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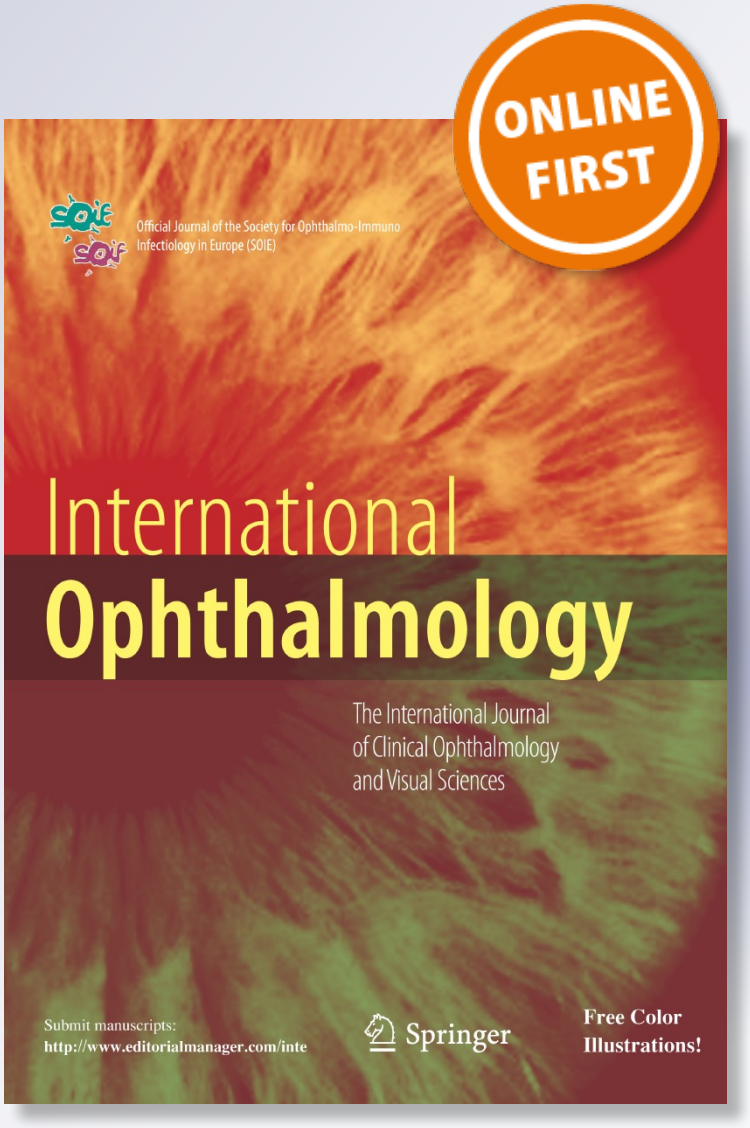

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ORIGINAL PAPER

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Abstract The study aimed to determine mean central corneal thickness (CCT) in a southern Egyptian population according to gender and age using ultrasonic pachymetry and to compare these CCT measurements to different populations. A prospective, observational, consecutive case series of 4,368 non-glaucomatous subjects (emmetropes and myopes) aged 16–70 years was carried out from August 2010 to March 2013 at the outpatient ophthalmology clinic in Sohag University Hospital and the Laser Vision Center in Sohag City, Egypt. Refraction, keratometry, slit-lamp examination, and intraocular pressure (IOP) measurements were obtained for all subjects. CCT was measured by ultrasonic pachymetry. The average CCT was 530.06 ± 38.03 μm. Average CCT was 532.6 ± 33.3 μm in emmetropes, 531.5 ± 31.3 μm in myopes <6 diopters (D), 531.1 ± 31.4 μm in myopes >6 D and 533 ± 33 μm in hyperopes, with no statistically significant difference between the groups. There was a statistically significant difference in CCT between age groups and gender. There was a strong correlation between CCT and IOP among the non-glaucomatous population. CCT was found to be lower in Egyptians than in Caucasian, Hispanic, and Japanese populations but comparable to African and African American populations.

