

Normative Values for Corneal Tomography and Comparison of Both Eyes in Young Saudi Males with 20/20 Vision Using Pentacam-HR Scheimpflug Imaging

Omar Alshehri¹, Ahmed M Abdelaal², Ghufraan Abudawood¹, Muhammad A Khan³, Saud Alsharif⁴, Hassan Hijazi¹, AlBaraa AlQassimi¹

¹Ophthalmology Department, King Fahad Armed Forces Hospital, Jeddah, Saudi Arabia; ²Ophthalmology Department, Prince Sultan Military Medical City, Riyadh, Saudi Arabia; ³Epidemiology and Public Health Department, King Saud Bin Abdulaziz University, Jeddah, Saudi Arabia; ⁴Faculty of Medicine, Imam Mohammad Ibn Saud Islamic University, Riyadh, Saudi Arabia

Correspondence: Ahmed M Abdelaal, Ophthalmology Department, Prince Sultan Military Medical City, Riyadh, Saudi Arabia, Tel +966 56 371 8789, Email ahmed3bdelaal@gmail.com

Purpose: Anterior segment evaluation using Scheimpflug imaging with the Pentacam scanner allows the acquisition of a plethora of information. It aids in screening and diagnosing corneal pathologies and determining suitability for keratorefractive procedures. This research has significant benefits in terms of establishing normative tomographic values, which is crucial in countries where Keratoconus (KC) is more prevalent, especially among young age group, along with aiding future research in the field of refractive surgery by providing relevant normative data.

Methods: A retrospective review of digital corneal tomography images for a group of medically and ophthalmologically free males aged between 18 and 21 years with 20/20 unaided distant visual acuity was performed.

Results: A total of 1272 subjects (2544 eyes) were included. Findings revealed a mean maximal corneal curvature (Kmax) of 42.91 ± 1.40 D (range 36.90–47.80D). The mean flat keratometry (K1) was 41.87 ± 1.31 D (range 36.00–46.40D). The mean steep keratometry (K2) was 42.66 ± 1.35 D (range 36.70–47.60D). The mean corneal astigmatism (CA) was 0.79 ± 0.37 D (range 0.00D–2.30D). The mean central corneal thickness (CCT) was 558.53 ± 33.84 μ m (range 421–677 μ m). The mean thinnest corneal location thickness (TCLT) was 551.64 ± 34.08 μ m (range 417–669 μ m). The mean corneal diameter (CD) and anterior chamber depth (ACD) were 12.13 ± 0.39 mm (range 10.50–13.60 mm) and 3.12 ± 0.29 mm (range 2.08–4.08 mm), respectively. The median differences between both eyes of the same subject were as follows: kmax difference of 0.20D (IQR 0.1–0.4); K1, K2 and CA difference of 0.20D (IQR 0.1–0.3) for all 3 parameters; CCT and TCLT difference of 5.00 μ m (IQR 3.0–9.0) and 6.00 μ m (IQR 3.0–10.0), respectively; CD difference of 0.10 mm (IQR 0.0–0.1); and ACD difference of 0.04 (IQR 0.02–0.06).

Conclusion: We believe our data can aid in establishing normative tomographic values and acceptable differences between both eyes. Our data may also help detect subtle corneal pathology and be useful for researchers and innovators in the field of ophthalmology.

Keywords: corneal tomography, corneal topography, pentacam, normative values, Saudi Arabia

Introduction

Mapping corneal topography using Scheimpflug photography as can be obtained by the Pentacam eye scanners has become increasingly important in routine patient care, providing topographic imaging and values of the cornea, as well as details of the anterior chamber. It has been widely used in both clinical and research settings since the turn of the century, and it has received Food and Drug Administration approval in the United States in 2003.^{1–3} In addition, the repeatability and reliability of information obtained from corneal topography using the Oculus Pentacam have been investigated and well established.^{4,5}

Over the last decade, increased safety and efficacy of both keratorefractive and intraocular refractive surgeries have also been noted.⁶ With increased interest in undergoing such procedures, corneal topography has been used to inform suitability for such procedures and detect subtle corneal ectasias that would prevent potentially unwarranted interventions.⁷⁻⁹ The importance of values obtainable via corneal topography is also influential in intraocular pressure measurement and consequent risk stratification for ocular hypertension and glaucoma.¹⁰

