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Corneal aberrations are associated with low-energy meniscus injuries

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Abstract

Background Visual impairment can cause balance problems. Therefore, visual impairment caused by an increase in corneal deviations can lead to sudden and unstable loads in the lower extremities. We aimed to investigate the possible relationship between low-energy meniscal injuries and corneal structural measures.

Methods This prospective, observational study included individuals aged between 18–40 years with a normal body-mass index. The study group consisted of 54 patients with grade 2 or 3 meniscus injuries after low-energy activity. The control group consisted of 54 healthy individuals without any complaints in the knee joint. The corneal parameters of all participants were evaluated with a Scheimpflug corneal topography and specular microscopy device. Simulated keratometry (SimK), minimum central corneal thickness (MCCT), cylindrical diopter (ClyD), corneal volume (CVol) spheric aberrations (SphAbb), high-order aberration (HOA), coma values, and endothelial parameters were recorded.

Results The research and control groups were similar in terms of age, body mass index, and gender distribution. There was no significant difference between the groups in the corneal SimK and CylD, parameters. However, HOA, Coma, SphAbb, and cell variability (Cv) values were significantly higher in the study group, and contrarily MCCT, CVol, and endothelial count (Cd) values were significantly lower.

Conclusions Our findings suggest that individuals with relatively lower MCCT values tend to develop meniscal damage after low-energy activity. Hence, the loss of corneal strength in these patients may be a sign of possible weakness in the meniscus. The HOA value above 0.26, the coma value above 0.16, and the SphAbb value above 0.1 may significantly increase the possible meniscus injury.

Keywords Meniscal tear, Corneal topography, Corneal aberrations, Collagen, Risk factor

Background

The cornea is a transparent, avascular tissue as the outermost part of the eye and creates the strongest refractive environment for the rays to fall on the fovea. The scattered hexagonal arrangement of Type 1 and 5 collagens, mainly found in the stroma of the cornea, provides corneal transparency. Collagen metabolism disorders form the basis of several corneal diseases such as keratoconus, pellucid marginal degeneration, and hereditary corneal dystrophies [1, 2]. Consequently, the corneal aberration, endothelial cell count and refractive properties of the cornea are altered in these diseases [3, 4].

Ninety-percent of the collagen in the meniscus structure is type 1 collagen, followed by type 2 and a lesser amount of type 3, 5 and 6 collagens [5]. The meniscuses carry, transmit and provide shock absorption at the knee joint [6–8]. The formation of meniscus tears are classified as traumatic and degenerative causes. The traumatic tears are mostly observed in young and active people, wheras

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the latter is a commonly a matter of elderly patients. Although traumatic tears occur usually after contact sports such as football and basketball, low-contact sports such as swimming, running and even walking and squatting may cause these tears [9, 10].

Due to the variability of the cornea, pupil and intraocular lens structures, different light aberrations (deviation) occur while the light beam enters the eye. Since the cornea is not a completely perfect sphere, the rays coming from the periphery are not refracted as much as the rays coming from the center. This may cause blurry images at the edges. This is called spherical aberration. Coma is a type of aberration produced by the lens because of the large number of parallel rays coming obliquely to the lens surface and the high-order ocular aberrations (HOA) is used as an expression of higher order aberrations. Coma, spherical aberrations, and HOA are refractive aberrations that reduce the vision of healthy eyes below retinal limits.

Previous studies revealed that distal femoral cartilage thickness was thinner in patients with keratoconus due to structural similarities between the cornea and knee joint tissues, particularly via collagen [11]. This may indicate the simultaneous structural changes of the cornea and the articular cartilage. However, the relationship between meniscal injuries and structural changes of the cornea has not been evaluated so far.

Our hypothesis is that individuals with visual impairment due to corneal problems may have more meniscus injuries without high-energy trauma. Due to visual impairments, balance issues can arise during activities such as walking, running, and climbing stairs [12]. This can cause sudden, uncontrolled stress on the knee joint. These repeated low-energy traumas may lead to injuries in the menisci. In this study, we compared the corneal parameters of young patients with meniscal injury after low-energy activity and healthy individuals. It was aimed to evaluate the possible relationship between the topographic and specular microscopic evaluation of the cornea and low-energy meniscal injury.

Methods

This prospective, observational study included patients diagnosed with stage 2–3 meniscus injury from 05/2022 to 11/2022 after low-energy activity in the Orthopedics and Traumatology clinic of a tertiary university hospital and healthy volunteers who were examined for other reasons in the same clinic as the control group.

