

Analysis of Age, Gender, and Refractive Error-Related Changes of the Anterior Corneal Surface Parameters Using Oculus Keratograph Topography

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Abstract

Purpose: To assess refractive error, gender, and age-related differences in corneal topography of a normal population with Oculus Keratograph 4.

Methods: This cross-sectional study included a total of 500 normal eyes of 500 individuals with ages ranging from 10 to 70 years. All participants underwent detailed ocular examinations, including visual acuity measurement, slit-lamp examination, and refractive error evaluation. Slit-lamp examination was performed for all individuals to rule out apparent corneal diseases. Corneal topography parameters were assessed using Oculus Keratograph. The data were analyzed based on gender, refractive error, and age groups using independent sample *t*-test and one-way analysis of variance.

Results: Of a total of 500 participants (age: 29.51 ± 11.53 years) recruited for the present study, 66.4% were female, and 33.6% were male. The mean spherical equivalent of refraction was -0.98 ± 1.65 diopters. Significant differences were noted in steep keratometry ($P = 0.035$) and corneal astigmatism ($P = 0.014$) between genders. Assessment of the data based on refractive error revealed significant differences in an index of vertical asymmetry ($P < 0.001$), index of height asymmetry ($P = 0.003$), and index of height decentration ($P = 0.011$). Considering age groups, significant differences were observed in flat keratometry readings ($P < 0.001$), mean corneal astigmatism ($P = 0.02$), minimum radius of curvature ($P = 0.037$), and apex power ($P < 0.001$).

Conclusions: There was a prominent variation in some topographic parameters based on gender, age, and refractive error. The information on corneal parameters obtained with Oculus Keratograph from normal eyes provides a reference for comparison with diseased corneas.

Keywords: Age, Cornea, Gender, Keratograph, Refractive error, Topography

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INTRODUCTION

Cornea, the most important refractive structure, accounts for two-thirds of the total optical power of the eye.¹ Any alternation in corneal curvature directly influences the type and degree of refractive error. Accurate assessment of its optical properties is crucial for both diagnostic and therapeutic purposes¹ such as the diagnosis and management of Keratoconus,^{2,3} contact

lens fitting,⁴ refractive surgery assessment,⁵ and detection of any ectatic disorders after refractive surgeries.⁶ In addition, accurate corneal assessment is of great importance to improve vision following rigid contact lens fitting in irregular corneas, corneal ring implantation, and cornea transplantations following corneal ectasias.²

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With the advent of corneal topographers and their clinical application, the analysis of corneal measurement produces a variety of quantitative indices about which knowledge is appreciated in detecting early abnormalities. There are several commercially available corneal topography instruments for either clinical or research goals, such as Pentacam, Orbscan, Galilei Tomography System, and Oculus Keratograph.⁷⁻¹¹ Several published studies have investigated the repeatability and reproducibility of Pentacam, Orbscan, and Galilei Tomography systems.^{10,12,13}

Oculus Keratograph 4 (OCULUS, Wetzlar, Germany) is a new corneal topography which uses Placido ring-based videokeratography to provide corneal topography. This tool is universally used and is a computerized and examiner-independent system for corneal topography. Several studies report that Oculus Keratograph 4 provides repeatable measurements of corneal topography parameters in healthy eyes^{11,14-17} and has a high agreement with other topography devices.¹⁵

Refractive error, gender, and age-related differences are considered to play a key role in tissue structures changes,^{16,17} hence, evaluation of corneal features in a normal population should be precisely investigated. To the best of our knowledge, this article is the first to study the normality of oculus topography parameters as a function of gender, refractive error, and age in a large healthy population.

