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White-to-white corneal diameter distribution in an adult population

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Abstract

Purpose: To determine the normal distribution of corneal diameter in a 40- to 64-year-old population and its association with other biometric components.
Methods: In a cross-sectional population-based study, subjects were selected through multistage cluster sampling from the 40- to 64-year-old citizens of Shahroud in northern Iran. After obtaining informed consents, optometry tests including refraction and visual acuity and ophthalmic exams including slit lamp exams and retinoscopy were done for all participants. Biometric components and white-to-white (WTW) corneal diameter were measured with the LENSTAR/BioGraph.
Results: Of the 6311 invitees, 5190 (82.2%) participated in the study. After applying exclusion criteria, analysis was done on data from 4787 people. Mean WTW corneal diameter in this study was 11.80 mm (confidence interval: 11.78–11.81), and based on two standard deviations from the mean, the normal range for this index was from 10.8 to 12.8 mm. WTW corneal diameter strongly correlated with corneal radius of curvature ($r = 0.422$) and axial length ($r = 0.384$). According to multiple linear regression, lower age, thinner cornea, longer AL, thicker lens, and flatter cornea were significantly related to higher WTW corneal diameter. Spherical equivalent significantly increased at higher corneal diameters (hyperopic shift).
Conclusion: The average and normal range of corneal diameter, as measured with the BioGraph, was studied in an Iranian population for the first time. The corneal diameter strongly correlates with AL and radius of curvature. WTW is larger at younger ages.

Keywords: Corneal diameter; Cross-sectional study; Middle East; Adult

Introduction

White-to-white (WTW) corneal diameter is one of the ocular biometric components which has had applications in selecting anterior chamber lenses for years.[1] It also has a role in calculating the lens power with the Holladay formula in cataract surgery.[2] WTW corneal diameter can be measured with various devices. Racial and ethnic differences are some factors that can affect this index. Also, different methods, from simple measurement with a ruler to sophisticated measurement with imaging devices, have lead to a wide range of normal values in different reports.[1,3–7] LENSTAR/BioGraph is a new generation device which measures different ocular biometrics. Knowledge of normal biometric values with this device in different populations can be helpful in detecting abnormal cases when using this device in clinical settings. In this report, we present the normal corneal diameter, as measured with the LENSTAR/BioGraph, in a 40- to 64-year-old Iranian population by age and sex. Since the WTW corneal diameter is one of the ocular biometrics that can be simply measured with a ruler, knowledge of the relationship of this component with other ocular biometric components can be helpful in getting an

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estimate of various ocular biometrics in the absence of imaging devices. Thus, the second objective of this study is to determine the relationship between corneal diameter and other ocular biometrics.

Materials and methods

This report concerns part of the first phase of the Shahroud Eye Cohort Study which was conducted cross-sectionally from February 2009 to January 2010. Details of the methodology have been published elsewhere,[8] but here we briefly describe the sampling methods and examinations.

In this study, multistage sampling was applied to the 40- to 64-year-old population of Shahroud, a city in northern Iran. Three hundred clusters from 9 strata (health care centers) were randomly selected, and from each cluster, 20 people were invited to have complete eye examinations. After obtaining written consents from the participants, interviews were conducted to collect demographic and economic data, as well as information about their occupation, smoking habits, and medical and ocular history.

Optometry tests and ophthalmic exams were done for all participants. Optometry tests included measurement of near and far visual acuity with and without correction and autorefraction with the Topcon AR 8800 autorefractometer (Topcon Corporation, Tokyo, Japan), the results of which were used to conduct objective refraction (with the Heine retinoscope) and subjective refraction. Next, an ophthalmologist performed slit lamp exams, and when there was no contraindication, cyclopentolate 1% eye drops were instilled prior to retinoscopy. Eventually, cycloplegic refraction results were recorded.

Biometric examinations

Biometric examinations were done after checking visual acuity and before ophthalmic and cycloplegic refraction tests. Ocular biometrics were measured using the LENSTAR/BioGraph (WaveLight AG, Erlangen, Germany).

Statistical analysis

The mean and 95% confidence intervals of WTW corneal diameter are described by age and sex. In calculating the standard error, adjustments were made for the cluster sampling method. To show the distribution of WTW corneal diameter, 25%, 50%, 75%, 95%, and 99% percentiles were determined. The mean ± 2 standard deviation was determined to show the normal range of WTW corneal diameter. Simple and multiple linear regressions were used to examine relationships between age, sex, and other biometric components. Pearson correlation coefficients and scatter plots were used to demonstrate correlations between WTW corneal diameter and other biometric components. In statistical analyses, data from aphakic people was used, and those with any prior history of ocular surgery were excluded.

