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Analysis of age, refractive error and gender related changes of the cornea and the anterior segment of the eye with Scheimpflug imaging☆,☆☆

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ABSTRACT

Purpose: To assess age, refractive error and gender related changes occurring in the cornea and the anterior segment of the eye using a Scheimpflug system.
Methods: The study included 666 healthy eyed subjects with a mean age of 39.3 ± 19.7 years (range: 3–85 years). All analyses were based on the right eyes of the patients as all measured parameters correlated well between the right and left eyes. Each parameter was correlated with age and the right eye's spherical equivalent (SE) using Pearson correlations. Univariate linear regression models were constructed for analyses of parameters.
Results: The anterior corneal surface asphericity showed significant positive correlations whereas posterior corneal surface asphericity showed significant negative correlations with age. Anterior chamber depth (ACD), volume (ACV) and angle (ACA) showed significant negative correlations with age and SE. Age explained 25% of the variance in anterior corneal surface asphericity, 22% of variance in posterior corneal surface asphericity, 26% of variance in ACV, 27% of variance in ACD, and 19% of variance in ACA. In the SE model SE was identified to account for 25% of variance in ACV, 22% of variance in ACD, each, and 17% of variance in ACA. Significant differences were detected in anterior and posterior keratometry values, ACV, ACD and ACA among gender groups ($p < 0.01$).
Conclusions: The cornea shows a tendency for a decrease in anterior corneal surface asphericity and an increase in posterior corneal surface asphericity with advancing age. Men have flatter corneas and women have shallower anterior chambers and narrower anterior chamber angles.

1. Introduction

Physiological and pathological changes occur in the eye with aging as in all other organs of the body. The incidence of age-related maculopathy, liquefaction of the vitreous and cataract increases with age. Aging changes occur from the eyelids to the macula causing various effects. Corneal changes occurring as a consequence of increasing age include variation in corneal toricity and changes in the corneal endothelium. Change in corneal toricity shifts astigmatism from "with-the-rule" to "against-the-rule" in the elderly [1]. Changes in the endothelium include a decrease in endothelial cell density, increase in cellular polymegathism and cellular pleomorphism, and a decrease in endothelial pump function [2]. Other corneal changes described include a decrease in corneal sensitivity and an increase in corneal fragility [3,4].

To date the effects of aging on the posterior corneal surface have been investigated to a limited degree. Few studies showed a decrease in the corneal radius of curvature and a shift of astigmatism from with-the-rule to against-the-rule with aging [5,6]. Apart from aging, gender related changes in the cornea and the anterior segment of the eye have also been documented. The cornea of elderly men is flatter than those of elderly women [7].

Advances in anterior segment imaging have improved ability to evaluate and measure parameters defining the anterior segment of

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the eye in an objective manner. We herein report aging and gender changes of the cornea and the anterior segment of the eye as measured by the Scheimpflug imaging system in a large healthy population.

2. Patients and methods

Our study is a clinic-based study of 317 men (47.6%) and 349 women (52.4%) with an age of three to 85 years. Subjects were recruited consecutively from September 2011 to April 2012 as they attended a private eye hospital (Kudret Eye Hospital, Istanbul, Turkey) for routine ocular examination. Also were included those who were refractive surgery candidates or those who applied due to minor external ocular discomfort. Volunteers and employees of the same hospital were chosen as subjects as well. The study was performed in adherence to the tenets of the Declaration of Helsinki and was approved by the ethics committee of the Dr. Lutfi Kirdar Kartal Training and Research Hospital. The volunteers were explained the purpose of the study and an informed consent was obtained from the subjects who aged 16 or more and from the parents of those who were under the age of 16 years.

Exclusion criteria were previous eye trauma, corneal or intraocular surgery, including laser treatment, corneal diseases such as keratoconus and pellucid marginal degeneration, and corneal abnormalities including irregular epithelium, infiltration, edema, opacities and scars on slit-lamp examination. Patients with a previous diagnosis of dry eye or those who were using artificial tears regularly were also excluded. Contact lens users including rigid contact lenses were included in the study after discontinuation of lens wear for 1 and 4 weeks, respectively.

Measurements were taken with a high-resolution rotating Scheimpflug imaging system. The Pentacam (Oculus Optikgeräte GmbH, Wetzlar, Germany) system uses a rotating Scheimpflug camera and a monochromatic slit-light source that rotate together around the optical axes of the eye for measuring the anterior segment topography. All Pentacam measurements were taken between 9:00 am and 6:00 pm by three different technicians. All images were obtained in the same room for all patients with a consistent environment in each screening using the same device, after the equipment's calibration. The room lights were switched off for all examinations to get a reflex-free image. The subjects were asked to position themselves, blink a couple of times, and fixate on the black target in the center of the blue fixation beam. Patients were instructed to close their eyes between shots for at least 10 s to moisten the eyes. The rotating Scheimpflug imaging was automatically performed when the image was in focus and the corneal vertex correctly aligned. The camera rotated 180°, obtaining 25 slit images of the anterior segment, and generated a three-dimensional model of the anterior eye. The subject's eye movement was constantly monitored by the system, and the quality factor was automatically evaluated. Only scans with a quality factor (QS) of >95% were saved.