Local ethics committee approval was obtained before the study and all participants signed the written informed consent. This study was conducted in accordance with the principles of the Declaration of Helsinki.

Magnetic resonance imaging (MRI) was performed in patients aged 18–40 years, with BMI 18.5–24.9, without previous knee and/or eye surgery, chronic autoimmune and/or systemic disease, uveitis, glaucoma, and topical/systemic drug use. Individuals with knee pain that started after a history of trauma and patients with concomitant ligament injury, advanced stage chondral injury, or advanced bone or soft tissue edema suggestive of trauma on MRI were excluded from the study. In addition, those with malalignment in the lower extremities, muscle atrophy, discoid meniscus, ligament laxity, pregnant and lactating individuals, and those with BMI values outside the normal range were also excluded. Besides, individuals over the age of 40 were excluded from the study to exclude degenerative meniscal tears. Volunteer-healthy individuals who did not have any complaints such as pain, snagging, locking, and/or swelling in the knee joint formed the control group.

Ophthalmologic examination

All participants underwent a routine ophthalmological examination including best spectacle-corrected visual acuity with Snellen chart, tonometry, anterior segment biomicroscopy, and fundoscopy. Afterward, the participants were evaluated with the Sirius Scheimpflug corneal topography (CSO, Italy) device. Simulated keratometry (SimK), minimum central corneal thickness (MCCT), cylindrical diopter (ClyD), corneal volume (CVol), spheric aberration (SphAbb), high-order ocular aberrations (HOA) and coma aberrations values were recorded. The corneal endothelial count (Cd) and, cell variance (Cv) values of the participants were evaluated with a non-contact specular microscope (Tomey EM-4000, Japan). Topographic values were analyzed according to the eye with the lowest MCCT, and specular microscopy values were determined in the same eye.

Orthopedic examination

The joint line tenderness, Mc Murray test, Apley test, and Ege test were examined in young patients with complaints such as pain, tripping or locking after low-energy activities (walking, squatting, climbing stairs, etc.) in the knee joint. If at least two of the tests were positive, the knee joint was imaged with MRI. Patients were evaluated with a 1.5 T clinical MR-sim scanner (Magnetom Aera, Siemens Healthineers, Erlangen, Germany) in the supine position and knee in full extension. T1 and T2 sequences of axial, coronal, and sagittal sections were recorded. Stage 2 (linear signal increase in the meniscus that does not reach the surface) and stage 3 (signal increase extending to the free edge of the meniscus) changes in the meniscus patients were recruited for the study.

Statistical analysis

The categorical variables are given as numbers/percentages. Continuous variables that provide normal distribution are given as mean ± SD, while variables that do not provide normal distribution are given as median (Min–Max). The Shapiro–Wilk test was applied to test normality. The chi-square test was used to compare categorical variables, and the Welch t-test was applied for continuous variables with normal distribution. Statistical significance was set as 0.05.

The ROC curve and the cut-off point of each marker were determined according to Youden's method and the area under the curve was calculated. The probability of being positive for the patient group compared to the healthy group was calculated. The SPSS Statistics for Windows version 22.0 (IBM Corp, Armonk, NY, USA) and R Studio 4.2.1 (R Foundation for Statistical Computing Vienna, Austria) versions were used for statistical analysis.

The sample size was calculated as the type I error (alpha) is 0.05, the power of the test is 95%, and the effect size is 0.6, the alternative hypothesis (H1) is two-sided. The minimum sample size required to find a significant difference using this test was 48 for each group.

Results

There were 54 participants in both groups. The demographic characteristics of the patients are shown in Table 1. There was no significant difference between the groups in terms of age and gender distribution. The right-meniscal injury was observed in 24 of the 54 patients and 30 on the left side. Medial meniscus injuries occurred in 34 patients (63%), the lateral meniscus was affected in 8 patients (15%), and the injury was bilateral in 12 patients (22%). Forty-four of the meniscus-injured patients (81%) had grade 2 injuries and 10 patients (19%) had grade 3 injuries. Higher-graded meniscal injuries were recorded for statistical analysis in patients with bilateral-meniscal injuries.

There was no significant difference between the groups simK and CylD parameters ($p > 0.05$). Whereas HOA, coma, SphAbb, and Cv values were significantly higher in the meniscal tear group compared to healthy controls. Contrarily MCCT, CVol, and Cd values were significantly lower. The topographic and specular microscopy data of the participants are shown in Table 2. The ROC analysis results of HOA, coma, and SphAbb values were calculated to determine meniscal injury predictions and the results are demonstrated in Table 3.