Furthermore, diagnostic information for conditions such as keratoconus (KC) may be obtained at earlier stages, as well as the astigmatic effect of ocular surface disorders such as pterygia and limbal dermoids.⁷ Early detection of KC is crucial in countries with a high prevalence of KC.^{8,11,12} This would potentially help decrease the magnitude of corneal transplantations performed for this indication, where KC remains the most common indication for keratoplasty.¹³

Corneal curvature, corneal diameter or white-to-white distance and, anterior chamber depths of several age groups and populations with variable degrees of ametropia have been previously recorded in several studies with differences found based on age, gender, and geographic location.¹⁴⁻¹⁶

In our study, we aim to report the normal corneal and anterior chamber values, as well as the expected difference between both eyes of a large group of young medically and ophthalmologically free Saudi males with unaided distant visual acuity (UDVA) of 20/20 in both eyes, obtained from Scheimpflug photography imaging using the Pentacam HR (high-resolution) tomographer (Oculus, Wetzlar, Germany). We hope our reported values can help detect abnormal corneas and anterior segments by providing normal values, ranges, and acceptable inter-ocular differences associated with UDVA of 20/20 in ophthalmologically free individuals. In addition, these values may also help inform future keratorefractive or intraocular refractive innovations and future research.

Materials and Methods

A retrospective review of digital corneal topography images of both eyes for a group of medically and ophthalmologically free Saudi males between the ages of 18 and 21 seeking employment was performed. Those who qualified for topographic evaluation all demonstrated: 20/20 UDVA in both eyes (OU), normal color vision using the Ishihara test OU and the absence of anterior or posterior ocular pathology in either eye on slit-lamp evaluation. Persons not meeting any of the above criteria did not undergo imaging using the Pentacam HR.

Inclusion and Exclusion Criteria: inclusion criteria were all eyes who qualified for and underwent Pentacam HR imaging. Exclusion criteria for those who did undergo Pentacam HR imaging were any individual with quality specifications (QS) issues as indicated by the study due to factors such as blinking or poor fixation in either eye; for such findings, OU were excluded from the study to allow for comparison between OU of all individuals.

All data were collected and recorded into spreadsheets directly from imaging reviewed on the Pentacam HR Program. Data collected from all eyes included maximal corneal curvature (Kmax), flat keratometry (K1), steep keratometry (K2), corneal astigmatism (CA), central corneal thickness (CCT), thinnest corneal location thickness (TCLT), corneal diameter (CD) and anterior chamber depth (ACD) for OU of all those who met our inclusion and exclusion criteria. The parameters from both of an individual's eyes were used to calculate the difference between OU. An informed consent obtained from the study participants prior to study commencement although no identifying information was recorded throughout the study, and every precaution was taken to preserve the confidentiality of participants.

Statistical methods: Data analysis was performed with the help of using IBM Statistic SPSS (SPSS Inc., Chicago, IL, USA) version 20.0. Frequencies and percentages were calculated and presented in graph format. Descriptive analysis was conducted to summarize the data set by presenting all the numerical data as mean + standard deviation/median and interquartile range (IQR) as appropriate.

The study was conducted in accordance with the Declaration of Helsinki. The ethical approval was obtained from The Research Ethics Committee of the Medical Services Department for Armed Forces, Scientific Research Center.

Results

A total of 1301 subjects qualified for topographic evaluation after careful examination established UDVA of 20/20 OU, normal color vision, and the absence of any ocular pathology on slit-lamp evaluation. A review of topographic studies of

OU of the 1301 subjects revealed 29 subjects who had QS issues in either eye, which excluded the data of both their eyes from our study. Thus, in total, data of 1272 subjects and 2544 eyes were included in our analysis.

