White-to-White Corneal Diameter: normal values in the adult black South African population obtained with the Nidek AL-Scan

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Introduction

The human cornea has an ellipsoid shape with its greatest diameter in the horizontal meridian, known as the white-to-white (WTW) corneal diameter. The WTW corneal diameter was traditionally used to diagnose and manage congenital glaucoma, microcornea and megalocornea.[1] In the workup to ocular surgery, WTW additionally assists the ophthalmic surgeon in selecting specific ophthalmic devices such as contact lenses, corneal suction rings, corneal trephines, corneal implants, and premium intraocular lenses (IOL).[2–6]

The WTW was previously measured using handheld callipers or scales attached to slit lamps.[3] With the advent of modern ocular biometers, measuring WTW has become automated, more reliable and efficient.[7] However, the normal WTW range varies amongst different ethnic groups.[2,6,8–11] An Iranian study using the Orbscan II topography system reported a mean WTW distance of 11.65 ± 0.36 mm.[3] Another Iranian study utilising the Lenstar reported a mean WTW distance of 11.80 ± 0.5 mm.[6] Rüfer et al. reported the mean WTW distance in the German population to be 11.71 ± 0.42 mm. A Spanish and Canadian study reported a mean WTW distance of 11.9 + 0.2mm and 11.97 + 0.51mm, respectively.[9,10] A large retrospective study conducted in China on 39 986 eyes reported a mean WTW of 11.69 ± 0.46mm.[8] In the East Asian population, anterior segment structures (WTW, anterior chamber depth and corneal vault) are smaller than Caucasians.[2] This anatomical variation puts East Asians at increased risk of developing primary angle-closure glaucoma.

There is a paucity of data for the black population regarding WTW. A Nigerian study reported a mean horizontal corneal diameter of 11.39 ± 0.69mm.[11] This study utilised

a millimetre ruler to measure WTW instead of an ocular biometer, which could account for the significantly smaller WTW than other population-based studies.

Obtaining average WTW values for the black population can support future studies, especially those looking at anterior segment parameters and associated pathologies. In addition, if differences in WTW exist in black patients' corneas, this information can guide size-specific manufacturing of contact lenses, corneal implants, and intraocular lenses.

This study describes the normal WTW values of adult black South Africans aged 40 to 90 years. The secondary objective is to stratify normal WTW values by race, age and gender.

Methodology

This is a retrospective comparative record review of WTW corneal diameter measured by the Nidek AL-Scan in adult black and white South African patients between 40 and 90 years. The WTW of black patients was obtained at St John Eye Hospital in Soweto, where most of the patients consulting are black based on the hospital's geographic location. The WTW of white patients was collected from two private ophthalmology practices in South Africa. The University of the Witwatersrand Human Research Ethics Committee approved this study (M171047), and it adhered to the tenets of the Declaration of Helsinki.

The WTW distance of adult black patients recorded between January 2017, and June 2021 was analysed. These data were cross-referenced with the Chris Hani Baragwanath Academic Hospital computerised database (Medi-com) to verify each patient's race, age and gender. The WTW distance of adult white patients was included if captured on the Nidek AL-scan before June 2021. Patients' race, age and gender were pulled from the onsite database at the two private practices. WTW corneal diameters that fell out of the age range were excluded. If the WTW of the right eye was unavailable, the WTW of the left eye was used. The WTW measurements associated with incomplete patient information (gender, age or race) were also excluded from the study.

The WTW data was divided into ten age groups for the black patients, each spanning 5 years from 40 – 90 years. Each age category for the two gender groups required at least 30 WTW measurements to reliably determine the mean, median, 5^{th}, 10^{th}, 25^{th}, 75^{th} and 95^{th} percentiles for the WTW in the black population. With a given sample size of 600 for the black group, the white group's sample size was targeted at 400 to provide a total of 1000 patients. Smaller sample size for the white group was required because calculating the WTW norms for each age category between 40 - 90 years for the two genders was not the aim of the study.

