Comparative Evaluation of the Corneal and Anterior Chamber Parameters Derived From Scheimpflug Imaging in Arab and South Asian Normal Eyes

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Purpose: To evaluate the differences in the normal corneal and anterior segment Scheimpflug parameters in Arab and South Asian eyes.

Methods: This hospital-based study was performed at a cornea and refractive surgery service in Abu Dhabi. A total of 600 consecutive normal candidates of South Asian (group 1, n = 300) and Arab (group 2, n = 300) origins underwent Scheimpflug imaging (Sirius; Costruzione Strumenti Oftalmici, Italy). One eye was randomly selected for evaluation.

Results: The age and sex distributions in both groups were comparable. The pachymetric variables were statistically higher in group 2 (group 2 vs. group 1, 544.3 ± 32.2 μm vs. 535.1 ± 31.4 μm for central corneal thickness, 541.0 ± 32.6 μm vs. 531.9 ± 31.5 μm for minimum corneal thickness, 571.7 ± 43.2 μm vs. 558.1 ± 42.3 μm for apical thickness, and 58.1 ± 4.2 vs. 57.3 ± 4.3 mm^3 for the corneal volume; $P < 0.05$). The anterior chamber volume (group 2 vs. group 1: 166.4 ± 16.4 vs. 161.6 ± 20.5 mm^3) and angle (group 2 vs. group 1: 44.6 ± 6.2 vs. 43.5 ± 5.8 degrees) were also higher for group 2 ($P < 0.05$). Central corneal curvature and apical corneal curvature (apex K) were higher in group 1 ($P < 0.05$) with comparable astigmatism. The flat keratometry (K), steep K, and apex K were 43.6 ± 2.2 diopters (D), 44.9 ± 1.8 D, and 45.7 ± 1.8 D for group 1, and 43.1 ± 2.2 D, 44.5 ± 2 D, and 45.2 ± 1.9 D for group 2. The effect size (Cohen d) for significant parameters ranged from 0.2 to 0.3.

Conclusions: Normal eyes of Arab ethnicity tend to have statistically thicker and flatter corneas and less-crowded anterior segments than those of the South Asian counterparts. These epidemiological differences have a mild to moderate biological effect size (Cohen d), but they should be considered when evaluating these eyes for anterior segment or corneal procedures.

Key Words: corneal thickness, corneal topography, anterior chamber biometrics, South Asian, Arab, ethnic comparison

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In the recent past, some excellent studies have been performed to look at the changes in central corneal thickness (CCT) and anterior chamber (AC) biometrics between demographic groups.[1–12] Racial variations between population cohorts such as Asian Chinese, Malay, Asian Indian, Aboriginal, or whites have been noticed.[9–12] Interethnic comparative studies from the same clinical or population setting are particularly useful as they help in creating normative data and risk-based limits for eyes of different ethnicities, especially for glaucoma diagnosis and refractive surgery screening.[13–15] With a population of approximately 384 million, the Arab ethnicity (AE) is a sizable cohort.[16] However, there is no detailed comparative study looking at the corneal and AC characteristics for AE.

Many population-based large studies have been performed using ultrasound pachymetry (USP) or keratometry. However, newer devices based on Scheimpflug imaging and optical coherence tomography perform a more comprehensive evaluation of the AC and, thus, help us better understand the anatomy and related pathology. For example, we are now aware that not only the CCT or steepness but also multiple other parameters such as the apex thickness and keratometry are altered in corneal diseases such as keratoconus.[17,18] Also, the use of novel parameters such as the volume of the AC or the cornea can give new insights into pathology.[19–22] Some studies have focused on the AC volume in certain ethnic groups; however, very few studies have compared the ethnic variations encompassing keratometric, corneal pachymetric, AC biometric, and novel diagnostic parameters in a single study.[23–25]

To address these lacunae, more so in our part of the world, in this study, we compare these parameters derived from Scheimpflug imaging in normal Arab eyes with those from South Asian (Indian Subcontinental) eyes.

METHODS

This comparative observational case series was performed at NMC Speciality Hospital, Abu Dhabi. The study was approved by the Institutional Review Board, NMC

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Specialty Hospital, and followed all tenets of the declaration of Helsinki. All candidates (or their parents, if the candidate was less than 18 years old) gave informed consent for their participation. Soft contact lens users were advised not to wear them for 2 weeks before the tests. None of the subjects in our study wore hard contact lenses. No eye drops, including cycloplegic or local anesthetic drops, were instilled to the eyes during 7 days before the tests. All candidates underwent detailed history-taking sessions and slit-lamp evaluation. There was no ocular morbidity in the patients other than refractive errors. Exclusion factors were dry eyes, any previous surgical or laser intervention in the eye or corneal scars/irregularity, corneal ectasia, visually significant cataract (corrected vision <20/20), or any other ocular morbidity (except refractive errors). All cases underwent Scheimpflug topographic analysis [Sirius, Costruzione Strumenti Oftalmici (CSO), Italy]. All measurements were performed between 10.30 AM and 12.30 PM to avoid possible effects of diurnal variation.

Details of the Sirius System

The Sirius system combines a monochromatic 360-degree rotating Scheimpflug camera and a Placido disc–based corneal topographer. The scanning process acquires a series of 25 Scheimpflug images (meridians) and 1 Placido top-view image with 22 rings.[26,27] A 475-nm blue LED light is used to measure 35,632 points from the anterior corneal surface and 30,000 points from the posterior cornea.[28] The height, slope, and curvature data are calculated from the Placido images, and the profiles of the corneal surfaces (anterior and posterior), anterior lens, and iris surfaces are calculated from the Scheimpflug images.[26] A pachymetric map is reconstructed using the point-by-point anterior and posterior corneal surface data.