Values of All Parameters for All Eyes Obtained by Pentacam HR Imaging

Findings from all eyes from all subjects in our study revealed a mean Kmax of $42.91 \pm 1.40D$ ranging from 36.90D to 47.80D. The mean K1 was $41.87 \pm 1.31D$ ranging from 36.00D to 46.40D. The mean K2 was $42.66 \pm 1.35D$ with a range of 36.70D to 47.60D. The mean CA for all eyes was $0.79 \pm 0.37D$ ranging from 0.00D to 2.30D. The mean CCT of all eyes from all subjects in our study was $558.53 \pm 33.84\mu\text{m}$ (range 421–677 μm). The mean TCTL was $551.64 \pm 34.08\mu\text{m}$ (range 417–669 μm). The mean CD of all eyes in our study was $12.13 \pm 0.39\text{ mm}$, with a range of 10.50 mm to 13.60 mm. The average ACD of all eyes in our study was $3.12 \pm 0.29\text{ mm}$, ranging from 2.08 mm to 4.08 mm. Table 1 summarizes the minimum, maximum, and mean values of the parameters obtained from all eyes.

Distribution of Values for All Parameters of All Eyes

For Kmax values, the majority of eyes (77.7%) had Kmax readings of 41–44, (19.9%) had Kmax > 44D, and (2.4%) had Kmax \leq 40D. K1 values showed a similar distribution with (72.9%) of eyes having K1 readings of 41–44D, (18.7%) of eyes having a K1 > 44D, and (8.4%) of eyes having K1 values of \leq 40D. The distribution of K2 values behaved similarly to the distribution of Kmax and K1 in our study, with (78.8%) of eyes having a K2 of 41–44D, (18.1%) of eyes having a K2 of >44D, and (3.1%) of eyes having a K2 of \leq 40D. The most frequently encountered CA values in our study were in the range of 0.5–0.9D with (50.8%) of eyes, followed by CA of 1.0–1.4D (26%), CA of \leq 0.4D (18.7%), and CA of \geq 1.5D in (4.5%) of eyes. The majority (49.9%) of eyes had CCT values in the range of 550–599 μm , (35.2%) of eyes had a CCT of 500–549 μm , (10.6%) of eyes had a CCT of \geq 600 μm and (4.3%) of eyes had a CCT of \leq 499 μm . TCTL distribution was similar to the distribution of CCT with most eyes (44.7%) having TCTL of 550–599 μm , followed by a TCTL of 500–549 μm in (41.4%) of eyes, a TCTL of \geq 600 μm in (7.7%) of eyes and only (6.3%) of eyes having a TCTL of \leq 499 μm . The most frequently encountered CD were in the range of 12–12.4 mm (49.1%), followed by CD in the range of 11.5–11.9 mm (27.3%), CD 12.5–12.9 mm (17.7%), CD 11.0–11.4 mm (3.6%), \geq 13 mm (1.8%) and CD <11 mm (0.5%). The majority of eyes had ACD values between 3.00 and 3.49 mm (57.3%), followed by ACD of 2.50–2.99 mm (32.5%), ACD of \geq 3.50 mm (9.5%) and ACD <2.5 mm (0.7%). Figure 1 shows the distribution of the values ranges for all parameters obtained from all eyes included in the study.

Table 1 Number, Range and Mean with Standard Deviation Values for All Study Parameters

Parameter	N	Min	Max	Mean	SD
Kmax	2544	36.90	47.80	42.91	1.40
K1	2544	36.00	46.40	41.87	1.31
K2	2544	36.70	47.60	42.66	1.35
CA	2544	0.00	2.30	0.79	0.37
CCT	2544	421.00	677.00	558.53	33.84
TCTL	2544	417.00	669.00	551.64	34.08
CD	2544	10.50	13.60	12.13	0.39
ACD	2544	2.08	4.08	3.12	0.29

Abbreviations: Kmax, maximal corneal curvature; K1, flat keratometry; K2, steep keratometry; CA, corneal astigmatism; CCT, central corneal thickness; TCTL, thinnest corneal location thickness; CD, corneal diameter; ACD, anterior chamber depth.