The effect of race, age, gender, and their interactions on WTW was assessed by a General Linear Model (GLM) with WTW as the dependent variable and age, gender, race, and two-way interactions as the independent variables. Non-significant interaction terms were removed from the model.

The data analysis was carried out in Stata (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC). A 5% significance level was used.

Results

A total of 1039 eyes from 1039 patients were included in the study; 680 were black patients (65.4%), and 359 were white patients (34.6%). There were not enough black patients (total patients less than 30) in the following age groups to calculate norms: 40-44 years (both genders), 45-49-year-old males, and 85-90 years (both genders). There were more females than males in both race groups. For the white patients, there were more data for older female patients above 65 years of age. There were 673 right eyes in total (64,8%). Table 1 shows the proportion of patients in each category: race, gender, age groups and eye laterality.

Table 1. Descriptive Characteristics of the Entire Study Sample

Characteristic	Category	n	%
Total		**1039**	
Race	Black	680	65,4
	White	359	34,6
Gender (black and white patients)	Female	609	58,6
	Male	430	41,4
Age group (black and white patients)	40-44y	53	5,1
	45-49y	68	6,5
	50-54y	74	7,1
	55-59y	89	8,6
	60-64y	120	11,5
	65-69y	154	14,8
	70-74y	169	16,3
	75-79y	133	12,8
	80-84y	114	11,0
	85-90y	65	6,3
Eyes (black and white patients)	Left	366	35,2
	Right	673	64,8

The mean WTW for the black patients was 11.58 $\pm$ 0.56 mm, and for the white patients, it was 11.84 $\pm$ 0.58 mm. The mean WTW distance in black patients (11.58 mm; 95% CI 11.55 – 11.64 mm) was significantly smaller than the mean WTW distance in white patients (11.88 mm; 95% CI 11.81 – 11.84 mm) ($p < 0.001$). In black patients, 0.1% had WTW corneal diameters of less than 10 mm, and 3.5% had WTW of greater than 12.5 mm. In white patients, 0.8% of patients had corneal diameters of less than 10 mm and 9.2% of patients had WTW greater than 12.5 mm.

The percentiles (5^{th}, 10^{th}, 25^{th}, 50^{th}, 75^{th}, 90^{th} and 95^{th}) for each gender-age category combination for black patients are shown in figure 1.