METHODS

Among all healthy individuals who came for routine optometry examination, 500 participants were recruited for the present study considering inclusion and exclusion criteria and based on the simple random sampling technique. The study followed the tenets of the Declaration of Helsinki and was approved by the Research Ethics Committee of the institute (Grant code: 930431). After a complete explanation, written informed consent was obtained from each participant. Inclusion criteria were as follows: no ocular surgery, no ocular diseases, no refractive surgery, no contact lens usage, best corrected visual acuity 20/25 or better, and no ophthalmic drugs (especially dry eye drugs) usage. A slit-lamp examination was performed for all individuals to rule out apparent corneal diseases. All examinations were performed by the same experienced examiner (N.M.). All participants underwent detailed ocular examinations, including measurement of visual acuity, slit-lamp examination, evaluation of refractive error, and corneal topography. After slit-lamp examination of the anterior segment, refractive error was determined with an auto-refractometer (AR-610, Nidek Co, Ltd., Tokyo, Japan) and was refined with subjective refraction. Maximum plus to maximum visual acuity was determined as an endpoint in subjective refraction. Myopia was defined as a mean spherical equivalent (MSE) < -0.50 Diopter (D), emmetropia was defined as MSE between -0.50 and $+0.50$ D, and MSE more than $+0.50$ D was considered hyperopia.¹⁸ All participants were

divided into six groups by age: 10–20 years, 21–30 years, 31–40 years, 41–50 years, 51–60 years, and 61–70 years. The cornea was evaluated using Keratograph 4 (OCULUS, Wetzlar, Germany) corneal topography. Mire uniformity reflected from cornea was evaluated to check the image quality. Any participants with any irregularity in mires (i.e., those with dry eye) were excluded from the study population. Measurements were repeated three times for each participant. Oculus Keratograph 4 (OCULUS, Wetzlar, Germany), a new corneal topography, is a Placido disc-based device which consists of 22 rings and measures 22,000 points on anterior corneal surface by reflecting illuminated rings on the cornea. It could assess tear film, contact lens fitting pattern, lid-angle, and pupil diameter. It is also equipped with a camera that can capture both videos and still images.^{19,20}

Evaluated indices are the following (Oculus Keratograph Instruction Manual, version 1.53, 2002):

- Index of surface variation: The corneal surface irregularity
- Index of vertical asymmetry (IVA): The value of curvature symmetry, with respect to the horizontal meridian as the axis of reflection
- Keratoconus index: The ratio between mean radius values in the upper and lower segment
- Central keratoconus index: The ratio between mean radius values in a peripheral ring divided by a central ring
- Index of height asymmetry (IHA): The degree of symmetry of height data with respect to the horizontal meridian as the axis of reflection
- Index of height decentration (IHD): The degree of decentration in the vertical direction, calculated on a ring with a radius 3 mm
- Minimum radius curvature (R_{\min}): The smallest radius of sagittal corneal curvature.

Statistical analysis

Statistical analyses were performed with SPSS software for Windows version 11.5 (SPSS Inc., Chicago, IL, USA). All data were reported as means and standard deviation. Normality for continuous variables was determined using the Kolmogorov–Smirnov test. The data were analyzed based on gender, refractive error, and age groups using independent sample *t*-test and one-way analysis of variance (ANOVA). Bonferroni *post hoc* corrections were applied for multiple comparisons. The level of statistical significance was set at 0.05. To avoid statistical bias and due to the similar nature of the two eyes, data from only the right eyes were included in all analyses.

RESULTS

Of a total of five hundred participants (age: 29.51 ± 11.53 years) recruited for the study, 332 (66.4%) were female (age: 27.39 ± 9.94 years), and 168 (33.6%) were male (age: 33.79 ± 13.26 years). The MSE of the refractive error was -0.98 ± 1.65 D (range, -7.88 D to $+4.75$ D). Topographic and refractive data were analyzed according to age, refractive

error, and gender. The topographic parameters based on gender are summarized in Table 1. The average of steep keratometry showed significant differences toward flattening in males ($P = 0.035$). Corneal astigmatism also presented statistically significant changes in the result ($P = 0.014$). However, other corneal parameters did not show any significant differences according to gender.