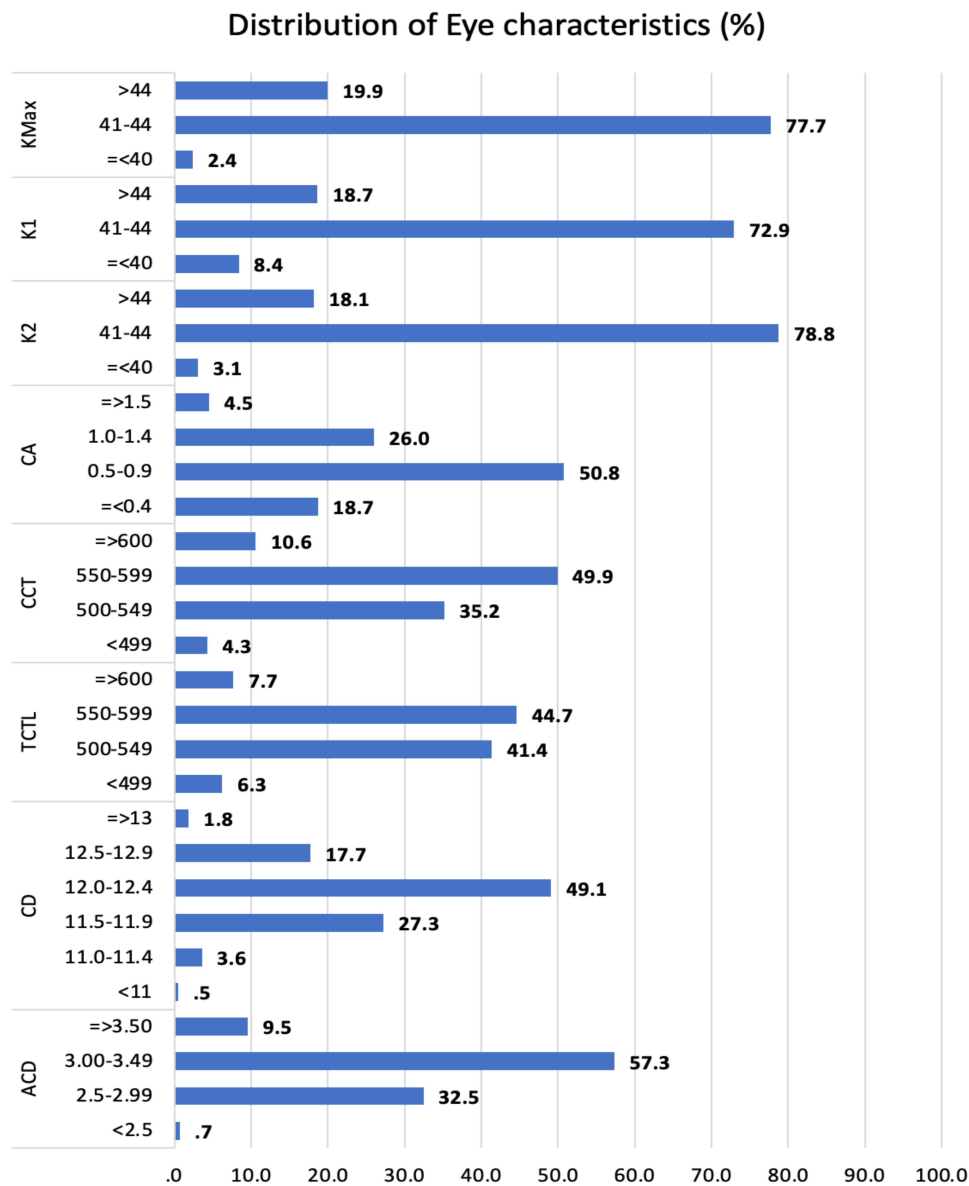


Figure 1 Distribution of Values for all Study Parameters.

Abbreviations: Kmax, maximal corneal curvature; K1, flat keratometry; K2, steep keratometry; CA, corneal astigmatism; CCT, central corneal thickness; TCTL, thinnest corneal location thickness; CD, corneal diameter; ACD, anterior chamber depth.

The Difference in Values Between Both Eyes of the Same Individual for All Subjects

The median difference in Kmax between the two eyes of the same subject was 0.20D (IQR 0.1–0.4). The median difference in K1, K2, and CA between the same subject’s eyes was found to be 0.20D (IQR 0.1–0.3) for all three parameters. The median difference in CCT and TCTL between the two eyes of the same subject study was 5.00 μm (IQR 3.0–9.0) and 6.00 μm (IQR 3.0–10.0). The median difference in thickness between CCT and TCTL between the two eyes of a single subject was 2.00 μm (IQR 1.0–4.0). The median difference in CD between the two eyes of the same subject was 0.10 mm (IQR 0.0–0.1), and the median difference in ACD between the two eyes of the same subject was 0.04 (IQR 0.02–0.06). Table 2 shows the median difference and IQR between both eyes of the same subject for all individuals in the study.

