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Comparison of corneal topographic measurements and high order aberrations in keratoconus and normal eyes

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ABSTRACT

Purpose: The aim of this report was to compare corneal topographic measurements and anterior high order corneal aberrations in eyes with keratoconus and normal eyes by using Scheimpflug-Placido topography.

Methods: Eighty cases diagnosed with mild (group 1), moderate (group 2), and advanced (group 3) stage keratoconus (KC) according to Amsler-Krumeich Classification and 81 healthy (control group) cases were retrospectively examined. The mean keratometric measurements (as both diopters (K_{avg}) and mm values (mm_{avg})), central corneal thickness values (CCT), high order aberration (HOA), total wavefront aberration (TWA), coma, trefoil, and spherical aberration measurements were performed using Sirius topography equipment. The topographic values were compared between the groups.

Results: There were 25 cases in group 1 KC (15.5%), 34 cases in group 2 KC (21.1%), 21 cases in group 3 KC (13.1%), and 81 cases (50.3%) in the control group. In terms of mean age and gender distributions, there was no statistically significant difference between the groups ($p > 0.05$). However, there was significant difference between the groups in terms of K_{avg}, CCT, HOA, TWA, coma, trefoil, and spherical aberration values ($p < 0.01$). Mean HOA, TWA, coma, trefoil, and spherical aberration values were observed to increase with the severity of KC disease.

Conclusions: Anterior high order corneal aberrations were significantly increased in eyes with moderate and advanced keratoconus. Anterior high order corneal aberration measurements are a useful tool to guide the physician in diagnosis and classification of keratoconus.

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1. Introduction

Keratoconus (KC) is a disease where the cornea gets thinner bilaterally and progressively, and steepens in a conic manner [1]. Previously, KC was described as a non-inflammatory disease but is now known to be an inflammatory disease [2,3]. The disease starts during puberty and progresses until the 3rd–4th decades. While the exact etiology is unknown, genetic, environmental, biochemical, and biomechanical factors are thought to play a role [4]. Histopathologically, changes in the corneal collagen structure and organization as well as the extracellular matrix, keratocyte apoptosis, necrosis in the anterior stroma and Bowman's layer, and iron accumulation in the epithelial basal membrane and lacerations of the Bowman's layer are seen [1,5]. Matrix metalloproteinases (MMP), tissue inhibitors, cytokines, and oxidative stress are reported to be effective in the pathogenesis [6].

KC is asymptomatic in the early stages of the disease. Corneal protrusion, which becomes evident with the progression of the disease, causes severe myopia and irregular astigmatism. Along with decreased vision, stromal thinning, and Fleischer ring, Vogt's striata and corneal apical scarring are observed in patients during biomicroscopic examination [7].

Today, high-definition topographic images are obtained in multiple planes and locations of the anterior segment in the eyes via the new Scheimpflug imaging technique for the diagnosis of KC [8].

Along with biomicroscopic properties, various corneal topographic and biomechanical methods are used in KC classification. Corneal aberrations have also been used for classification during the recent years. In optics, aberrations may be defined as unwanted characteristics, which stem from refractile environments and negatively affect the quality of vision [9–11]. High order, total, and

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coma and spherical aberrations were observed to increase in KC patients [12–14].

This study was performed to evaluate the effect of anterior corneal higher-order aberrations in the diagnosis and classification of keratoconus. Topographic measurements and the anterior corneal higher-order aberrations were measured and compared quantitatively in normal eyes and eyes with keratoconus using Scheimpflug-Placido topography.

2. Methods

2.1. Study group

This study was approved by the local ethics committee of Fatih University Faculty of Medicine and adhered to the tenets of the Declaration of Helsinki. All subjects provided written informed consent.

Patients between the ages of 16–34 with intraocular pressures (IOP) less than 18 mmHg, C/D ratios less than 0.4, and without any other ophthalmological pathologies aside from keratoconus were included in the study. Patients with glaucoma, cataracts, dry eyes, retinal and choroidal pathology, past ophthalmological surgeries, and systemic diseases such as diabetes or hypertension were excluded from the study. In bilateral cases, one of the eyes was randomly chosen for analysis.

Chosen KC patients had mild (group 1), moderate (group 2), and advanced stage (group 3) disease according to Amsler-Krumeich criteria (80 cases) [15].

Group 1: mean central K reading less than 48.00 D, myopia and/or astigmatism less than 5.00 D; eccentric steeping

Group 2: mean central K reading less than 53.00 D, myopia and/or astigmatism 5.00–8.00 D; no central corneal scars, minimal corneal thickness greater than 400 mm.