The minimum variation in pachymetry that the instrument is able to resolve is approximately 2 μm (personal communication through e-mail on May 18, 2015, with Engineers Gabriele Vestri and Francesco Versaci, R&D division, CSO, Italy). The horizontal visible iris diameter (HVID) is defined as the distance between the right and left iris edges of the grayscale image sampled on the horizontal meridian passing through the corneal vertex, where the edge is determined by the zero crossing of the second derivative of such a spatial profile. The horizontal anterior chamber diameter (HACD) is defined as the distance between the vertices of iridocorneal angles on the horizontal Scheimpflug image (personal communication through e-mail on April 7, 2015, with Gabriele Vestri and Francesco Versaci, R&D division, CSO, Italy).

The software of the device automatically decides the acquisition quality based on the centration and coverage and denotes it with a green icon. Three consecutive good scans were taken for each eye.

Sample Size Determination

We performed an initial pilot data collection for 50 consecutive eyes each of AE and South Asian ethnicity (SAE). Three major variables, CCT, apex keratometry (apex K), and the anterior chamber depth (ACD) representing pachymetry, topography, and AC parameters, respectively, were used to determine the sample size. Using an alpha of 0.05, and a desired power of ≥0.8, the minimum acceptable sample sizes were as follows: 236 for CCT (SAE mean 532.5, AE mean 540.3, and pooled SD 30.2), 204 for apex K (SAE mean 45.9, AE mean 45.4, and pooled SD 1.8), and 270 for the ACD (SAE mean 3.2, AE mean 3.3, and pooled SD 0.3). Therefore, we decided to use a sample size of 300 cases in each group (group 1, South Asian; group 2: Arab). Using a very large sample size may have paradoxically resulted in a higher number of rejections of null hypotheses, despite poor clinical relevance of the difference (a poor effect size, explained below in the Statistical Analysis section). Therefore, we kept the sample size just enough to sufficiently cover the expected power of the study.

Recruitment

Three hundred consecutive candidates fitting the inclusion criteria were recruited into both the groups (total 600 candidates). One of the eyes was randomly included for analysis using a randomized computer-generated binary sequence (OD 1, OS 0). The best-quality scan (decided on the coverage and centration percentage denoted by the software of the Scheimpflug device) of the selected eye was used for analysis. In case of a tie in scores, 1 of the 2 scans was randomly selected. Therefore, finally, each group had 300 eyes of 300 patients.

Statistical Analysis

All the included data were exported as JPEG images and manually entered into an MS Excel (Microsoft, Richmond, VA) sheet. The data were then transferred to SPSS 16.0 (SPSS Inc, IL) for the analysis. The 1-sample Kolmogorov–Smirnov test was used to establish the normality of the distribution. The Student *t* test was used to analyze the difference in mean for parametric variables, and the rank sum test was used for nonparametric variables.[29]

Sometimes, when comparing data from 2 normal population sets, the observer may contemplate whether a statistically seen difference is large enough to be clinically significant (clinical vs. statistical significance). A useful measure in such a scenario is the effect size. The effect size is the quantitative measure of the clinical strength of a statistically seen difference. One of the methods to estimate the effect size is to compute the Cohen d.[30,31] The Cohen d is computed as the difference between 2 means, divided by the pooled SD. The *P* value can be affected by the variations in the sample size; and larger the sample, the higher the chance that a clinically small difference would turn out to be statistically significant. Therefore, using the Cohen d and 95% confidence intervals can provide better interpretation of the biological effect of a difference.[32] Cohen[30] has cautiously noted that the effects may be classified as mild (≤0.2), moderate (≤0.5), and large (>0.5) as an approximate guideline. A study such as ours compares normal cases, and one may not expect a difference as large as that seen between normal and pathological eyes (for example, normal vs. keratoconic corneas or normal vs. angle closure cases). Therefore, the Cohen d is expected to be mild to moderate in ours or similar studies. However, the use of confidence intervals and the Cohen d is a useful addition to the null hypotheses and enhances the comparability of data with other research; hence, they are included in our study. In addition, double-sided bar charts were drawn to demonstrate the spread of data over both groups, and best-fit curves were drawn to estimate the relationship of some variables with age.

RESULTS

Demographic Distribution

The mean age was comparable between both groups [group 1 (South Asian) 22.3 ± 7.7 years, group 2 (Arabs) 22.4 ± 8.3 years; $P = 0.9$]. The sex distribution was also comparable [female:male = 139:161 (group 1) and 125:175 (group 2); $\chi^2 = 1.3$, $P = 0.25$, χ^2 test].

Corneal Pachy-Volumetric Parameters

The distribution pattern for both groups is given in Figures 1A–D. The central, minimum, and apex corneal thickness and the corneal volume at 10 mm were higher in the cases of AE (group 2) compared with South Asians (group 1) ($P < 0.05$, Tables 1 and 2).

Keratometric Parameters

The distribution pattern for both groups is given in Figures 2A–C. The central 3-mm simulated keratometry reading was steeper for the South Asian eyes ($P < 0.05$, Tables 1 and 2). However, the difference between steep and flat keratometry (SimK astigmatism) was comparable ($P \geq 0.05$, Tables 1 and 2).