Table 2 Difference in Value Between Both Eyes of the Same Subject for All Parameters

Difference in Parameter	Median	IQR
Kmax	0.20	0.1–0.4
K1	0.20	0.1–0.3
K2	0.20	0.1–0.3
CA	0.20	0.1–0.3
CCT	5.00	3.0–9.0
TCTL	6.00	3.0–10.0
Difference between CCT and TCTL of both eyes	2.00	1.0–4.0
CD	0.10	0.0–0.1
ACD	0.04	0.02–0.06

Abbreviations: Kmax, maximal corneal curvature; K1, flat keratometry; K2, steep keratometry; CA, corneal astigmatism; CCT, central corneal thickness; TCTL, thinnest corneal location thickness; CD, corneal diameter; ACD, anterior chamber depth.

Discussion

Imaging performed using the Pentacam delivers an abundance of corneal parameters that provide important diagnostic information and has shown to be highly accurate in ascertaining clinical and subclinical corneal pathology.^{17,18}

Parameters that may be obtained from Pentacam imaging include keratometry values related to corneal curvature. The Pentacam has become invaluable to clinical practice when investigating for and diagnosing corneal ectasias such as KC. Diagnostic criteria for KC have been suggested based on parameters obtained by corneal topography and include keratometry readings of >45D.⁹ Lower keratometry values of <40D are also possible indicators of diagnosis, such as cornea plana.¹⁹ In our study, keratometry values (Kmax, K1, and K2) that had achieved UDVA of 20/20 ranged from 36.70 to 47.80D.

High CA is also suggestive of KC, and a study on 137 patients with KC showed a mean CA of 3.90 ± 2.75 D using Pentacam HR imaging.²⁰ In our study on emmetropic eyes for UDVA of 20/20, CA ranged from 0.0 to 2.30D with a mean CA of 0.79 ± 0.37 D, which is considerably lower than the mean CA from eyes with KC and another study on normal eyes which included eyes with ametropia.^{20,21} Our CA finding was also substantially less than the mean CA values of 1.12 ± 1.10 (range 0.0–7.00) found in an older population who were presenting for elective cataract surgery.²²

Other corneal parameters classically obtained by the Pentacam include corneal thickness, which has been shown to affect IOP and glaucoma risk stratification.^{23–25} CCT and TCTL also have implications on patient suitability for keratorefractive procedures for correction of ametropia, with lower values considered increasing the risk of ectasias following such procedures.^{26,27} In our study CCT, ranged from 421 μ m to 677 μ m with a mean CCT of 558.53 ± 33.84 μ m, while TCTL ranged from 417 μ m to 669 μ m with a mean TCTL of 551.64 ± 34.08 μ m. Other studies on different populations and ethnic backgrounds suggest no variation in mean CCT with mean CCT values ranging from 525 ± 38.4 – 570 ± 31.8 μ m spanning the mean CCT value in our study.^{28–32} In addition, results from a local study comparing two different modalities of corneal thickness measurement showed very similar results.³³

CD is classically used to aid in diagnoses such as microcornea, megalocornea, and congenital glaucoma; however, no value can be used as a clear cut-off between normal and abnormal. In our study, clinically normal eyes capable of UDVA of 20/20, corneal diameters varied from 10.50 mm to 13.60 mm. Our results for CD are similar to other studies on populations of varying ages, ethnicities, and refractive statuses.^{34–39}

ACD is another value that can be routinely obtained with the Pentacam and has become a more significant value in the field of refractive surgery with implications on the suitability and success of phakic intraocular lenses.⁴⁰ The evolution of intraocular refractive surgery and the advent of newer intraocular lenses allow spectacle and contact lens

freedom for those unable to undergo keratorefractive surgeries due to high levels of ametropia or due to common ocular surface abnormalities such as keratoconjunctivitis sicca when values including ACD permit. In our study, the ACD ranged from 2.08 to 4.08 mm with a mean ACD of 3.12 mm and (66.8%) of eyes having ACD of ≥ 3.00 mm.