Ethical considerations

All participants signed written consent forms after the project and methods were sufficiently explained to them, and before they had any examination. This study was approved by the Ethics Committee of Shahroud University of Medical Sciences.

Results

6311 people were invited to participate in the study; of these, 5190 people (82.2%) responded. Biometric examinations were done on 5111 participants; of these, 151 were excluded due to a history of surgery (cataract surgery: 115, glaucoma surgery: 7, retinal surgery: 8, and post-trauma surgery: 21). An additional 252 people were excluded due to lack of cooperation, pterygium, or erroneous measurements. Eventually, analyses were conducted on data from 4787 people. Their mean age was 50.7% $\pm$ 6.2 years, and 58.1% were female.

In light of the high correlation of WTW corneal diameter in contralateral eyes (r = 0.801), here we report results from right eyes only. Table 1 presents the 5%–99% percentiles of WTW corneal diameter in the studied sample. Table 2 contains the mean and 95% confidence interval of WTW corneal diameter by age and sex. Mean WTW corneal diameter was 11.80 mm (11.78–11.81) in the total sample. WTW corneal diameter was significantly higher in men ($p < 0.001$) and decreased by 0.013 mm with every year's increase in age ($p < 0.001$). No significant correlation was found between WTW corneal diameter and spherical equivalent (p = 0.639) and corneal arcus in the simple linear regression analysis.

Among various biometric components, the strongest correlations were found between WTW corneal diameter and radius of corneal curvature (r = 0.422, coefficient = −0.13, $p < 0.001$), followed by AL (r = 0.384, coefficient = 0.19, $p < 0.001$), lens thickness (r = 0.080, coefficient = −0.13, $p < 0.001$), and corneal thickness (r = 0.053, coefficient = −0.001, p = 0.002). Table 3 summarizes the results of the multiple linear regression model and the relationship of corneal diameter with the studied variables. All variables, except sex, significantly correlated with the corneal diameter. Age and corneal thickness correlated inversely with WTW corneal diameter, and AL, lens thickness, and corneal radius of curvature correlated directly with WTW corneal diameter. Spherical equivalent, which showed no correlation with corneal diameter in the simple model, significantly increased towards hyperopia with increases in corneal diameter in the multiple model.

Table 1
The percentiles of white-to-white corneal diameter (mm) by age and sex in the 40- to 64-year-old population of Shahroud, Iran, 2009.

	Percentile 5%	25%	50% (median)	75%	95%	99%
Total	11.05	11.52	11.81	12.10	12.52	12.86
Female	11.03	11.47	11.77	12.03	12.46	12.78
Male	11.11	11.60	11.88	12.18	12.61	12.96
Age group						
40–44	11.20	11.65	11.92	12.19	12.64	13.00
45–49	11.11	11.59	11.87	12.14	12.54	12.81
50–54	11.08	11.52	11.79	12.09	12.49	12.86
55–59	10.97	11.40	11.72	12.02	12.44	12.71
60–64	10.87	11.43	11.68	11.98	12.43	12.68

Table 2
The mean and 95% confidence intervals (95% CI) of white-to-white corneal diameter (mm) by age and gender. Shahroud, Iran, 2009.

Age group (year)	Male Mean (95% CI)	Female Mean (95% CI)	Total Mean (95% CI)
40–44	11.99 (11.93–12.05)	11.87 (11.84–11.91)	11.91 (11.88–11.94)
45–49	11.91 (11.86–11.95)	11.80 (11.77–11.83)	11.84 (11.82–11.87)
50–54	11.88 (11.84–11.92)	11.72 (11.68–11.75)	11.79 (11.76–11.82)
55–59	11.79 (11.74–11.83)	11.62 (11.58–11.66)	11.70 (11.67–11.73)
60–64	11.73 (11.67–11.79)	11.61 (11.55–11.67)	11.67 (11.63–11.71)
Total	11.87 (11.84–11.89)	11.75 (11.73–11.77)	11.8 (11.78–11.81)

CI: confidence interval.

Discussion

The validity of LENSTAR/BioGraph has previously been shown in studies by Holzer et al[9] and Buckhurst et al.[10] Its ease of use, high repeatability of its measurements,[10] and multiplicity of the measurements possible with this device, the LENSTAR/BioGraph may become more popular in epidemiologic and clinical studies. In this report, the WTW corneal

Table 3
The association of white-to-white corneal diameter (mm) with variables according to multiple linear regressions.