Horizontal Diameters

Both the horizontal visible iris diameter (HVID) and the horizontal anterior chamber diameter (HACD) were slightly larger in Arab eyes (Tables 1 and 2). The distribution patterns are given in Figure 2D (HVID) and Figure 3A (HACD).

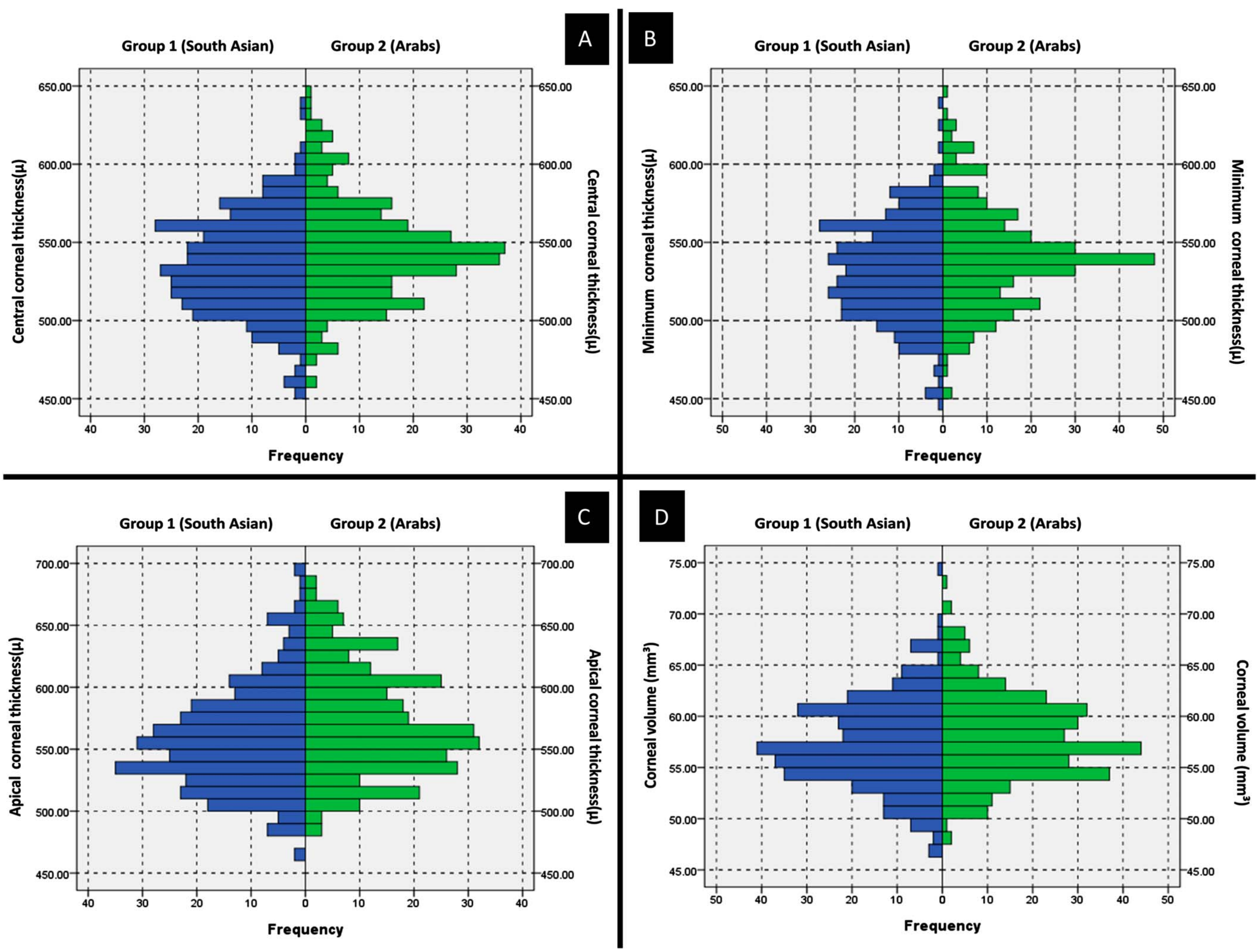

FIGURE 1. Frequency distribution polygon showing the distribution and frequency of various corneal pachy-volumetric parameters in group 1 (South Asian) and group 2 (Arab): A, for CCT (μm); B, for MCT (μm); C, for apical corneal thickness (μm); and D, for the corneal volume at 10 mm diameter (mm³).