Group 3: mean central K reading greater than 53.00 D, myopia and/or astigmatism 8.00–10.00 D, or immeasurable refraction; central corneal scar; minimal corneal thickness <400 mm.

One eye of 81 healthy age and gender matched subjects were included in the control group. Control subjects were selected from volunteers. For the control group, the spherical or cylindrical refractory error was smaller than ±1.5 D. Control subjects with any glaucoma, keratoconus, cataracts, dry eyes, retinal and choroidal pathology, ocular surgery, and systemic diseases such as diabetes or hypertension were excluded from the study.

Detailed ophthalmological examinations including visual acuity, anterior segment and fundus examinations, and intraocular pressure (IOP) measurements were performed on the included cases. The data were evaluated retrospectively.

2.2. Corneal topography

The corneal measurements were done by the same experienced operator in the scotopic environment without pupillary dilation using Sirius topography equipment (CSO Inc., Italy). High order aberrations were obtained by conversion of the corneal elevation profiles, which are recommended by the Optical Society of America into wave front data using Zernicke polinomials (Zernike 3–6) in pupillary areas of 6-mm.

The Sirius imaging technique evaluates corneal topography with a non-contact, rapid, repeatable, and 360°-rotating Scheimpflug camera and a placido disk. The camera scans the area between the anterior corneal surface and the posterior surface of the lens in seconds and obtains three dimensional maps. The topography of the anterior and posterior corneal surfaces and elevation maps, anterior chamber analysis (depth, angle and volume). Anterior and posterior corneal keratometric values provide the pachymetric mapping and wavefront analysis of the whole cornea [16–18]. Average keratometric measurements ($K_{avg,}$ mm_{avg}) an central corneal thicknesses (CCT) were obtained from a pupillary area of 3-mm and the high order aberration (HOA), total wave front aberration (TWA), coma, trefoil, and spherical aberration measurements were obtained from a pupillary area of 6.00-mm and recorded.

2.3. Statistical evaluations

The NCSS 2007 (Number Cruncher Statistical System; NCSS, LLC Kaysville, Utah, USA) program was used for statistical analyses. Where applicable, we report the mean, standard deviation, median, frequency, and rate. A one-way Anova test was used for the comparison of variable groups with normal distributions; and Pearson Chi-Square test was used for the comparison of Kruskal Qualitative data of variable groups without normal distributions. The results were evaluated according to a confidence interval of 95% and a p-value of less than 0.05 was considered the significance threshold.

3. Results

The study was performed on a total of 161 cases, 86 of which (53.4%) were male and 75 of which (46.6%) were female, in the Ophthalmology Department of Fatih University Faculty of Medicine Hospital between January 2013 and May 2015. Twenty-five of the cases (15.5%) were group 1, 34 of them (%21.1) were group 2, 21 of them (13.1%) were group 3 keratoconus. Eighty-one (81) cases (50.3%) made up the control group. There were 42 (52.5%) males and 38 (47.5%) females in the keratoconus group, and 44 (54.3%) males and 37 (45.7%) females in the control group. Demographic characteristics of the groups are given in Table 1. In terms of mean age and gender distributions, there was no statistically significant difference between the groups ($p > 0.05$) (Table 1).

The K_{avg} values of the cases were 46.1 ± 0.9 D in group 1, 50.2 ± 1 D in group 2, 58.9 ± 1.3 D in group 3, and 42.7 ± 1.1 D in the control group. There was a statistically significant difference between the groups in terms of K_{avg} values ($p < 0.01$) (Tables 2 and 3).

The mm_{avg} values of the cases were 7.3 ± 0.1 mm in group 1, 6.7 ± 0.1 mm in group 2, 5.7 ± 0,1 mm in group 3, and 7.9 ± 0.2 mm

Table 1
Demographic characteristics of groups.

		Keratoconus groups			Control group	p[a]
		group 1	group 2	group 3		
Age	mean ± SD	24.52 ± 5.25	24.15 ± 4.80	25.14 ± 4.52	25.43 ± 5.19	0.613[a]
(year)	Min–Max (Median)	17–34 (27.0)	16–33 (24.5)	18–34 (27.0)	17–34 (27.0)	
Gender	Male	13 (52.0)	17 (50.0)	12 (57.1)	44 (54.3)	0.956[b]
n (%)	Female	12 (48.0)	17 (50.0)	9 (42.9)	37 (45.7)	

[a] Oneway ANOVA test.
[b] Pearson Chi-square.

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