoral Cartilage Thickness			
Right			
LFC	1.74±0.32	1.95±0.35	<0.001
ICA	1.81±0.33	1.95±0.31	0.004
MFC	1.88±0.31	2.13±0.35	<0.001
Left			
LFC	1.81±0.28	1.98±0.34	<0.001
ICA	1.82±0.32	1.98±0.29	<0.001
MFC	1.88±0.3	2.04±0.34	0.001
Femoral Cartilage Surface			
Right			
Smooth	39 (38.2%)	74 (79.6%)	<0.001
Irregular	63 (61.8%)	19 (20.4%)	<0.001
Left			
Smooth	40 (39.2%)	72 (77.4%)	<0.001
Irregular	62 (60.8%)	21 (22.6%)	<0.001
Suprapatellar Effusion			
Right			
Yes	55 (53.9%)	32 (34.4%)	0.006
No	47 (46.1%)	61 (65.6%)	
Left			
Yes	50 (49.0%)	35 (37.6%)	0.109
No	52 (51.0%)	58 (62.4%)	
QT thickness			
Right	5.99±0.79	6.50±0.80	<0.001
Left	5.80±0.82	6.48±0.71	<0.001
PT thickness			
Right	3.58±0.59	3.57±0.57	0.697
Left	3.57±0.54	3.60±0.54	0.639

(ICA: intercondylar area, LFC: lateral femoral condyle, MFC: medial femoral condyle, PT: patellar tendon, QT: quadriceps tendon).

as cartilage, bone, and tendons. Tissues that accumulate AGEs become weaker[10]. In some MRI studies[8,9] in the literature, increased cartilage lesions were reported in the knee joint, and significantly higher cartilage T2 values were detected in the patella and medial femoral condyle, indicating cartilage degeneration in diabetic patients. Chanchek et al[8] studied diabetic individuals up to 79 years of age with symptomatic knee OA and evaluated the MRI-based T2 relaxation time of the knee cartilage. They found higher cartilage T2 values in the medial femur and patella, indicating increased articular cartilage degeneration in diabetics[8]. In our study, the individuals were up to 55 years of age and had no knee OA symptoms. However, supporting the study of Chanchek et al[8], distal femoral cartilage thickness was thinner in diabetics than the control group, probably as an indicator of cartilage degeneration. Neumann et al[9], in their MRI-based study, found that in diabetic patients, cartilage changes, especially in the patella and femur, were significantly greater than in the control group; further, changes for ligaments or effusion were not significantly different between the two groups. Our sonographic findings regarding femoral cartilage changes in diabetic patients are supported by other knee MRI studies[8,9] in the literature. Our assumption is that hyperglycemia induces changes in cartilage composition, and thin-irregular cartilage indicates increased cartilage degeneration in diabetics. Therefore, symptomatic knee joint abnormalities in the diabetic population may occur in later years as a complication of the disease. In fact, recent studies[6,17] have demonstrated that DM may adversely affect articular cartilage regeneration and cause osteoarthritis.

In the present study, the presence of effusion in the right suprapatellar recess and thinning of quadriceps tendon were statistically significant in diabetics compared to the control group. However, we did not find a statistical difference in patellar

tendon thickness. Thinning of the quadriceps tendon can adversely affect joint function and the strength of the joint structure. There are few studies[10,11] in the literature evaluating the quadriceps and patellar tendon with US or MRI in the diabetic population. Altinel et al[11] evaluated quadriceps and patellar tendon with US and MRI in the diabetic population, and no significant difference was found between the diabetic and control groups. Abate et al[10] reported degenerative changes in Achille and patellar tendons in diabetic patients, but they could not find a statistical difference in patellar tendons between diabetic and control groups. As far as we could evaluate, there was no data in the literature to support our findings regarding the decrease in quadriceps tendon thickness.

Limitations

The relatively small number of participants is the main limitation of the study. However, we think that it will be a guide for future studies in which treatment and laboratory records of patients with diabetes are included, and the number of participants is higher.

Conclusions

As a result of this study, it may be possible to detect changes in cartilage and tendon structure by routine sonographic evaluation of the knees of diabetic patients. Ultrasonographic imaging of the knee joint in patients with diabetes can be standardized, and its reproducibility improved. Thus, possible physical or medical treatment methods can be applied to prevent the side effects of diabetes on the knee joint.

Ethics Approval

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Hitit University Faculty of Medicine Clinical Research Ethics Committee (number of approval: 151).

Informed Consent

Informed consent from patients that participated in the study was obtained in accordance with the Local Ethical Committee recommendations.

Availability of Data and Materials

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Conflict of Interest

We declare that we have no conflict of interest.

Funding

No funding was obtained for this study.

Authors' Contributions

All authors contributed to the study conception and design, analysis and interpretation of data. The first draft of the manuscript was written by Zeynep Banu Aydın and Derya Köseoğlu. All authors commented on previous versions of the manuscript. All authors read and approved the final manuscript, and they agreed to make critical revisions related to the content of the manuscript and approved the final version of the article to be published.

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