	Coefficient (95% CI)	p-value
Age (year)	−0.013 (−0.015 to −0.011)	< 0.001
Spherical equivalent (diopter)	0.081 (0.069–0.094)	< 0.001
Axial length (mm)	0.268 (0.238–0.298)	< 0.001
Lens thickness (mm)	0.119 (0.071–0.167)	< 0.001
Corneal curvature (mm)	0.153 (0.072–0.234)	0.002
Central corneal thickness (micron)	−0.001 (−0.002 to −0.001)	< 0.001
Arcus	−0.010 (−0.043 to −0.021)	0.648

CI: confidence interval.

diameter distribution measured in the normal population with the LENSTAR/BioGraph is presented for the first time.

Findings of this study are not only applicable to Iran, but since there are no other reports of measuring WTW corneal diameter in this age group with the LENSTAR/BioGraph, they can also be used as a reference in other parts of the world. According to our findings, mean WTW corneal diameter was 11.8 mm, and based on this mean and two standard deviations, the normal range of this index was 10.8–12.8 mm. The range reported in other studies largely varies from 9.98 mm[11] in newborns, using a digital camera, up to 12.25 mm[1] in a 20- to 51-year-old group, using a digital camera. Other reported values include 12.16 mm with the IOLMaster,[12] 11.71 mm using the Orbscan,[5] 12 mm with the video camera,[13] and 11.91 mm[14] using the partial coherence interferometry (PCI) (IOL-Master). The corneal diameter, as measured with Orbscan, was 11.56 mm in the 40–49 and the 50–59 age groups in Tehran.[3] There are other studies reporting various findings on WTW corneal diameter.[15–19] All these findings point to the variability of this index. Although the effects of race and ethnicity, and even different sample ages in these studies cannot be ignored, the main cause of the observed differences appears to lie in the choice of measurement technique. The normal range in this study, which was 10.8–12.8 mm, points to the need to update cutoff points for defining macrocornea and microcornea in ophthalmology textbooks[20] need to be updated based on different devices for Iranian population.

In this study, although sex significantly correlated with WTW corneal diameter in the simple regression model, the correlation was not seen in the multiple model. As we will discuss further, the inter-sex differences in AL and the strong correlation between AL and WTW corneal diameter probably biased the results seen for WTW corneal diameter and sex; nonetheless, literature concerning this issue is inconclusive.[3,5,7] As demonstrated, WTW corneal diameter significantly decreased linearly from 11.91 mm in the 40- to 44-year-old age group to 11.67 mm in the 60- to 64-year-old age group. This relationship was not observed in Tehran, where a wide range of people were examined,[3] but in agreement with our results, Rüfer et al[5] and Lee[21] found an age-related decrease in the corneal diameter. This decrease may be due to the atrophy of the ocular structures with aging. Previous reports have described decreases in the axial length of the eye with aging[21,22]; thus, part of the WTW corneal diameter change with age may be due to the correlation between AL and WTW corneal diameter.

As demonstrated, all biometric components significantly correlated with WTW corneal diameter, however, the correlations ranged from 0.422 for the corneal radius of curvature to 0.053 for the central corneal thickness.

Our findings indicated that corneas with a larger radius of curvature, i.e. flatter surface, are larger in diameter. This was previously reported in other studies. In keratorefractive surgery, there appears to be a higher risk of free cap with flatter corneas. In such situations, a larger suction diameter should be selected to create a larger flap. Thus, knowledge of the strong correlation between the corneal diameter and radius of curvature may have important applications in choosing the right microkeratome suction ring in laser surgeries.[23]

After radius of curvature, the axial length of the eye had the second strongest correlation with WTW corneal diameter. Since the axial length of the eye is one of the important indices of eye size, when it is large, other ocular components would be large as well. This relationship was previously reported.[24–26] There seems to be an optical explanation for this observation. We believe that as part of the emmetropization process in long eyes, which tend to be myopic, the cornea might elongate to increase the radius of curvature and shift towards hyperopia to compensate for myopia.[24–26] On the other hand, as demonstrated, WTW corneal diameter directly correlated with spherical equivalent. This relationship is due to the role of corneal radius of curvature in different types of refractive error. Cases with larger WTW corneal diameter had flatter corneas, and from previous studies, we know that the corneal radius of curvature is not only larger in cases of hyperopia, but they also have flatter corneas.[27,28]

In summary, we reported the mean and normal range of WTW corneal diameter measured with Biograph in an Iranian population. WTW corneal diameter significantly correlated with AL and radius of curvature.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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