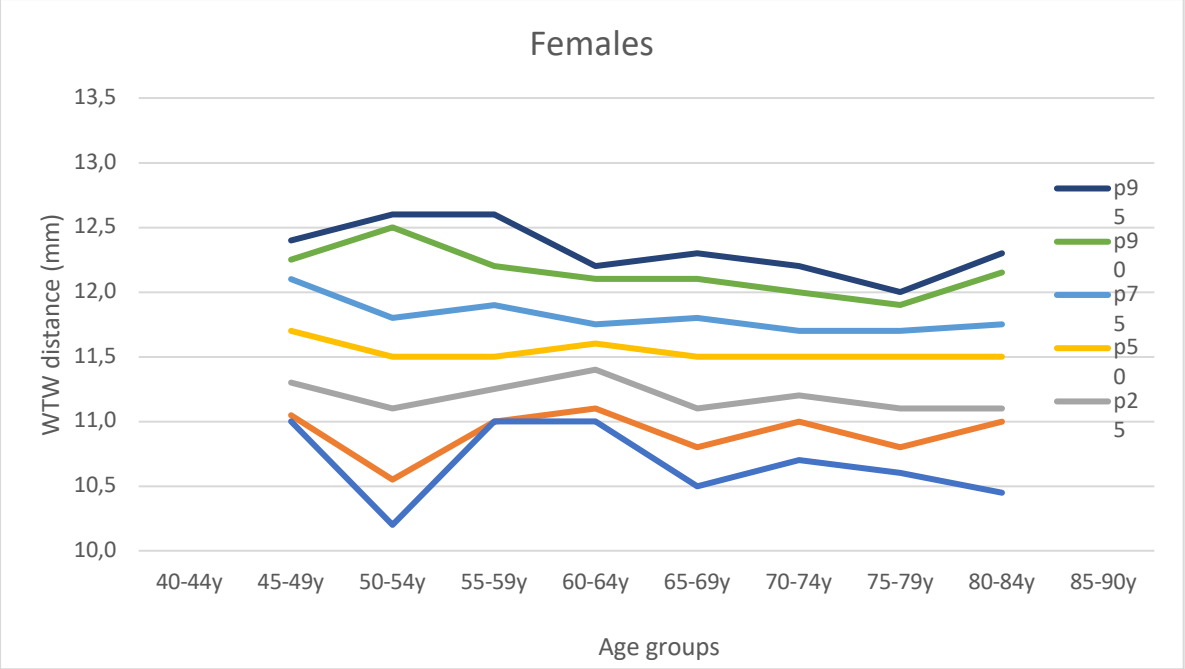

Figure 1a. The WTW percentiles for black patients plotted for the female sex-age category.

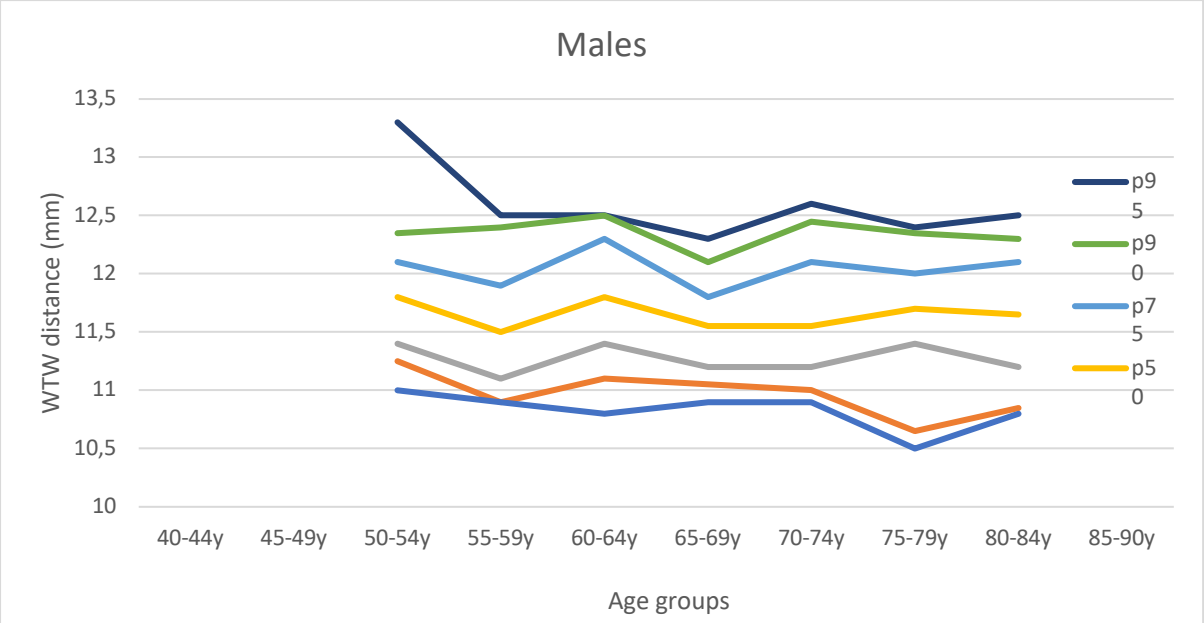

Figure 1b. The WTW percentiles for black patients plotted for the male sex-age category.

The effects of age category, gender and race on WTW were significant (p=0.0035, 0.0001 and < 0.001, respectively). However, none of the two-factor or three-factor interactions were significant and so were removed from the model.