TABLE 1. Means of Both Groups and Correlations With Age

Parameter	Group*	Mean	SD	95% CI Mean Upper	95% CI Mean Lower	Correlation With Age‡	*P*‡
CCT, μm	Group 1	535.1	31.4	531.5	538.6	**−0.12**	**0.04**
	Group 2	544.3	32.3	540.6	548	**−0.27**	**<0.01**
MCT, μm	Group 1	531.9	31.5	528.3	535.5	**−0.13**	**0.02**
	Group 2	541	32.6	537.3	544.7	**−0.27**	**<0.01**
Apical corneal thickness, μm	Group 1	558.1	42.3	552.3	562.3	0.02	0.7
	Group 2	571.7	43.2	566.7	576.6	−0.04	0.5
Corneal volume at 10 mm, mm^3	Group 1	57.3	4.3	56.8	57.7	**−0.15**	**0.01**
	Group 2	58.1	4.2	57.6	58.6	**−0.20**	**<0.01**
Keratometry at apex, D	Group 1	45.7	1.8	45.5	45.9	−0.10	0.1
	Group 2	45.2	1.9	45	45	−0.08	0.2
Flat SimK at 3 mm†, D	Group 1	43.6	2.2	43.4	43.9	−0.10	0.1
	Group 2	43.1	2.2	42.8	43.4	−0.10	0.1
Steep SimK at 3 mm†, D	Group 1	44.9	1.8	44.7	45.1	−0.09	0.1
	Group 2	44.5	2	44.2	44.7	−0.08	0.1
Astigmatism SimK at 3 mm†, D	Group 1	1.3	1.3	1.2	1.5	0.01	0.9
	Group 2	1.4	1.3	1.2	1.5	0.11	0.06
HVID, mm	Group 1	12.1	0.4	12.1	12.2	0.06	0.2
	Group 2	12.2	0.4	12.1	12.2	0.09	0.1
HACD, mm†	Group 1	12.2	0.5	12.2	12.3	−0.10	0.1
	Group 2	12.3	0.5	12.2	12.4	−0.09	0.1
Iridocorneal angle, degrees	Group 1	43.5	5.8	42.8	44.1	0.00	0.9
	Group 2	44.6	6.2	43.9	45.3	−0.06	0.3
ACD, mm	Group 1	3.2	0.3	3.2	3.2	**−0.15**	**0.01**
	Group 2	3.3	0.3	3.2	3.3	**−0.13**	**0.02**
AC volume, mm^3	Group 1	161.6	20.5	159.3	163.4	**−0.11**	**0.03**
	Group 2	166.4	16.4	164.5	168.3	**−0.14**	**0.02**

*Group 1: South Asian; group 2: Arab.
†SimK: simulated keratometry at 3 mm.
‡Correlation between age and various parameters (Pearson: parametric; Spearman: nonparametric); *P* value significant if <0.05, significant correlations are highlighted in bold.
CI, confidence interval; D, diopters.

AC Parameters

The distribution pattern for both groups is given in Figures 3B–D. The iridocorneal angle and the AC volume were also larger in Arab eyes. The rest of the AC parameters were comparable (Tables 1 and 2).

Correlation With Age

The central and minimum corneal thickness (MCT), corneal volume at 10 mm, ACD, and AC volume were significantly correlated with the age of both groups (Table 1). The best-fit curves for the CCT and ACD, 2 of the major parameters, with age are given in Figures 4A, B. Both these parameters were inversely correlated with age.

DISCUSSION

The Sirius topography system has been used in multiple studies in the literature with good repeatability and reliability. Milla et al[27] measured the corneal thickness at different locations in the cornea with the Sirius system and found that the same-observer (intraobserver) intraclass correlation coefficient of repeated measures ranged from 0.99 to 0.997. The intraobserver coefficient of variation was lower than 1%, and the SD of the repeated measurements (Sw) was below 6 μm at all corneal locations.[27] In another study, Huang et al evaluated the intrasession and intersession variations in the performance of the Sirius system.[33] The intraobserver repeatability of the central (CCT) and MCT readings was estimated. The intra-measurement SD (Sw) was 3.3 and 3.2 μm for CCT and MCT, respectively. The intraclass correlation was 0.99 for both CCT and MCT. The intersession standard deviations for reproducibility of CCT and MCT were 3.8 and 3.5 μm, respectively. The intraclass correlation was 0.99 for both central and MCT.[33] These results suggest good reproducibility and reliability of the Sirius system and reassure its usage in clinical and research settings.

Looking at our data, we found that the Arab candidates had higher corneal thickness—not only central but also minimum and apical thickness—compared with their South Asian counterparts. Also, the corneal volume was significantly larger for the Arab eyes. These differences were statistically significant but had a moderate biological (clinical) effect size for the thickness parameters (Cohen d = 0.3).

The resolution of the Sirius device is approximately 2 μm for pachymetry as has been mentioned in the Methods section. Reinstein et al[34] compared the resolution of various devices used for anterior segment biometry. According to

TABLE 2. Mean Differences, Their Statistical Evaluation, and Effect Size Computation

Parameter	Mean Difference*	SE Difference	95% CI of Difference Upper†	95% CI of Difference Lower†	P‡	Cohen d§
CCT, μm	−9.2	2.6	−14.3	−4.1	<0.001	0.3
MCT, μm	−9.1	2.6	−14.3	−4.0	0.001	0.3
Apical corneal thickness, μm	−13.6	3.5	−20.5	−6.8	<0.001	0.3
Corneal volume at 10 mm, mm^3	−0.8	0.3	−1.5	−0.1	0.02	0.2
Keratometry at apex, D	0.5	0.1	0.2	0.8	0.001	0.2
Flat SimK at 3 mm¶, D	0.5	0.2	0.2	0.9	0.004	0.2
Steep SimK at 3 mm¶, D	0.5	0.2	0.2	0.8	0.001	0.2
Astigmatism SimK at 3 mm¶, D	−0.03	0.10	−0.23	0.18	0.6	0.2
HVID, mm	−0.1	0.0	−0.1	0.0	0.01	0.2
Horizontal anterior chamber diameter, mm	−0.09	0.04	−0.16	−0.01	0.03	0.2
Iridocorneal angle, degrees	−1.1	0.5	−2.1	−0.1	0.02	0.2
ACD, mm	−0.04	0.03	−0.09	0.01	0.1	0.1
AC volume, mm^3	−4.8	1.5	−7.8	−1.8	0.009	0.3