Table 1 Demographic distribution of participants

	Meniscus	Control	*p* value
Gender			
Male	26 (48.1%)	28 (51.9%)	0.70
Female	28 (51.9%)	26 (48.1%)	
Age (years)	32.44 ± 6.9	30.82 ± 6.54	0.260

Discussion

This study aimed to investigate the effect of corneal disorders on the development of meniscus damage after low-energy activity in patients aged between 18–40 years. The topographic and specular microscopic evaluation of the cornea was performed and compared with the healthy control group. Patients with meniscus injury revealed significantly higher mean HOA, coma, and Sphabb values and significantly lower mean SimK, Thickmin, CVol, and Cd values.

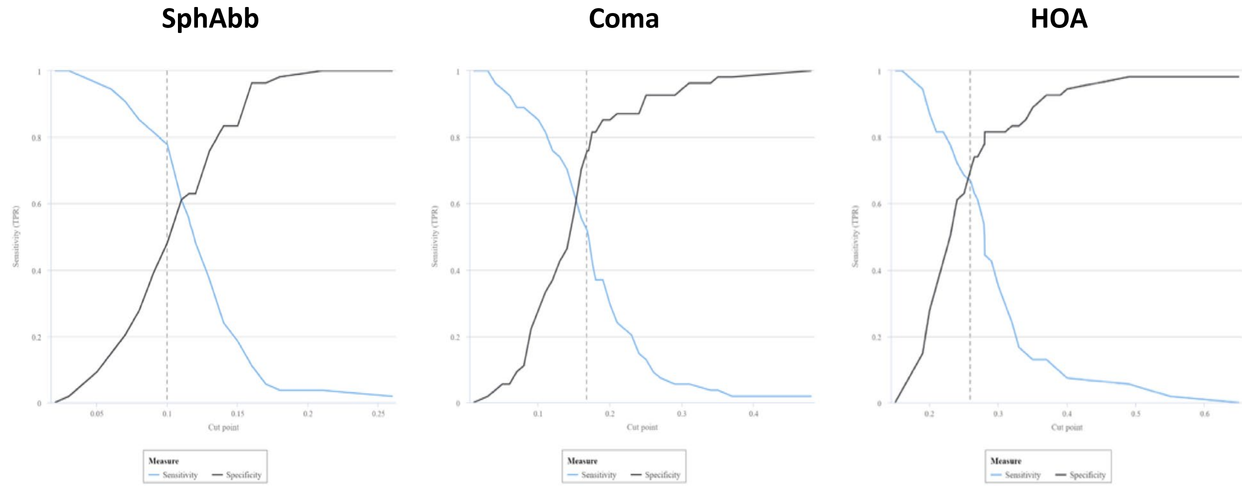
There is a significant amount of collagen in both cornea and meniscus structures, in particular, type 1 collagen [2, 13]. Lysyl oxidase (LOX) enzyme plays an important role in the synthesis of collagen [14, 15]. It was previously shown that there is a defect in the collagen structure and the LOX enzyme in keratoconus patients [16, 17] and that these patients have high aberrations [18, 19]. Moreover, keratocytes, which play a role in collagen synthesis and repair, increase IL-1 receptor expression in keratoconus patients, and a decrease in collagen synthesis occurs as a result of the increase in collagenase and metalloproteinase production [20]. It is inevitable that this decrease in collagen synthesis will adversely affect the durability of menisci containing high amounts of collagen. Nevertheless, collagen deficiency and irregularities in the microstructure of collagen also cause deterioration in the meniscus structure [13, 21]. The endogenous and/or exogenous LOX enzyme application supports the maturation of the collagen network and the improvement of

Table 2 Corneal topography and specular microscopy parameters of participants

	Meniscus	Control	Test statistics	*P* value
SimK	42.99 ± 1.32	43.42 ± 1.57	-2.2987	0.122
MCCT	528.07 ± 35.79	543.50 ± 33.38	-2.3170	**0.022**
CylD	-0.79 ± 0.44	-0.98 ± 0.61	1.9156	0.055
HOA	0.28 ± 0.08	0.24 ± 0.08	2.3669	**0.020**
Coma	0.17 ± 0.08	0.14 ± 0.07	1.846	**0.007**
SphAbb	0.11 ± 0.03	0.09 ± 0.03	1.43	**0.022**
CVol	57.63 ± 2.59	59.04 ± 3.29	-2.4748	**0.015**
Cd	2536.69 ± 179.42	2629.35 ± 234.36	-2.3071	**0.023**
Cv	40.6 ± 6.78	38.1 ± 5.10	2.1312	**0.035**