The post-hoc tests showed that the least squares (LS) estimated mean WTW diameter was significantly larger for those aged 40-44 years and 45-49 years than those aged 85-90 years (p=0.034 and 0.003, respectively), as shown in figure 2. Males (black and white patients) had a significantly larger mean WTW (11.80 mm; 95% CI 11.75-11.86 mm) compared to females (11.67 mm; 95% CI 11.62-11.72 mm) (p=0.0001).

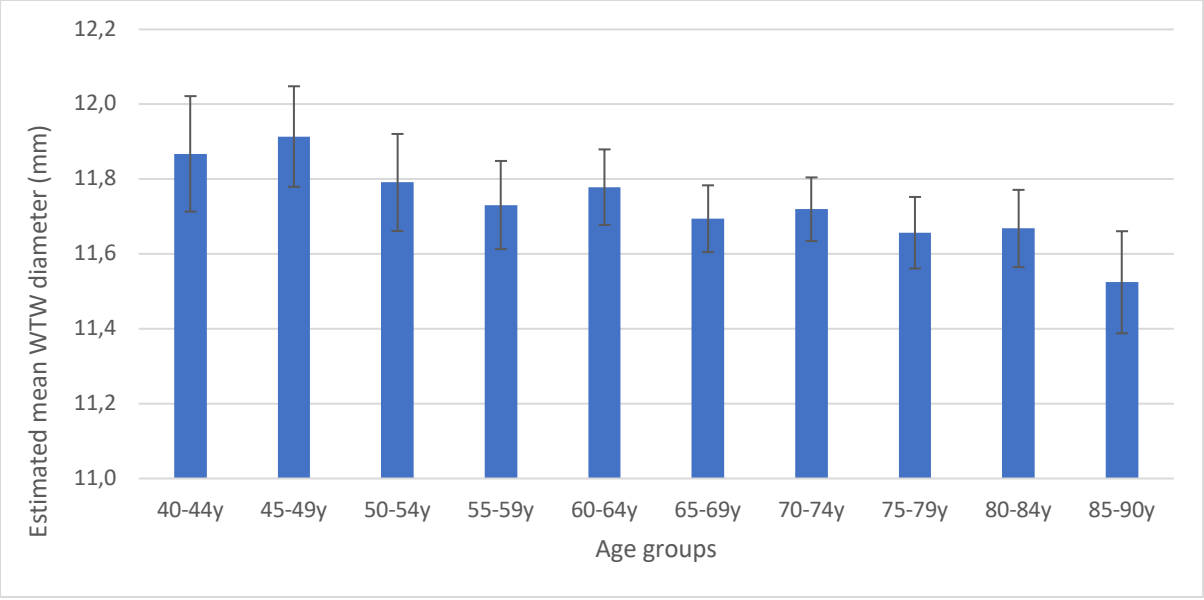

Figure 2. The least squares (LS) estimated mean WTW diameter plotted for each age group. This is an estimation of the mean WTW for age across race and gender. *The error bars in the figure below denote the 95% confidence interval for the mean.*

Discussion

The WTW distance is an ocular biometer variable used for diagnosing and managing congenital glaucoma, microcornea and megalocornea.[1] Its use has expanded into the sizing of ophthalmic devices such as contact lenses, corneal suction rings, corneal trephines, corneal implants, and premium intraocular lenses (IOL).[2–6]

This study found South African black patients to have significantly smaller WTW corneal diameters with a mean of 11.58 mm (95% CI 11.55 – 11.64 mm) compared to white patients with a WTW mean of 11.88 mm (95% CI 11.81 – 11.84 mm) ($p < 0.001$) using measurements from the Nidek AL-Scan. There have been no prior studies aimed at calculating population WTW norms utilising the Nidek AL-scan. However, other studies used WTW as a measuring parameter to compare the Nidek AL-scan to other optical biometers, e.g. Sirius (CSO, Florence, Italy), Galilei Dual Scheimpflug Analyzer (Ziemer, Port, Switzerland)[12–14], and therefore had smaller sample sizes.