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Keywords Central corneal thickness · Ultrasonic pachymetry · Egypt · Ethnicity

Introduction

Accurate measurement of corneal thickness is important in corneal refractive procedures, especially laser in situ keratomileusis, which is currently the most popular approach for the correction of refractive errors [1]. The measurement of central corneal thickness (CCT) is indispensible in the clinical evaluation of glaucoma [2]. Extremes of CCT can lead to errors in intraocular pressure (IOP) measurement, and some studies have shown that individuals with thinner corneas are more likely to develop glaucomatous optic neuropathy [3–5].

Multiple studies have investigated mean CCT values of various worldwide ethnic communities and populations—Whites [6–10], African Americans [7–9], Blacks [10], Latinos [9, 11], Greenland Eskimos [12], Asians [9] (including Hong Kong [13–15], Chinese [16], Korean [17], Japanese [18], Singapore [19], and Mongolian [20]), Switzerland [21], Germany [22, 23], Spain [24], Denmark [25, 26], Holland [27], Turkey [28], Canada [29], New Zealand [30], and India [31, 32].

However, most of the information about the distribution of CCT and the systemic and ocular factors that may influence it has come from clinical

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trials outside our region. The purpose of our study was to evaluate CCT in a southern Egyptian population as well as to investigate the possible associations between CCT and age, gender, spherical equivalence (SE), IOP and mean keratometry. In addition, this study aimed to compare the CCT measurements with those of other populations.

Patients and methods

A prospective observational study was conducted from 1st August, 2010 to 31st March 2013. This study included emmetropes presenting to the outpatient clinic of Sohag University Hospital for ophthalmological consultation and ametropic subjects who presented to the Laser Vision Center, Sohag City (500 km south of Cairo), Egypt for pre-operative assessment of refractive surgery. Ametropia aside, exclusion criteria included patients who underwent previous ocular surgery, corneal ectasia (keratoconus or forme fruste keratoconus), corneal disease (dystrophies), history of ocular trauma and glaucoma patients. No contact lens use was allowed for two weeks before examination in the case of soft lenses or four weeks in the case of gas-permeable and hard lenses.

Slit-lamp examination was performed to rule out the presence of any corneal pathology. Refraction was performed using a Nidek auto-refractometer (Japan). IOP was then measured using a Goldmnn applanation tonometer. Nidek corneal topography (Japan) was used for obtaining keratometry readings. CCT was measured by Sonogage Corneo-Gage Plus pachymeter (Ohio, USA). For pachymetry, the subject was comfortably seated with the head upright and eyes in the primary position of gaze. The probe was sterilized with 70 % alcohol and allowed to air-dry. A drop of topical anesthetic (benoxinate hydrochloride 0.4 %) was instilled into the subject's eye. The probe was carefully aligned in the center of the cornea perpendicular to the pupil axis. A minimum of five measurements were taken and the average was considered as that corresponding to the real center of the cornea. All measurements were performed by one physician.

The study was approved by the Research and Ethics Committee of the University in accordance with the Helsinki Dec-laration of human subjects and written informed consent was obtained from all participating subjects.

All data were analyzed by SPSS ver. 15.0 (SPSS Inc., Chicago, IL, USA). Descriptive analysis of demographic variables was performed, followed by Pearson's bivariate correlational analysis between CCT and age, gender, refractive error and keratometry. A p value of <0.05 was considered significant.

Results

A total of 4,368 subjects [2,009 (46 %) male, 2,359 (54 %) female] aged 16–60 years, were recruited into the study. The subjects were divided in three groups—group 1 included emmetropes (±0.50 D), group 2 (myopia) was divided into subjects with SE of <-6 D and those with ≥ -6 D, and group 3 included hyperope subjects.

As there was no statistical difference between the CCT measurements of the right and left eyes, only the readings of the right eye were used for analysis (Table 1).

The mean CCT for the whole group was 530.2 ± 30.8 μm. Table 2 shows the demographics of the three groups. The percentage of patients with a CCT $\leq$ 500 μm was 31.9 % in the emmetrope group, 37.9 % in the myopic group, and 22.9 % in the hyperope group.