*Difference: value for group 1 minus group 2. The numerical value for the mean difference is noted up to 1 decimal place, except when the difference was smaller than |0.5|, where it has been noted up to 2 decimal places to differentiate from a difference of zero.
†95% CI: 95% confidence intervals of the difference of mean, upper, and lower.
‡*P* value: Student *t* test and rank sum test for normally and nonnormally distributed variables, respectively. The *P* value was considered significant if $P < 0.05$.
§Cohen d: the difference of means divided by the pooled SD, it is a measure of the effect size.
¶SimK: simulated keratometry at 3 mm.
D, diopters.

them, the Scheimpflug imaging by the Pentacam (Oculus GmbH, Wetzlar, Germany) has an axial resolution of 10 μm and by the Galilei (Ziemer, Port, Switzerland) has an axial resolution of <1 μm.[34] Similar resolution for the Galilei has also been noted in another recent article on techniques of angle assessment.[35] Therefore, there is a wide variation in the reported resolution of Scheimpflug devices. For the device we have used in the study (ie, Sirius), all differences noted in the thickness (central, minimum, and apex corneal thickness of both groups) were more than the device resolution, reassuring the validity of these findings.

There has been a lot of variation in the observed mean CCT for eyes with SAE. Two large population-based studies from India noted the ultrasound-based CCT (with population >40 years) to be approximately 510 μm (514 ± 33 μm, mean age ~49 ± 13 years by Nangia et al[1]; and 511 ± 33, age >40 years by Vijaya et al[7]). In comparison with this, a multiethnic study from Singapore found that the CCT in South Asian Indians (aged ~58.5 ± 10 years) was 561 ± 34 μm using anterior segment optical coherence tomography (OCT).[5] Ahmadi Hosseini et al looked at the anterior segment parameters in 120 eyes of 60 Indian young adults in Iran using the Pentacam (Oculus GmbH). Although their range of age was similar to that seen in our study, the mean central, minimum, and apex corneal thickness and corneal volumes were slightly higher (544.9 ± 35.4 μm, 542 ± 35.2 μm, 545.4 ± 35.5 μm, and 61.6 ± 4.1 μm, respectively) than our current results with the Sirius Scheimpflug device.[36] The difference between the 2 Scheimpflug devices, Pentacam and Sirius, can be a possible reason. It has been noted that in comparison with the Sirius values, the Pentacam values are approximately 10 μm higher for CCT and 12 μm for MCT.[37]

There are fewer studies looking at the Arab ethnic cohort, and none of them is a comparative study. In a relatively large study from a refractive surgery clinic in Yemen, 2304 eyes of Yemenis citizens were evaluated by USP. The mean age of the cohort was 26.7 ± 6 years, and the CCT was 521.7 ± 31.6 μm (range 432–643 μm).[38] In another study that included young adults of Saudi origin, 982 myopic eyes (491 patients) and 158 emmetropic eyes (79 controls) were evaluated.[39] The mean ultrasound CCT were 543.8 ± 35.4 μm for myopic eyes (mean age ~28 years) and 545.7 ± 27.6 μm for emmetropic eyes (mean age ~30 years).[39]

There are no large studies evaluating the ACD in Arab eyes. However, the South Asian cohort has been evaluated previously. In a study with the Pentacam on 120 Indian eyes, Ahmadi Hosseini et al[36] found that the mean ACD was 3.1 ± 0.3 mm, the mean AC volume was 177.8 ± 29.0 mm^3, and the mean AC angle was 39.4 ± 5.4 degrees. In a large multiethnic study from Singapore, the ACD based on partial coherence interferometry in 3400 Indian patients (>40 years of age) was noted to be 3.2 ± 0.4 μm.[40] In another ultrasound-based study from rural central India, 4711 subjects who were more than 30 years old were evaluated. They had an ACD of 3.2 ± 0.3 mm.[41] These values are comparable to the ACD of 3.2 ± 0.3 mm in our study.

Certain factors should be kept in mind when evaluating studies using different methods for AC assessment, such as ultrasound (requires contact with the eye), OCT and Scheimpflug imaging (both noncontact devices). The most important factor is the comparability between these devices. Seismek et al[42] compared CCT measurement results obtained by RTVue OCT (Optovue Inc, Fremont, CA), Lenstar (Haag-Streit AG, Switzerland), Sirius topography, and USP (OcuScan, Alcon Labs, Fort Worth, TX) in healthy subjects. They noted that RTVue OCT and Sirius topography significantly underestimated the CCT compared with USP.