An African study investigating the relationship of age, gender, corneal diameter, corneal curvature, and central corneal thickness in Nigerians with normal intraocular pressure obtained a mean horizontal corneal diameter of 11.39 $\pm$ 0.69 mm in the age range of 20-79 years.[11] The smaller horizontal corneal diameter from the Nigerian study compared to the mean WTW of 11.58 + 0.56 mm for black patients in our study could be related to their measurement technique. The horizontal corneal diameter was manually measured with a millimetre ruler, recording the distance between the nasal and temporal visible iris at the limbus junction along the centre of the pupil. This measurement is not the true WTW, as the WTW is the horizontal distance between the corneal limbus and not the visible iris. [3]

Males (black and white) in this study had larger WTW corneal diameters than females 11.80 mm (95% CI 11.75-11.86 mm) vs 11.67 mm (95% CI 11.62-11.72 mm) (p=0.0001). This finding echoes the results of other studies.[6,8,11] However, Rüfer et al[15] found no significant difference in the WTW means between genders. Iranian research by Gharaee et al[3] found males to have smaller WTW corneal diameters than females; 11.60 mm (SD 0.35 mm) vs 11.71 mm (SD 0.36 mm), respectively.

The progression between the age categories in black males and females was not smooth due to the small sample sizes. Post-hoc analysis showed that the estimated Least Squares mean WTW diameter was significantly larger for those aged 40-44 years and 45-49 years than those aged 85-90 years (p=0.034 and 0.003, respectively). This result is similar to other studies that showed a negative correlation between WTW distance and age.[3,6,8,15] A reduction in corneal size with age may have clinical implications, such as the increased risk of glaucoma due to compacting of angle structures.[15]

There is a high correlation between right and left eyes[3,6–8], therefore, left WTW corneal measurements were used in this study when right WTW corneal measurements were unavailable. The normal WTW range for black patients in South Africa is between 10.46 mm and 12.7 mm, examined with the Nidek AL-scan at the 95% confidence interval. At present, the accepted WTW range is between 10 to 13 mm.[7] However, the definition of microcornea and megalocornea varies depending on the textbook or article. Microcornea is defined as 10[1] to 11 mm[16,17] or less, and megalocornea is

defined as 12.5 mm[18] to 13 mm[1,18] or more. Based on the normal range of this study, black patients' corneas less than 10.46 mm should be considered microcornea, and corneas greater than 12.7 mm should be regarded as megalocornea.

It is known that black patients are at increased risk of primary open-angle glaucoma (POAG) and that thinner central corneal thicknesses (CCT) are a risk factor for the development of glaucoma.[19] A South African study by Bagus et al confirmed that many black patients have thinner corneas.[20] Therefore, it is of interest to investigate the relationship between WTW corneal diameters with other anterior segment parameters, including CCT, and whether there are WTW differences in POAG and non-POAG patients in the black South African population.

The retrospective nature of this study has inherent limitations. Patients with pterygiums, ocular surface diseases, and prior intraocular or extraocular surgeries could not be identified and excluded. Distortion of the ocular surface can result in inaccurate WTW measurements. The WTW data reported on the Nidek AL-scan have been measured by multiple examiners and are therefore subject to inter-operator errors. The Nidek AL-scan was used to measure WTW, which is less reliable compared to the IOLMaster.[14,21]

The application of WTW has evolved from simply diagnosing and managing anterior segment pathologies to the sizing of various ophthalmic devices, especially intraocular lenses. Our study is the first to investigate the normal WTW corneal diameters in

black South African patients. Future studies could investigate the relationship between WTW and other anterior segment parameters in the black South African population and its role in ocular pathologies.

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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