When questioned as to systemic disorders, patients reported having diabetes mellitus ($n = 70$), and hypertension ($n = 86$); however, hypertension (Student's t test, $p = 0.945$) and diabetes mellitus (Mann–Whitney U test, $p = 0.294$) did not seem to affect CCT values.

CCT and age

Age and CCT were correlated for the entire study group (Pearson correlation test, $r = -0.073$, $p = 0.045$) implying a decrease in CCT with increasing age. The most representative age group was 20–39 years which accounted for 40.4 % ($n = 1{,}680$) of patients (Table 3).

CCT and gender

There was a statistical difference in CCT between male and female subjects, with males having slightly

Table 1 Demographics of the whole group for right and left eye in both genders

	Male		Female	
	Right eye	Left eye	Right eye	Left eye
CCT	529.7 ± 32.33	530.1 ± 33.2	530 ± 35.4	530.9 ± 34
IOP	13.2 ± 3.5	13.4 ± 3.3	12.9 ± 3.2	13.1 ± 3.3
Mean K	42.5 ± 1.6	42.9 ± 1.9	43.1 ± 1.6	43.2 ± 2.1

CCT central corneal thickness, *K* keratometry, *IOP* intraocular pressure

Table 2 Demographic and ocular characteristics for both groups

	Group 1 Emmetropes	Group 2 Myopic subjects		Group 3
		<−6 D SE	≥−6 D SE	
Numbers	2,140 (49 %)	1,145 (26.2 %)	891 (20.4 %)	192 (4.4 %)
M/F	102 5 (47.9 %)/1,115 (52.1 %)	542 (47.3 %)/603 (52.7 %)	405 (45.5 %)/486 (54.5 %)	97 (50.5 %)/95 (49.5 %)
Age (years)	26.9 ± 7.5	27.9 ± 8.5	27.5 ± 7	28.5 ± 9
CCT(μm)	532.6 ± 33.3	531.5 ± 31.3	531.1 ± 31.4	533 ± 33
≤500	683 (31.9 %)	456 (39.8 %)	317 (35.6 %)	44 (22.9 %)
>500	1,457 (68.1 %)	689 (60.2 %)	574 (64.4 %)	148 (77.1 %)
Mean K	43.3 ± 2.2	44 ± 2.1	44.1 ± 2.2	42.4 ± 1.5
IOP (mmHg)	12.9 ± 3.1	12.8 ± 2.9	12.7 ± 3.1	13 ± 3.1
SE (D)	0	−3.2 ± 2.9	−7.25 ± 3.1	+4 ± 2.9

CCT central corneal thickness, *K* kerstometry, *IOP* intraocular pressure, *SE* spherical equivalence, *D* diopters

Table 3 CCT and age groups

Age (years)	*n* (%)	Emmetropes	Myopes <6 D	Myopes >6 D	Hyperopes	Total
<20	805 (18.4)	531 ± 32	530 ± 35	530 ± 35.5	533 ± 33	530.3 ± 34
20–39	1,760 (40.3)	531 ± 31.5	530.7 ± 32.6	530.4 ± 35.5	535 ± 33	530.7 ± 34
40–59	1,310 (30)	530.5 ± 34.8	530.1 ± 37	530.2 ± 36	534 ± 34.6	530.3 ± 35.9
>60	493 (11.3)	529.6 ± 34.1	529 ± 32.3	529.2 ± 33	532 ± 34	529.3 ± 33.1

D diopters

thicker corneas. In addition there was a correlation between CCT and gender (Pearson correlation test, $r = 0.014$, $p = 0.04$) (Table 4).

CCT and spherical equivalence

There was no statistically significant correlation between SE and CCT (Spearman correlation test—myopia, $r = 0.023$, $p = 0.62$) ($p > 0.05$). On comparing CCT with the degree of myopia (myopic patients of ≥6 D and <6 D), there was still no statistically significant difference ($p = 0.56$). This also applies to the hyperope group ($p = 0.055$) (Table 4).