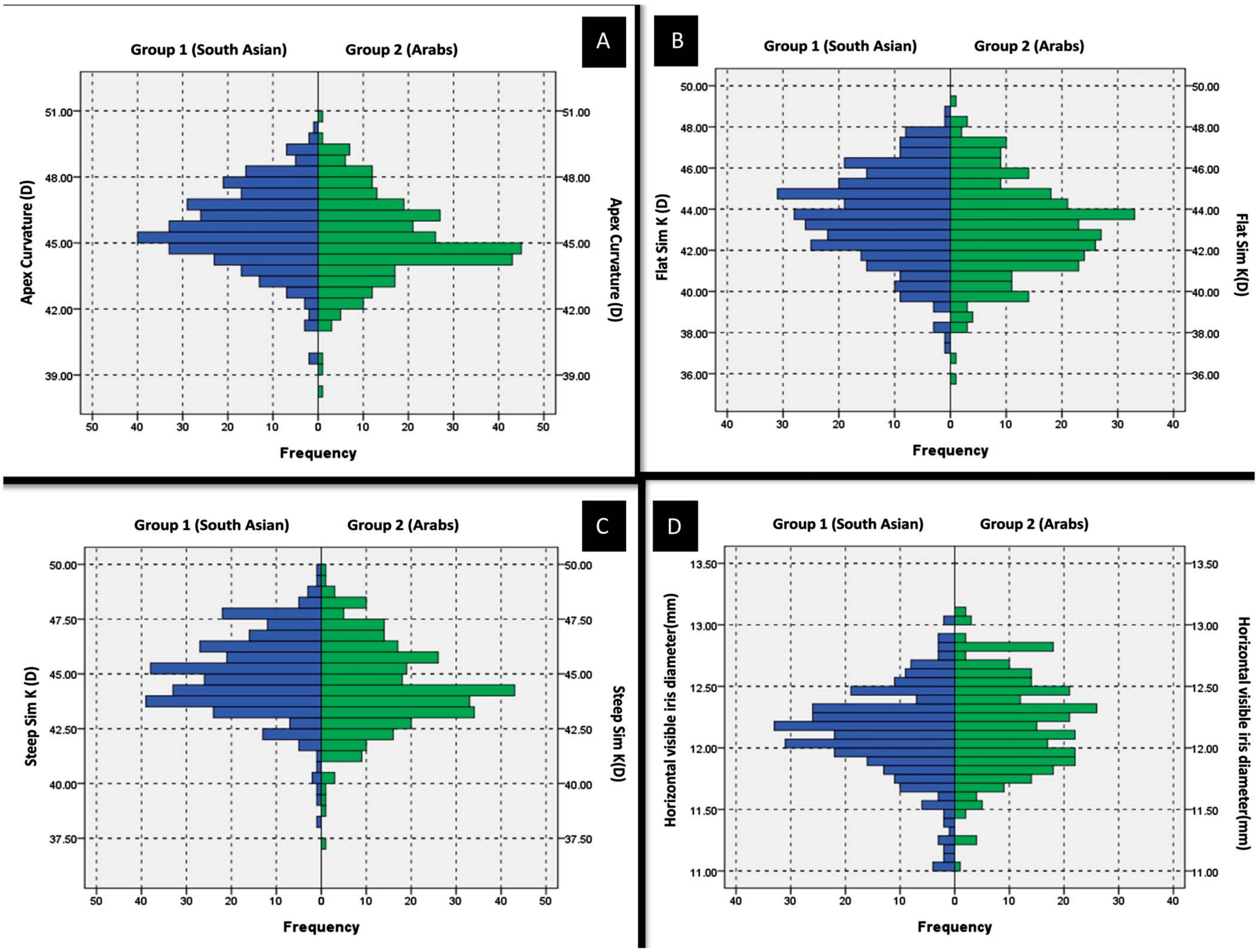

FIGURE 2. Frequency distribution polygon showing the distribution and frequency of various corneal curvature and diametric parameters in group 1 (South Asian) and group 2 (Arab): A, for apex curvature [diopters (D)]; B, for flatter simulated keratometry at 3 mm (SimK) (D); C, for steeper SimK (D); and D, for the horizontal visible iris diameter (HVID, mm)

Maresca et al[43] found that the average difference in corneal thickness measured with Sirius and USP was small but significant. The Sirius also showed precision and repeatability almost twice as much as USP.[43]

Bayhan et al[28] compared the RTVue, Sirius, Lenstar, and USP devices in terms of their agreement and repeatability of measuring CCT. The Pearson correlation coefficients were $\geq$0.97 for all comparisons. Intraexaminer repeatability was excellent for all devices with intraclass correlations being $>$0.98. The smallest difference in thickness was seen between the RTVue OCT and Sirius (-0.05 ± 6.8 μm). The difference between these 2 noncontact devices and the Lenstar was less than 5 μm. However, the mean difference between these 2 devices and USP was $>$17 μm, and the mean difference between the Lenstar and USP was 13 μm.[28]

In another study, Jorge et al[44] compared the outcomes of the Sirius Scheimpflug system with ultrasound measurements obtained for CCT by the SP100 Handy (Tomey, Nagoya, Japan) and for the ACD by the US800 biometer (Nidek, Gamagori, Japan) in normal eyes. They found a mean difference of 4.7 ± 10.5 μm for corneal thickness between the SP100 and Sirius. For the ACD from the endothelium to the lens surface, the mean difference was 0.2 ± 0.2 mm.[44]

It is interesting to note the comparison between OCT- and Scheimpflug-based devices. The benefits of Fourier domain anterior segment OCT and swept-source anterior segment OCT (SS-ASOCT) including nonmoving parts and faster acquisition speed leading to lesser motion artifacts have been discussed by us and by Jhanji et al in previous studies.[45,46] Fukuda et al[47] found that the corneal thickness and volume for normal eyes measured by SS-ASOCT were slightly less than those measured by the Scheimpflug camera (CCT and volume: 523.5 ± 25.2 μm and 57.2 ± 3.0 mm^3, respectively, by SS-ASOCT, 523.9 ± 26.1 μm and 59.4 ± 2.9 mm^3, respectively, by the Scheimpflug camera). Swept-source OCT (Casia SS-1000; Tomey, Nagoya, Japan) has been noted to have superior reproducibility coefficients and intraclass correlations compared with scanning slit-based corneal thickness (Bausch &