Table 2 shows the topographic parameters according to the refractive errors in view of *post hoc* results. One-way ANOVA showed that both the IHA and IVA significantly increased with increasing refractive error toward hyperopia ($P = 0.003$, $P < 0.001$, respectively). However, *post hoc* multiple comparisons illustrated that the difference in IHA was only statistically significant between myopia and hyperopia ($P = 0.003$). Multiple comparisons of the IVA between the three refractive groups also exhibited a statistically significant difference between myopia and hyperopia ($P < 0.001$) and between emmetropia and hyperopia ($P = 0.003$). In addition, the evaluation of IHD showed significant differences between the refractive groups ($P = 0.011$). Multiple comparisons showed that the differences between myopia and hyperopia ($P = 0.008$) and emmetropia and hyperopia ($P = 0.029$) were statistically significant. No other significant differences were observed between other corneal parameters based on refractive error.

Table 3 shows topographic parameters in each age group, taking into consideration *post hoc* results. One-way ANOVA analysis illustrated a significant steepening of the flat keratometry with increasing age ($P < 0.001$). However, *post hoc* multiple comparisons demonstrated significant differences in flat keratometry between the 10–20 years' subgroup with 41–50, 51–60, and 61–70 years ($P = 0.006$, $P < 0.001$, and $P = 0.005$, respectively). Significant differences were also noted between the 21–30 and 51–60 years' subgroups ($P = 0.004$). The mean corneal astigmatism significantly decreased with increasing

age ($P = 0.02$). Multiple comparisons showed a significant difference between 10–20 years and 51–60 years ($P = 0.003$). R_{\min} and apex power presented a significant steepening with increasing age ($P = 0.037$ and $P < 0.001$, respectively). A detailed assessment of apex power showed a distinct difference between 10–20 years with the 51–60 and 61–70 years' subgroups toward increasing power with increasing age ($P = 0.009$, $P = 0.043$, respectively).

DISCUSSION

The present study aimed to evaluate the age, gender, and refractive error-related changes in corneal parameters. Although several studies have evaluated the corneal parameters in a normal population with other topographic systems and also investigate the repeatability and reproducibility of diagnosis devices, there are few which comprehensively evaluate the Oculus Keratograph 4 in a large normal population. Oculus Keratograph was used to measure the corneal anterior surface parameters in a large, healthy population.

In an investigation of corneal parameters, we found significant differences in steep keratometry between male and female participants in agreement with Orucoglu *et al.*'s¹⁵ study. Orucoglu *et al.* evaluated the anterior segment of the eye with Pentacam Scheimpflug imaging in 666 healthy eye individuals. Similar to the previous studies, present findings also demonstrated that cornea was steeper in female group.^{15,21–24} Hoffmann and Hütz²² evaluated biometry parameters by IOLMaster biometer in 15448 patients and stated that female eyes tend to have steeper cornea and shallower anterior chamber that could be explained by shorter eyes in females.

Mean corneal astigmatism was significantly different between male and female groups. The opposite results were reported in Khabazkhoob *et al.*'s²⁵ study using Orbscan, which found no significant difference in mean corneal astigmatism between genders. Moreover, Orucoglu *et al.*¹⁵ also stated that there was no significant difference between genders with respect to corneal astigmatism. The conflicting results may be due to different applied devices.

In the evaluation of corneal parameters according to the refractive errors, the present study found significant differences in some corneal components. In agreement with previous studies,^{26,27} no statistically significant change in corneal curvature radius was observed in the study population with respect to refractive errors. Dogan *et al.*²⁶ assessed anterior segment parameters of myopic, hyperopic, and emmetropic children using optical biometry and reported no associations between the mean keratometric values and refractive states. Nieto-Bona *et al.*²⁷ also measured corneal parameters using Atlas videokeratoscope among adults and stated no significant corneal curvature radius between refractive groups. Hashemi *et al.*²⁸ also determined the distribution of axial length to the corneal radius of curvature (AL/CRC) ratio and evaluated its association with refractive errors in the Iranian population. They reported that the correlation between refractive errors