Our study is not without limitations. Due to the patient population seeking employment and consequently included in our study of emmetropic eyes, all eyes in this study belonged to males aged 18 and 21 years. Therefore, despite the large sample size and unique characteristics of ophthalmological free eyes with UDVA of 20/20, generalization of our results to different age groups and eyes belonging to females needs to be done carefully, taking into consideration findings of previous literature. Further studies on ophthalmological free eyes with UDVA of 20/20, including eyes belonging to both genders and more variable age groups would be ideal and help establish differences between genders, if any, and the change in values obtained by Pentacam at different ages.

Conclusion

We believe the data provided from our study can be beneficial for detecting subtle or subclinical abnormalities from corneal topography imaging, especially in unilateral or asymmetric disease, as we have reported a potentially normal reference range of acceptable and expected difference between both eyes in emmetropic individuals without ocular pathology. Our data may also help improve results following refractive procedures and prove useful for innovators in the field of keratorefractive surgery, manufacturers of intraocular lenses, and others to continue the evolution being witnessed in the field of refractive surgery and ophthalmology.

Funding

There are no funders to report.

Disclosure

The authors declare that they have no conflict of interest.

References

1. AlMahmoud T, Priest D, Munger R, Jackson WB. Correlation between refractive error, corneal power, and thickness in a large population with a wide range of ametropia. *Invest Ophthalmol Vis Sci.* 2011;52(3):1235–1242. doi:10.1167/iovs.10-5449
2. Zhang L, Wang Y. The shape of posterior corneal surface in normal, post-LASIK, and post-epi-LASIK eyes. *Invest Ophthalmol Vis Sci.* 2010;51(7):3468–3475. doi:10.1167/iovs.09-4811
3. Zhuang H, Zhou X, Xu J. A novel method for pachymetry mapping of human precorneal tear film using Pentacam with fluorescein. *Invest Ophthalmol Vis Sci.* 2010;51(1):156–159. doi:10.1167/iovs.08-3265
4. McAlinden C, Khadka J, Pesudovs K. A comprehensive evaluation of the precision (repeatability and reproducibility) of the Oculus Pentacam HR. *Invest Ophthalmol Vis Sci.* 2011;52(10):7731–7737. doi:10.1167/iovs.10-7093
5. Chen D, Lam AK. Reliability and repeatability of the Pentacam on corneal curvatures. *Clin Exp Optom.* 2009;92(2):110–118. doi:10.1111/j.1444-0938.2008.00336.x
6. Kim TI, Alio Del Barrio JL, Wilkins M, Cochener B, Ang M. Refractive surgery. *Lancet.* 2019;393(10185):2085–2098. doi:10.1016/S0140-6736(18)33209-4
7. Ghemame M, Charpentier P, Mouriaux F. Corneal topography in clinical practice. *J Fr Ophthalmol.* 2019;42(10):e439–e451. doi:10.1016/j.jfo.2019.09.001
8. Althomali TA, Al-Qurashi IM, Al-Thagafi SM, Mohammed A, Almalki M. Prevalence of keratoconus among patients seeking laser vision correction in Taif area of Saudi Arabia. *Saudi J Ophthalmol.* 2018;32(2):114–118. doi:10.1016/j.sjopt.2017.11.003
9. Holladay JT. Keratoconus detection using corneal topography. *J Refract Surg.* 2009;25(10 Suppl):S958–62. doi:10.3928/1081597X-20090915-11
10. Gordon MO, Beiser JA, Brandt JD, et al. The ocular hypertension treatment study: baseline factors that predict the onset of primary open-angle glaucoma. *Arch Ophthalmol.* 2002;120(6):714–730. doi:10.1001/archophth.120.6.714
11. Assiri AA. Incidence and severity of keratoconus in Asir province, Saudi Arabia. *Br J Ophthalmol.* 2005;89(11):1403–1406. doi:10.1001/archophth.120.6.714
12. Torres Netto EA, Al-Otaibi WM, Hafezi NL, et al. Prevalence of keratoconus in paediatric patients in Riyadh, Saudi Arabia. *Br J Ophthalmol.* 2018;102(10):1436–1441. doi:10.1136/bjophthalmol-2017-311391
13. Al-Towerki AE, Gonnah El S, Al-Rajhi A, Wagoner MD. Changing indications for corneal transplantation at the King Khaled Eye Specialist Hospital (1983–2002). *Cornea.* 2004;23(6):584–588. doi:10.1097/01.icc.0000121708.58571.5b
14. Brandt JD, Beiser JA, Kass MA, Gordon MO. Central corneal thickness in the Ocular Hypertension Treatment Study (OHTS). *Ophthalmology.* 2001;108(10):1779–1788. doi:10.1016/s0161-6420(01)00760-6
15. Reddy SP, Bansal R, Vaddavalli PK. Corneal topography and corneal thickness in children. *J Pediatr Ophthalmol Strabismus.* 2013;50(5):304–310. doi:10.3928/01913913-20130806-02