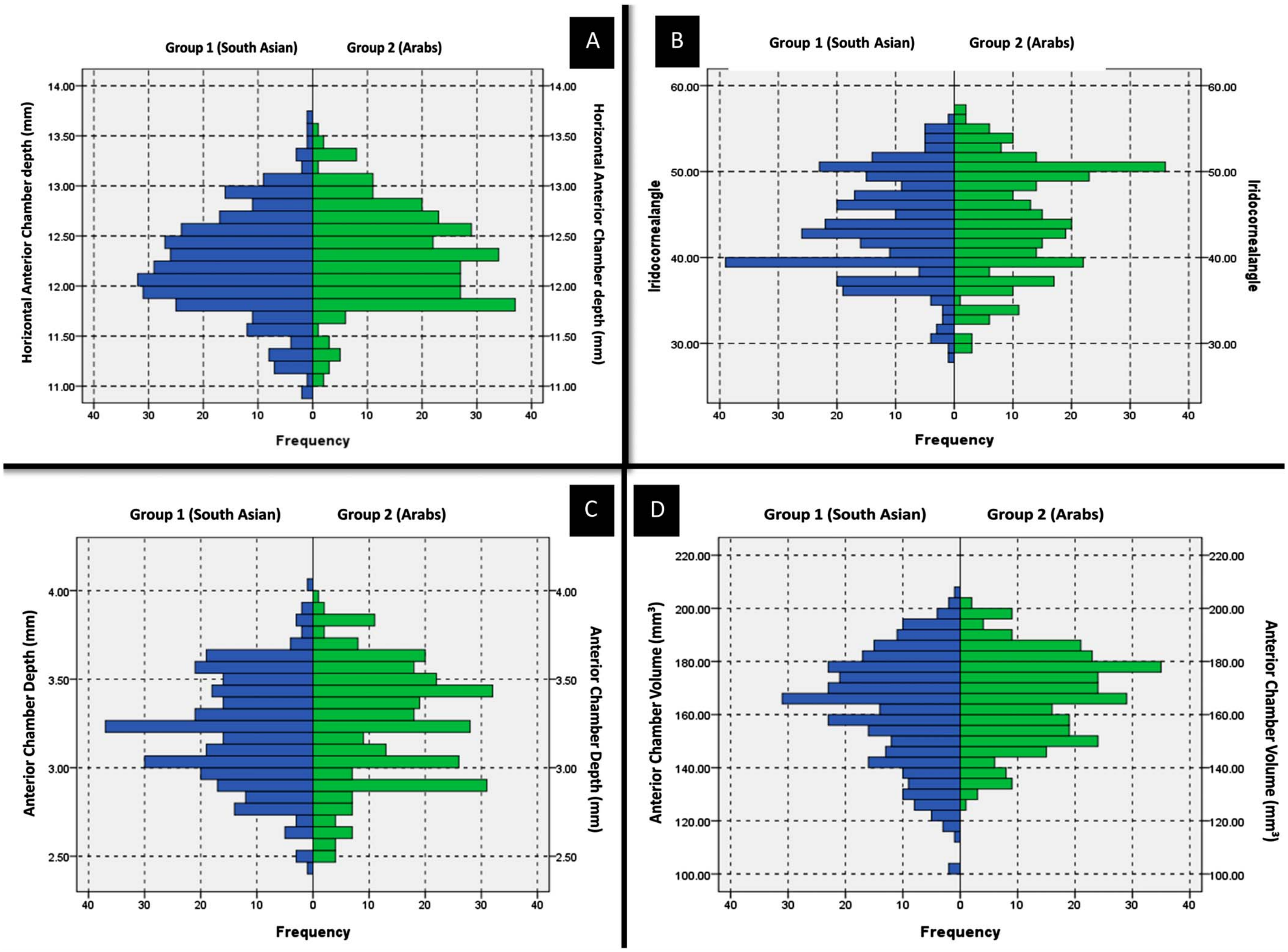

FIGURE 3. Frequency distribution polygon showing the distribution and frequency of various anterior segment parameters in group 1 (South Asian) and group 2 (Arab): A, for the horizontal anterior chamber diameter (HACD, mm); B, for the iridocorneal angle in degrees; C, for the ACD (endothelium to the anterior lens surface, mm); and D, for the anterior chamber volume (mm^3).

Lomb, Rochester, NY) and USP (Corneo-Gage Plus; Sonogage, Cleveland, OH) by Jhanji et al.[46] However, in normal eyes, CCT measured by SS-ASCOT was thinner compared with that by scanning slit and USP ($P \leq 0.0001$).[46]

Therefore, the interstudy variations in the values between the USP, anterior segment OCT, and Scheimpflug imaging for the same racial cohort and similar age groups can occur because of the use of different devices in different studies.[42–44,46–50] However, it is also interesting to note that irrespective of the device used, the SD for the corneal thickness was between 25 to 35 μm. Thus, this variation seems to be more of a systematic difference in devices and not a magnification of the measurement. Therefore, the outcomes with one device cannot be used to compare the values of another device. However, the trends can be used as a suggestive "difference guideline" when using another device. For example, if a study with device A shows that population 1 has a significantly thicker cornea than that of the other population 2, one may expect a similar result with device B. However, the actual values may differ based on the inherent difference in the measurement techniques of the 2 devices.

Previous studies comparing other ethnic populations have found similar clinically moderate, but statistically significant, differences. Wang et al[51] noted that Chinese, Japanese, and Koreans had corneas 6 to 13 μm thicker than those of South and Southeast Asians, Filipinos, and Pacific Islanders for each diagnosis ($P < 0.001$). Chua et al[9] have noted that the mean ultrasonic CCT was 552.3 ± 33.4 μm in Chinese, 540.9 ± 33.6 μm in Malays, and 540.4 ± 33.6 μm in Indians ($P < 0.001$).