Table 1: Topographic parameters based on gender

Factor	Female (n=332)	Male (n=168)	P
Kf (D)	43.45±1.43	43.39±1.54	0.676
Ks (D)	44.37±1.44	44.07±1.61	0.035
C.Ast (D)	-0.94±0.56	-0.81±0.51	0.014
Ecc	0.51±0.10	0.52±0.11	0.621
ISV	18.72±5.40	18.69±5.27	0.958
IVA	0.11±0.05	0.11±0.05	0.937
KI	1.01±0.01	1.01±0.01	0.075
CKI	1.00±0.005	1.00±0.005	0.921
R_{\min} (mm)	7.48±0.25	7.52±0.28	0.114
IHA	6.13±4.08	6.35±4.44	0.588
IHD	0.00±0.00	0.01±0.00	0.06
Apex (D)	44.26±1.44	44.06±1.54	0.171

All data has normal distribution. Bold text indicates a statistically significant value. Kf: Flat keratometry, Ks: Steep keratometry, C.Ast: Corneal astigmatism, Ecc: Eccentricity, ISV: Index of surface variation, IVA: Index of vertical asymmetry, KI: Keratoconus index, CKI: Central keratoconus index, R_{\min} : Minimum radius curvature, IHA: Index of height asymmetry, IHD: Index of height decentration, D: Diopter

Table 2: Topographic parameters based on refractive error

Factor	Myopia (1) (n=255)	Emmetropia (2) (n=209)	Hyperopia (3) (n=36)	Comparison pair by pair	P
Kf (D)	43.48±1.48	43.32±1.44	43.79±1.58	Not statistically significant	0.169
Ks (D)	44.37±1.54	44.15±1.47	44.34±1.55	Not statistically significant	0.264
C.Ast (D)	-0.95±0.60	-0.88±0.50	-0.74±0.43	Not statistically significant	0.074
Ecc	0.53±0.10	0.52±0.11	0.52±0.12	Not statistically significant	0.579
ISV	18.76±5.44	18.44±5.24	19.97±5.47	Not statistically significant	0.277
IVA	0.11±0.05	0.12±0.05	0.15±0.05	1<3*, 2<3*	<0.001
KI	1.01±0.02	1.01±0.02	1.02±0.02	Not statistically significant	0.450
CKI	1.01±0.01	1.01±0.01	1.01±0.01	Not statistically significant	0.088
R _{min} (mm)	7.48±0.27	7.52±0.27	7.47±0.24	Not statistically significant	0.375
IHA	5.79±4.08	6.36±4.24	8.27±4.33	1<3*, 2<3*	0.003
IHD	0.00±0.00	0.01±0.00	0.01±0.00	1<3*, 2<3*	0.011
Apex (D)	44.28±1.51	44.06±1.45	44.36±1.43	Not statistically significant	0.222

*Bonferroni *post hoc* test ($P<0.05$). All data have normal distribution. Bold text indicates a statistically significant value. Kf: Flat keratometry, Ks: Steep keratometry, C.Ast: Corneal astigmatism, Ecc: Eccentricity, ISV: Index of surface variation, IVA: Index of vertical asymmetry, KI: Keratoconus index, CKI: Central keratoconus index, R_{min}: Minimum radius curvature, IHA: Index of height asymmetry, IHD: Index of height decentration, D: Diopter