CCT and IOP

IOP and CCT had moderately significant correlations for males and females (Pearson correlation test—$r = 0.342$, $p = 0.000$ and $r = 0.445$, $p = 0.000$, respectively) where there is an increase in CCT with increased IOP (Table 4).

Table 4 Linear regression and Pearson correlation coefficient analysis for gender, age, mean K, IOP and spherical equivalence with CCT

	p	*r*	r^2
Gender	0.04	0.014	0.001
Age	0.045	−0.073	0.003
Mean K	0.00	0.139	0.002
IOP	0.00	0.39	0.14
Spherical equivalent	0.62	0.023	0.51

A p value of <0.05 is considered significant

K keratometry, *IOP* intraocular pressure

CCT and mean keratometry

There was a weak but statistically significant correlation between mean keratometry and CCT values for the group as a whole (Pearson correlation test—$r = 0.139$, $p = 0.000$) (Table 4).

Discussion

A considerable amount of research has been committed to investigating the mean CCT values of various worldwide ethnic populations [6–32].

To the best of our knowledge, this study is the first to document the CCT of a large population (both emmetropes and ammetropes) in Egypt. As Egypt belongs geographically to North Africa and to the Caucasian ethinicity, the study was carried out to provide reliable average values of this important variable and to compare our results to other ethnicities.

Our study reveals a CCT of 530 ± 30.8 μm. On reviewing studies regarding corneal thickness, a broad distribution of mean CCT values was found among the various ethnic groups surveyed. Comparing cohort-based CCT studies is confusing as methodological differences influence the results obtained, including inclusion or exclusion of glaucoma or ocular hypertensive patients, recruitment age, contact lens wear, interobserver measurement variability and, importantly, the type of measurement instrument used [33]. There have been notable discrepancies between different devices used to measure corneal thickness. Ultrasound is one of the widely used methods of pachymetry as it is fast, affordable, portable and easy-to-use, making it ideal for high-flow clinics [33].

There are few reports of CCT in African countries, other than African Americans actually living in the United States and Canada. In Rwanda, Forsius et al. [34, 35] reported that CCT measured by a slit-lamp device in 38 males and 38 females in Rwanda was 524 and 521 μm, respectively, which is similar to the reported average CCT in a meta-analysis of 125 studies using slit-lamp (525 vs. 544 μm using ultrasound pachymetry) Table 4.

Another report from Sudan reported an overall mean CCT of 530.15 ± 58.10 μm which adheres closely to our results. However, myopic patients had a thinner mean CCT (449.65 ± 39.27 μm) than our results and emmetropes had a mean CCT of 542.66 ± 46.35 μm which is also higher than our results [36]. The Sudanese sample size was small ($n = 94$) which may explain the huge discrepancies between corneal thicknesses.

Table 5 summarizes CCT in African populations; however, there are huge discrepancies in mean CCT ranging from 518 to 551 μm [36–49].

The wide range of variation in CCT is also witnessed among the same ethnic group in other studies such as Asian groups. Some studies are in agreement on CCT as in a Malay population of 541.2 μm [50],543.6 μm in a cohort of Singapore school children of mixed ethnic background [51], and 539.6 μm in Chinese adults in Singapore [52]; however, CCT was 534.5 μm in a large study of myopic Chinese adults undergoing laser refractive surgery in Singapore [53]; all these results were higher than the mean CCT in the current study.

There have been two studies investigating CCT in northern Africa. An interesting study by Lifshitz et al. compared subjects according to their parent's place of birth. They found that 121 descendants of North Africans had thinner CCT (518.6 ± 31.75 μm) than other subjects from origins such as Asia, Russia or the USA (545.36 ± 30.44 μm) [54]. Lazreg et al. compared corneal thickness between 221 French and 1,662 North African refractive surgery candidates. The mean CCT was statistically significantly thinner in North African patients (518 ± 36 μm; $p < 0.0001$); there was no significant difference in corneal hysteresis [47]. The percentage of subjects with CCT ≤ 500 μm in our study was higher than the North African subjects in the study by Lazreg et al. [47] (28.9 %); the percentage of French subjects in the same study