16. Feng MT, Belin MW, Ambrosio R Jr, et al. Anterior chamber depth in normal subjects by rotating scheinplufg imaging. *Saudi J Ophthalmol.* 2011;25(3):255–259. doi:10.1016/j.sjopt.2011.04.005
17. de Sanctis U, Loiacono C, Richiardi L, Turco D, Mutani B, Grignolo FM. Sensitivity and specificity of posterior corneal elevation measured by Pentacam in discriminating keratoconus/subclinical keratoconus. *Ophthalmology.* 2008;115(9):1534–1539. doi:10.1016/j.ophtha.2008.02.020
18. Hashemi H, Khabazkhoob M, Yazdani K, Mehravaran S, Mohammad K, Fotouhi A. White-to-white corneal diameter in the Tehran Eye Study. *Cornea.* 2010;29(1):9–12. doi:10.1097/ICO.0b013e3181a9d0a9
19. Al Hazimi A, Khan AO. Axial lengths in children with recessive cornea plana. *Ophthalmic Genet.* 2015;36(2):123–125. doi:10.3109/13816810.2013.851249
20. Kamiya K, Shimizu K, Igarashi A, Miyake T. Assessment of anterior, posterior, and total central corneal astigmatism in eyes with keratoconus. *Am J Ophthalmol.* 2015;160(5):851–857 e1. doi:10.1016/j.ajo.2015.08.016
21. Kobashi H, Kamiya K, Igarashi A, et al. Comparison of corneal power, corneal astigmatism, and axis location in normal eyes obtained from an autokeratometer and a corneal topographer. *J Cataract Refract Surg.* 2012;38(4):648–654. doi:10.1016/j.jcrs.2011.11.026
22. Ferrer-Blasco T, Montes-Mico R, Peixoto-de-matos SC, Gonzalez-Mejome JM, Cervino A. Prevalence of corneal astigmatism before cataract surgery. *J Cataract Refract Surg.* 2009;35(1):70–75. doi:10.1016/j.jcrs.2008.09.027
23. Feltgen N, Leifert D, Funk J. Correlation between central corneal thickness, applanation tonometry, and direct intracameral IOP readings. *Br J Ophthalmol.* 2001;85(1):85–87. doi:10.1136/bjo.85.1.85
24. Copt RP, Thomas R, Mermoud A. Corneal thickness in ocular hypertension, primary open-angle glaucoma, and normal tension glaucoma. *Arch Ophthalmol.* 1999;117(1):14–16. doi:10.1001/archophth.117.1.14
25. Anderson DR. Normal Tension Glaucoma S. Collaborative normal tension glaucoma study. *Curr Opin Ophthalmol.* 2003;14(2):86–90. doi:10.1097/00055735-200304000-00006
26. Dawson DG, Randleman JB, Grossniklaus HE, et al. Corneal ectasia after excimer laser keratorefractive surgery: histopathology, ultrastructure, and pathophysiology. *Ophthalmology.* 2008;115(12):2181–2191 e1. doi:10.1016/j.ophtha.2008.06.008
27. Randleman JB, Woodward M, Lynn MJ, Stulting RD. Risk assessment for ectasia after corneal refractive surgery. *Ophthalmology.* 2008;115(1):37–50. doi:10.1016/j.ophtha.2007.03.073
28. La Rosa FA, Gross RL, Orengo-Nania S. Central corneal thickness of Caucasians and African Americans in glaucomatous and nonglaucomatous populations. *Arch Ophthalmol.* 2001;119(1):23–27.
29. Shimmyo M, Ross AJ, Moy A, Mostafavi R. Intraocular pressure, Goldmann applanation tension, corneal thickness, and corneal curvature in Caucasians, Asians, Hispanics, and African Americans. *Am J Ophthalmol.* 2003;136(4):603–613. doi:10.1016/s0002-9394(03)00424-0
30. Hahn S, Azen S, Ying-Lai M, Varma R; Los Angeles Latino Eye Study G. Central corneal thickness in Latinos. *Invest Ophthalmol Vis Sci.* 2003;44(4):1508–1512. doi:10.1167/iovs.02-0641