Parameters of the printout retained for the analysis were keratometry readings (K1, K2, and Km), topographic astigmatism, axis and asphericity of the anterior and posterior corneal surface, pachymetry, corneal volume, and anterior chamber volume, angle and depth (ACV, ACA and ACD). The corneal surface asphericity data provided by the Pentacam was taken from 8 mm central cornea with reference to the anterior corneal apex. Corneal thickness is defined as the thinnest location within central 8 mm of corneal thickness map. Corneal volume reflects the volume of the cornea in a diameter of 10 mm, centered on the anterior corneal apex. Anterior chamber depth is defined as the distance from the corneal endothelium to the anterior surface of the lens capsule. The anterior chamber volume is calculated from endothelium down to iris and lens over a 12-mm diameter centered on the anterior corneal apex. The default angle displayed is the smallest angle in the horizontal position calculated from the Scheimpflug image. Spherical equivalent (SE: sphere + half the cylinder) values; in diopters (D), were calculated from cycloplegic refraction for each patient. With regard to axis of astigmatism, an axis of $180^\circ \pm 30^\circ$ was classified as with the rule (WTR), an axis of $90^\circ \pm 30^\circ$ was considered against the rule (ATR), and axes in-between were considered oblique astigmatism (OA).

There was a strong correlation between right and left eye's SE values and all measured Pentacam parameters, therefore analyses were based on the right eyes ($p < 0.001$). Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 20.0. Each Pentacam parameter was correlated with age and the right eye's SE using Pearson correlations. A Pearson correlation coefficient of 0.1 to 0.3 was considered as weak correlation, 0.4 to 0.6 as moderate correlation, 0.7 to 0.9 as strong correlation, and 1.0 of perfect correlation as suggested by Dancey and Reidy [8]. Pentacam parameters were tested for differences among gender groups. Univariate analysis included chi-square test and Student's *t*-test. Univariate linear regression models were constructed with Pentacam parameters as the dependent variables and age or SE as the covariates whenever there was a moderate or stronger correlation.

3. Results

Age distribution of 666 subjects with respect to gender is provided in Table 1. The mean age of male and female patients were 39.76 ± 19.19 years and 39.48 ± 20.17 years, respectively ($p > 0.05$). Mean SE of the male and female subjects were -1.43 ± 3.0 diopters (D) (range, −14.68 D to +5.63 D) and -1.28 ± 2.90 D (range, −12.0 to +7.50 D), respectively ($p > 0.05$). Mean Pentacam parameters of 666 subjects and the difference between male and female subjects are shown in Table 2. There was a statistically significant difference in the anterior and posterior keratometry values (flat, steep and mean), ACV, ACD and ACD between male and female subjects.

The distribution of astigmatic axis of the refractive, anterior and posterior corneal topographic astigmatism with respect to age is shown in Tables 3–5. The percentage of refractive and anterior corneal topographic ATR astigmatism showed a significant increase with age ($p < 0.001$).

The correlation of Pentacam parameters with age and SE is shown in Table 6. A moderately significant positive correlation was evident between anterior corneal surface asphericity and age ($r = 0.444$, $p < 0.001$). Posterior corneal surface asphericity, and ACV, ACD and ACA showed moderately significant negative correlations with age ($r = -0.447$, $p < 0.001$; $r = -0.512$, $p < 0.001$; $r = -0.481$, $p < 0.001$; $r = -408$, $p < 0.001$; respectively). Anterior and posterior corneal surface asphericities showed reverse correlation with age and met at around the age of 40 years (Fig. 1). The same distribution of anterior and posterior asphericity with respect to age was also observed in male and female subjects (Supplemental Figs. 1 and 2). Moderately significant negative correlations were observed between ACV, ACD and ACA and the SE of the eyes ($r = -0.490$, $p < 0.001$; $r = -0.472$, $p < 0.001$; $r = -3988$, $p < 0.001$; respectively).

Univariate linear regression models showed that age accounted for 25% of variance in anterior corneal surface asphericity, 22% of

Table 1
Age distribution with respect to gender.

Age groups (years)	Total *N* (%)	Male *N* (%)	Female *N* (%)
3–20	144 (21.6)	63 (19.9)	81 (23.2)
21–40	189 (28.4)	93 (29.3)	96 (27.5)
41–60	221 (33.2)	110 (34.7)	111 (31.8)
61–85	112 (16.8)	51 (16.1)	61 (17.5)
Total	666 (100)	317 (100)	349 (100)