SimK simulated keratometry, *MCCT* minimum central corneal thickness, *CylD* cylindric diopter, *HOA* high-order aberrations, *SphAbb* spheric aberrations, *Cvol* corneal volume, *Cd* Endothelial count, *Cv* cell variance

Table 3 ROC-analysis of significant corneal ocular aberration values



Variable	AUC	SD	Minimum	Maximum	z value	*p* value
HOA	0.6754	0.0532	0.5786	0.7624	3.2943	**<0.001**
Coma	0.6298	0.0546	0.5315	0.7207	2.3787	**0.017**
SphAbb	0.6265	0.054	0.5282	0.7177	2.3413	**0.019**

AUC area under curve, *HOA* high-order ocular aberrations, *SphAbb* Spherical aberrations

its functional properties in musculoskeletal tissues [15]. In our study, the significant increase in corneal aberrations in individuals with low-grade meniscal injury may be the result of deficiencies in collagen synthesis and structure due to deficiency in LOX enzyme or IL-1 receptor expression.

Meniscal tear is quite common, and their incidence is 9.0 in men and 4.2 in women per 10,000 per year [22]. While meniscal tears occur because of various traumas, often sports injuries, in young patients, it is known that degenerative tears are more common after the age of 40 [23]. In order to exclude degenerative tears and the negative effects of advanced age on vision, we did not include patients over the age of 40 in our study. Visual impairment is closely related to balance problems [24]. Therefore, the visual impairment caused by the increase in corneal aberrations may cause sudden and unbalanced loads on the lower extremities, which may cause an increase in the load on the meniscus and result in ruptures. The data of this study revealed that the incidence of ≥ grade 2 damage to the meniscus significantly increases as the HOA value is above 0.26, as the coma value is above 0.16, and as the SphAbb value is above 0.1.

Central corneal thinning is observed in diseases such as myopia, keratoconus, and pellucid marginal degeneration, which are accompanied by increased corneal refraction [25, 26]. Lower corneal thickness values in individuals with low-grade meniscal damage may suggest the loss of corneal strength in these patients and might also be a marker of possible weakness in the meniscus. Liu et al. evaluated patients with Marfan Syndrome and reported that corneal thickness was significantly lower in these patients compared to healthy individuals [27]. Disruptions in systemic collagen synthesis can lead to thinning of the cornea, hence may also provide a clue about the knee meniscus health of individuals. Similarly, the endothelial number was significantly lower in individuals who developed meniscal damage after low-grade trauma. That might also be considered as a significant pre-marker to evaluate the knee meniscus. However, since there is no study in the current literature in this area, further studies are needed to reveal the relationship between the thickness of the corneal layers and meniscus strength.

There were some limitations of this study. Firstly, the number of patients was limited and secondly the MRI was performed for the diagnosis instead of arthroscopy, which is the gold standard for defining meniscal injuries. Further studies in patients that underwent partial meniscectomy may provide pathological meniscus samples to evaluate collagen sequences. Besides, evaluating these patients not only with topographic parameters but also with corneal confocal microscopy may help to better correlate ocular parameters with knee injury risk.

Conclusions

Although several risk factors for meniscal injuries were suggested in the current literature, corneal aberration disorder was presented as a risk factor for the first time in our study [28]. Also, evaluation of individuals under the age of 40 who developed meniscal damage after low-energy activity in Ophthalmology clinics might assist to define subtle corneal disorders in these patients. Likewise, raising awareness of patients with corneal collagen pathologies, such as keratoconus, about traumas that may occur due to low-energy activity may be protective against future meniscus injuries. Studies investigating the need for collagen supplementation in these patients may also provide more concrete data on this topic.

Abbreviations

SimK	Simulated keratometry
MCCT	Minimum central corneal thickness
ClyD	Cylindrical diopter
CVol	Corneal volume
SphAbb	Spheric aberrations
HOA	High-order aberration
Cv	Cell variability
Cd	Endothelial count
MRI	Magnetic resonance imaging
LOX	Lysyl oxidase

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None.

Authors' contributions
All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Rıfat Şahin and Mehmet Gökhan Aslan. The first draft of the manuscript was written by Rıfat Şahin and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated and/or analyzed during the current study are not publicly available as the informed consent does not include the public sharing of personal information but is available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study approval was granted by the Ethics Committee of the University Recep Tayyip Erdogan, Turkey (Date. April 14, 2022/ No. 2022/99).

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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