31. Aghaian E, Choe JE, Lin S, Stamper RL. Central corneal thickness of Caucasians, Chinese, Hispanics, Filipinos, African Americans, and Japanese in a glaucoma clinic. *Ophthalmology.* 2004;111(12):2211–2219. doi:10.1016/j.ophtha.2004.06.013
32. Wong AC, Wong CC, Yuen NS, Hui SP. Correlational study of central corneal thickness measurements on Hong Kong Chinese using optical coherence tomography, Orbscan and ultrasound pachymetry. *Eye.* 2002;16(6):715–721. doi:10.1038/sj.eye.6700211
33. Al-Mezaine HS, Al-Amro SA, Kangave D, Sadaawy A, Wehaib TA, Al-Obeidan S. Comparison between central corneal thickness measurements by oculus pentacam and ultrasonic pachymetry. *Int Ophthalmol.* 2008;28(5):333–338. doi:10.1007/s10792-007-9143-9
34. Ashaye AO, Olowu JA, Adeoti CO. Corneal diameters in infants born in two hospitals in Ibadan, Nigeria. *East Afr Med J.* 2006;83(11):631–636. doi:10.4314/eamj.v83i11.9479
35. Hashemi H, Beiranvand A, Yekta A, Maleki A, Yazdani N, Khabazkhoob M. Pentacam top indices for diagnosing subclinical and definite keratoconus. *J Curr Ophthalmol.* 2016;28(1):21–26. doi:10.1016/j.joco.2016.01.009
36. Sanchis-Gimeno JA, Sanchez-Zuriaga D, Martinez-Soriano F. White-to-white corneal diameter, pupil diameter, central corneal thickness and thinnest corneal thickness values of emmetropic subjects. *Surg Radiol Anat.* 2012;34(2):167–170. doi:10.1007/s00276-011-0889-4
37. Zha Y, Feng W, Han X, Cai J. Evaluation of myopic corneal diameter with the Orbscan II topography system. *Graefes Arch Clin Exp Ophthalmol.* 2013;251(2):537–541. doi:10.1007/s00417-012-2069-6
38. Pinero DP, Plaza Puche AB, Alio JL. Corneal diameter measurements by corneal topography and angle-to-angle measurements by optical coherence tomography: evaluation of equivalence. *J Cataract Refract Surg.* 2008;34(1):126–131. doi:10.1016/j.jcrs.2007.10.010
39. Rufer F, Schroder A, Erb C. White-to-white corneal diameter: normal values in healthy humans obtained with the Orbscan II topography system. *Cornea.* 2005;24(3):259–261. doi:10.1097/01.ico.0000148312.01805.53
40. Alfonso JF, Fernandez-Vega L, Lisa C, Fernandes P, Jorge J, Montes Mico R. Central vault after phakic intraocular lens implantation: correlation with anterior chamber depth, white-to-white distance, spherical equivalent, and patient age. *J Cataract Refract Surg.* 2012;38(1):46–53. doi:10.1016/j.jcrs.2011.07.035

Clinical Ophthalmology

Dovepress

Publish your work in this journal

Clinical Ophthalmology is an international, peer-reviewed journal covering all subspecialties within ophthalmology. Key topics include: Optometry; Visual science; Pharmacology and drug therapy in eye diseases; Basic Sciences; Primary and Secondary eye care; Patient Safety and Quality of Care Improvements. This journal is indexed on PubMed Central and CAS, and is the official journal of The Society of Clinical Ophthalmology (SCO). The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit <http://www.dovepress.com/testimonials.php> to read real quotes from published authors.

Submit your manuscript here: <https://www.dovepress.com/clinical-ophthalmology-journal>