As seen in other studies, we also found that there was a decrease in the CCT and the ACD with age. This suggests that even with a relatively modest sample size, our study is representative of the normal data as its findings are in line with known variations with age.

There are certain other shortcomings in our study. First, perhaps, it would have been more useful to have a 4-group (Arab, Asian Indian, white, and East Asian) comparison. However, the latter 2 groups do not form a large number of patients in our practice, and an initial evaluation suggested that it would have been difficult to recruit a similar number of

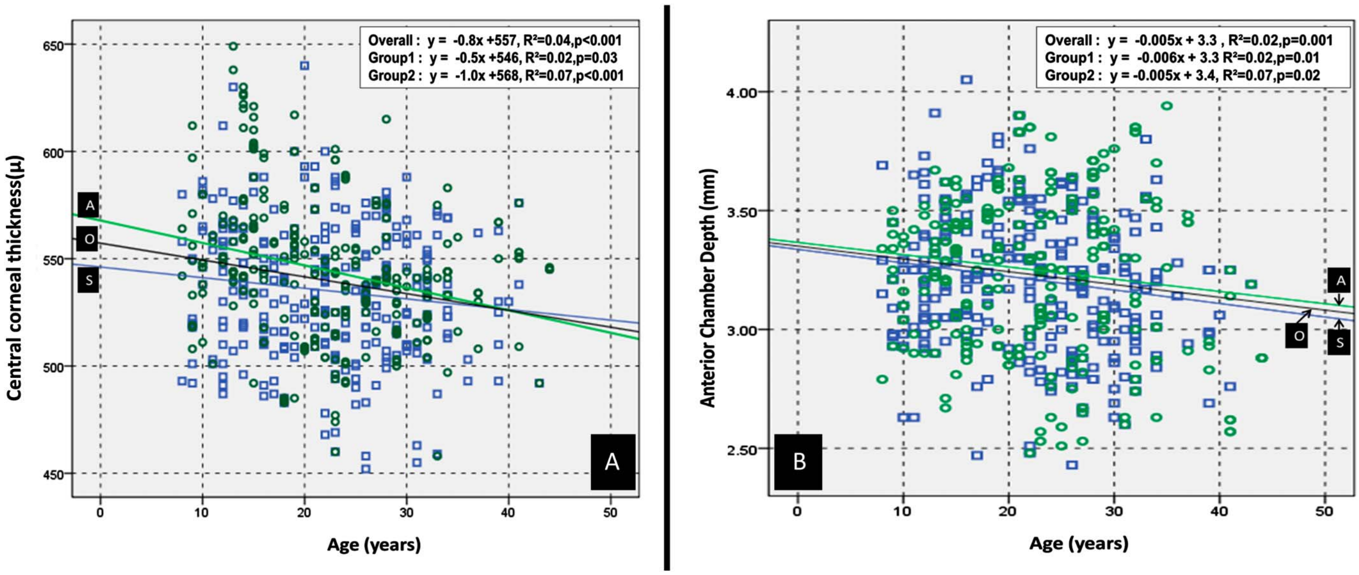

FIGURE 4. Best-fit curves showing the predictive relationship of age with other parameters. The individual data from the South Asian group (group 1) are denoted by rectangles and those from the Arab group (group 2) by circles. There are 3 best-fit lines. They are labeled as S for group 2, A for group 1, and O for the overall pooled data (600 eyes). The insert box shows the R^2 statistic, its *P* value, and the predictive equation for group 1, group 2, and the overall pooled data. A, CCT (*y* axis) versus age (*x* axis). B, ACD (*y* axis) versus age (*x* axis).

cases in a comparable time frame. Second, we did not look into diseased eyes, and thus our data represent only a normal population. Finally, this is a hospital-based study, and although the candidates were normal on clinical and Scheimpflug evaluation, the data may not be considered equivalent to a larger population-based study. Our sample size was sufficient according to the a priori power calculation and also for the a posteriori outcomes for major parameters. Larger sample sizes may have increased the statistical significance of some of the factors in our study. However, it must be noted that the size effect and Cohen d value should be computed along with *P* values in such larger studies, which is perhaps a more relevant combination of statistics. In this study, the Cohen d was between 0.2 and 0.3 for most of our variables, thus suggesting these differences to have a "small to medium" effect. This is an expected finding because both the population databases represent a normal population. Similar comparison and statistics in future studies or meta-analysis will be useful. Also, it needs to be reiterated that studies comparing a normative database have more epidemiological relevance than direct clinical relevance. Therefore, the knowledge that Arab eyes on average may have a corneal thickness of more than 10 μm compared with that of Asian eyes may not change the way a refractive surgeon approaches a pre-laser-assisted in situ keratomileusis evaluation, but would make the surgeon more aware as a whole of the differences between both groups. Similarly, a glaucoma specialist may be cautious of the differences in true intraocular pressure in these 2 ethnicities but would still treat each case on its own merit.

To conclude, our moderately sized, hospital-based study showed that the Arab eyes tend to have statistically thicker and flatter corneas and less-crowded anterior segments than their South Asian counterparts. Although these differences are clinically mild in terms of effect sizes, it could be useful to have this epidemiological perspective beforehand when evaluating candidates for refractive surgery, corneal pathology screening, glaucoma evaluation including intraocular pressure measurement, and anterior segment procedures.

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