ORIGINAL RESEARCH

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

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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 ± 1.40D (range 36.90–47.80D). The mean flat keratometry (K1) was 41.87 ± 1.31D (range 36.00–46.40D). The mean steep keratometry (K2) was 42.66 ± 1.35D (range 36.70–47.60D). The mean corneal astigmatism (CA) was 0.79 ± 0.37D (range 0.00D-2.30D). The mean central corneal thickness (CCT) was 558.53 ± 33.84 μm (range 421–677 μm). The mean thinnest corneal location thickness (TCLT) was 551.64 ± 34.08 μm (range 417–669μm). 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 μm (IQR 3.0–9.0) and 6.00 μm (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]

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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 ± 1.40D ranging from 36.90D to 47.80D. The mean K1 was 41.87 ± 1.31D ranging from 36.00D to 46.40D. The mean K2 was 42.66 ± 1.35D with a range of 36.70D to 47.60D. The mean CA for all eyes was 0.79 ± 0.37D ranging from 0.00D to 2.30D. The mean CCT of all eyes from all subjects in our study was 558.53 ± 33.84μm (range 421–677μm). The mean TCLT was 551.64 ± 34.08 μm (range 417–669 μm). The mean CD of all eyes in our study was 12.13 ± 0.39 mm, with a range of 10.50 mm to 13.60 mm. The average ACD of all eyes in our study was 3.12 ± 0.29 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 ≤ 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 ≤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 ≤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 ≤0.4D (18.7%), and CA of ≥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 500–549μm, (10.6%) of eyes had a CCT of ≥600 μm and (4.3%) of eyes had a CCT of ≤499 μm. TCTL distribution was similar to the distribution of CCT with most eyes (44.7%) having TCTL of 550–599μm, followed by a TCTL of 500–549 μm in (41.4%) of eyes, a TCTL of ≥600μm in (7.7%) of eyes and only (6.3%) of eyes having a TCTL of ≤499μm. 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%), ≥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 ≥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.
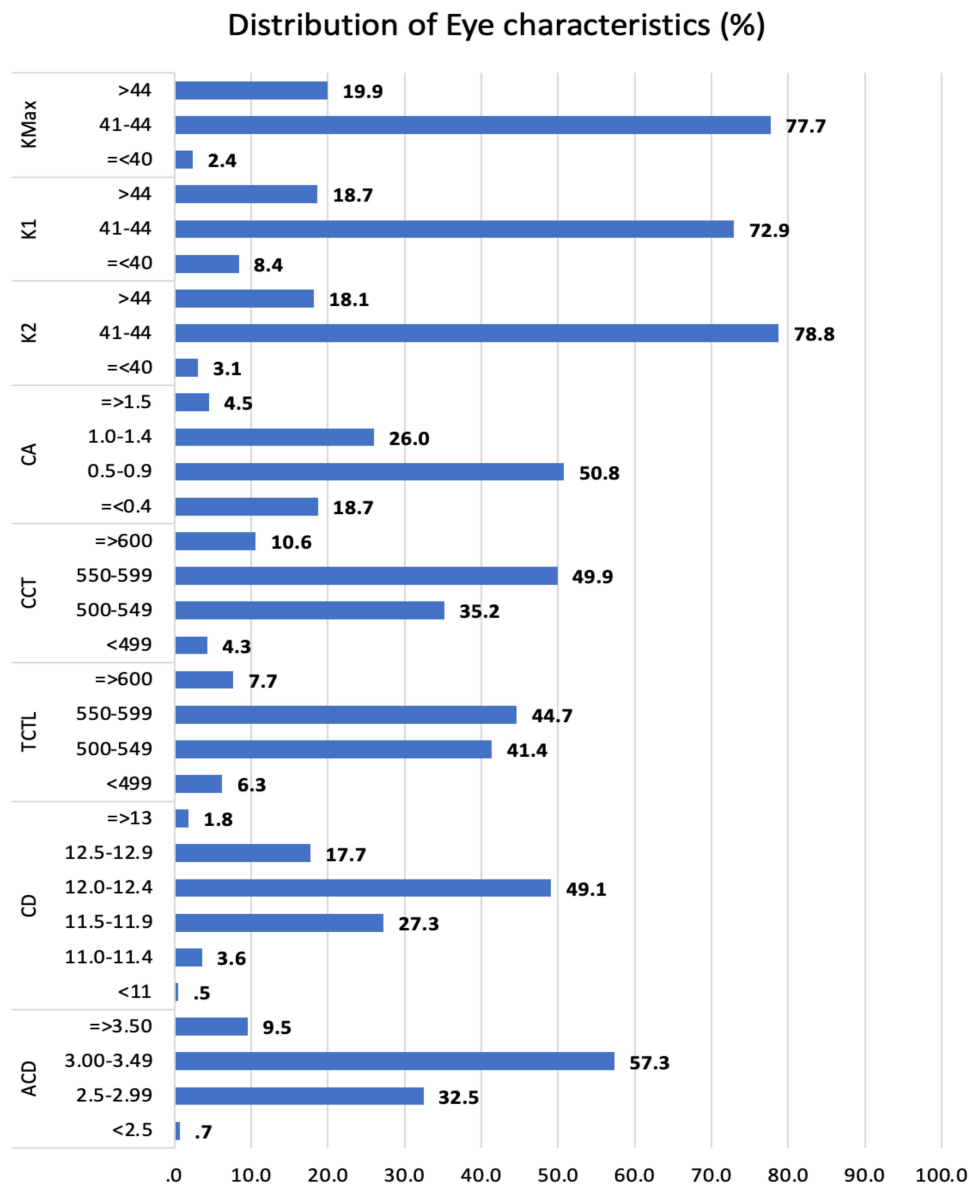
Distribution of Eye characteristics (%)

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 TCLT 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 TCLT 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 ± 2.75D 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 ± 0.37D, 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 μm to 677 μm with a mean CCT of 558.53 ± 33.84 μm, while TCTL ranged from 417 μm to 669 μm with a mean TCTL of 551.64 ± 34.08 μm. 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 μm 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.

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Disclosure

The authors declare that they have no conflict of interest.

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