Table 3: Topographic parameters based on age

Factor	10-20 years (1) (n=71)	21-30 years (2) (n=270)	31-40 years (3) (n=71)	41-50 years (4) (n=46)	51-60 years (5) (n=30)	61-70 years (6) (n=12)	Comparison pair by pair	P
Kf (D)	42.91±1.55	43.31±1.38	43.56±1.40	43.88±1.44	44.32±1.61	44.53±1.22	1<4*, 1<5*, 1<6*, 2<5*	<0.001
Ks (D)	43.94±1.63	44.20±1.41	44.40±1.52	44.49±1.52	44.75±1.91	44.91±1.32	Not statistically significant.	0.06
C.Ast (D)	-1.04±0.74	-0.92±0.53	-0.86±0.48	-0.81±0.46	-0.68±0.39	-0.70±0.40	1>5*	0.02
Ecc	0.53±0.11	0.53±0.10	0.51±0.10	0.51±0.14	0.51±0.12	0.46±0.14	Not statistically significant	0.170
ISV	19.63±4.74	18.98±5.62	17.22±4.45	18.67±6.23	18.30±4.59	17.33±4.68	Not statistically significant	0.101
IVA	0.12±0.05	0.12±0.05	0.10±0.04	0.12±0.06	0.13±0.04	0.13±0.06	Not statistically significant	0.141
KI	1.01±0.01	1.01±0.02	1.01±0.01	1.01±0.02	1.01±0.02	1.01±0.03	Not statistically significant	0.294
CKI	1.01±0.00	1.01±0.00	1.00±0.01	1.01±0.01	1.01±0.01	1.01±0.01	Not statistically significant	0.052
R _{min} (mm)	7.56±0.30	7.50±0.25	7.47±0.24	7.46±0.28	7.41±0.30	7.36±0.22	Not statistically significant	0.037
IHA	6.14±3.90	6.25±4.25	5.53±3.78	6.12±4.24	7.96±5.06	5.57±4.63	Not statistically significant	0.192
IHD	0.01±0.00	0.01±0.00	0.00±0.00	0.01±0.00	0.01±0.00	0.01±0.00	Not statistically significant	0.058
Apex (D)	43.72±1.60	44.13±1.41	44.31±1.39	44.48±1.49	44.82±1.71	45.08±1.06	1<5*, 1<6*	<0.001

*Bonferroni *post hoc* test ($P<0.05$). All data have normal distribution. Bold text indicates a statistically significant value. Kf: Flat keratometry, Ks: Steep keratometry, C.Ast: Corneal astigmatism, Ecc: Eccentricity, ISV: Index of surface variation, IVA: Index of vertical asymmetry, KI: Keratoconus index, CKI: Central keratoconus index, R_{min}: Minimum radius curvature, IHA: Index of height asymmetry, IHD: Index of height decentration, D: Diopter

was significantly stronger with the AL/CRC ratio than with AL and CRC alone.

IHA and decentration showed a significant difference between the three refractive groups, and it was greater in hyperopia. IHA and decentration are the main factors in keratoconus diagnosis and staging.²⁹ Overall, this information may help clinicians better define normal from abnormal in the clinical setting and in refractive surgery screenings.

With regard to age, statistically significant changes were observed in some of the corneal anterior surface parameters. With aging, flat keratometry reading showed a significant change towards steepening. In contrast, Shukur³⁰ reported no considerable differences in flat keratometry with age. The results of the present study showed that the average corneal astigmatism significantly decreased with age. However, Lyle³¹ reported that corneal astigmatism increased up to the third decade of life and showed a decrease in older individuals.

The minimum radius of curvature and apex power in the present study had a gradual trend toward steepening with aging; however, Hashemi *et al.*³² reported no significant age-related changes in corneal radius. The most likely explanation of the controversy may be explained by various mean age and different measurement devices.

One of the limitations of the current study is an unequal number of individuals with respect to refractive error, gender, and age subgroups. Moreover, further studies using other topographic devices for the assessment of the corneal surface are recommended to compare with Oculus topographer.

In summary, the strong aspects of the present study include the assessment of gender, refractive error, and age-related changes on the anterior corneal surface in a relatively extended normal population assessed by Oculus Keratograph 4. Given that corneal anterior surface parameters showed considerable variation in relation to age, gender, and refractive error, these

data will hopefully prove useful for future studies of various corneal diseases.

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Conflicts of interest

There are no conflicts of interest.

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