Table 5 CCT distribution in Africa

Country	No. of participants	Mean CCT ± SD	Age group	Glaucoma	Method	Reference
Cameron	485	529.29 ± 35.9	5–75	No	Ultrasound	Eballe et al. [37]
Cameroon	102	538.06 ± 38.03	5–16	No	Ultrasound	Eballe et al. [38]
Ethiopia	300	518.7 ± 32.9	42.57 ± 16.71	No	Ultrasound	Gelaw et al. [39]
Ghana	155	525.3 ± 33.5	40–98	?	Ultrasound	Kim et al. [40]
Nigeria	49	551.6 ± 44.5	20–69	No	Ultrasound	Iyamu et al. [41]
Nigeria	34	535 ± 38	?	No	Ultrasound	Mercieca et al. [42]
Nigeria	88	537.9 ± 38.4	46.0 ± 13.8	Yes	Ultrasound	Babalola et al. [43]
Nigeria	85	550 ± 36.3	20–69	No	Ultrasound	Iyamu et al. [44]
Nigeria	130	548.97 ± 34.28	20–79	No	Ultrasound	Iyamu and Osuobeni [45]
Nigeria	95	547.0 ± 29.5	>20	No	Ultrasound	Iyamu et al. [46]
North Africa	1,662	518 ± 36		No	Pentacam	Lazreg et al. [47]
Rwanda	76	522	?	No	Ultrasound	Forsius et al. [34]
Uganda	297	516.19 ± 39.93	?	Yes	Ultrasound	Mbumba et al. [48]
South Africa	Blacks = 100 Indian = 100	526.5 ± 37.2 512.4 ± 38.9	18–25	No	Non-contact tonography	Sardiwalla et al. [49]
Sudan	94	530.15 ± 58.10	?	No	Ultrasound	Mohamed et al. [36]
Our study	4,368	530 ± 30.8	16–70	No	Ultrasound	

CCT $\leq$ 500 was 7.7 %. This concludes that a CCT of more than one-third of our population falls <500 μm.

All previous studies have pursued evidence to support a genetic component for CCT. There are multiple studies that have investigated the heritability of CCT. The heritability estimates ranged from 0.6 to 0.95 resulting in the conclusion that there was 'a major genetic influence on CT'. Environmental factors such as occupation and place of residence were proposed as accounting for some of the remaining variation [12, 55–57].

On comparing our results with other ethnicities we can conclude that the mean CCT in southern Egypt was greater than that of the Mongolian population who have the thinnest reported CCT (504.5 μm) [20], the Indian population (520.7 μm) [58] and the Japanese population (521 μm) [59, 60]. However, the southern Egyptian mean CCT was less than CCT in a Latino cohort from the USA (546.9 μm) [11], the Beijing Eye study (556.2) [61], the Rotterdam Study (537.4) [27] and participants of the Ocular Hypertension Treatment Study (OHTS; 555.7 μm in African Americans in the OHTS, and 579 μm in Whites) [8].

Several studies have revealed a significant correlation between CCT and gender, reporting that CCT is slightly higher in males compared with females [9, 14, 20, 60], whereas other investigators did not notice a difference between males and females [62–64]. In our study, we noticed a statistically significant difference between males and females according to average CCT. Our study shows that there was a positive correlation between CCT and IOP which is consistent with numerous studies [7, 8, 35].

In a meta-analysis of >230 different articles involving measurements of >14,000 individuals by Doughty and Zaman [35], they considered that the normal cornea averages 536 ± 0.031 μm; however, our CCT was thinner, as well as African Americans [7, 9, 10, 65, 66].

The mean CCT obtained from 4,368 subjects using ultrasonic pachymetry in a southern Egyptian population was 530 ± 30.8 μm. The CCT was associated significantly with age, gender and corneal curvature in multiple regression analyses. People of African descent, including North Africans, tend to have a lower mean CCT than other populations. These results might warn ophthalmologists in Egypt to be extra cautious in evaluating patients seeking refractive surgery. Hopefully our results will also increase anticipation of primary open-angle glaucoma in our area.

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Conflict of interest The author declares no conflict of interest in this paper.

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