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ORIGINAL RESEARCH

Correlation Between Myopic Refractive Error, Corneal Power and Central Corneal Thickness in the Egyptian Population

Mohamed Kotb [ID]
Sherif A Eissa [ID]

Ophthalmology Department, Kasr Alainy, Faculty of Medicine, Cairo University, Cairo, Egypt

Purpose: To find out the correlation between myopic refractive error, corneal power and central corneal thickness (CCT) in the adult Egyptian population.

Methods: A retrospective observational cross-sectional study in which we analyzed the preoperative data of 1401 Egyptian myopic patients (1401 eyes) who underwent keratorefractive procedures between 2016 and 2019 in a private eye surgery center.

Results: Mean age of patients was 28.1 ± 5.79 years (range 18–40). Mean CCT in the Egyptian population sample in our study was 539.23 ± 32.24. Only the corneal power parameters (flat K, steep K and average K) showed a statistically significant difference (p-value <0.001) between males and females. A statistically significant and weak positive correlation of average K with the absolute value of refractive astigmatism ($r = 0.063$, p-value = 0.018), and between myopic error with average K ($r = 0.136$, p-value <0.001) was found.

Conclusion: Among the myopic adult Egyptian population, the greater the myopic error measured, the steeper the cornea, with a weak positive correlation between refractive error and corneal power.

Keywords: myopia, cornea, central corneal thickness, corneal power, Egyptian

Introduction

Laser in situ keratomileusis (LASIK), since its introduction by Pallikaris and his team in 1990,[1] has become the most frequently performed corneal refractive procedure all over the world, with millions of LASIK procedures completed to date.[2]

Assessment of corneal parameters, especially the central corneal thickness (CCT) and the corneal curvature (the corneal power), is crucial before proceeding with laser vision correction (LVC) procedures. Decision making before LVC procedure and calculation of percentage of tissue altered (PTA) should rely on cut-off values like CCT that vary among different population groups.[3]

Conventionally, corneal thickness normally ranges between 537 μm and 550 μm. Five hundred microns has been accepted as a cut-off value for safe refractive surgery. Thinner corneas are at risk for ectasia, haze and less predictable refractive outcomes.[3]

Analysis of causes of post-LASIK ectasia revealed that thin CCT (below 500 μm) and anterior corneal topographic irregularities are among the most important risk factors.[4,5]

In addition, measurement of CCT has become very important in assessment of glaucoma patients, as intraocular pressure (IOP) was found to be positively

Correspondence: Mohamed Kotb
3 Montaser Housing, Elharam, Giza, Egypt
Tel +201226356283
Email d_msabry@yahoo.com

correlated with CCT. Thin corneas result in false low IOP while thicker corneas tend to show false high IOP.[6,7]

Assessment of CCT and corneal power has been made easier and more accurate by the introduction of Pentacam with the Scheimpflug camera system, being a very rapid, non-contact, accurate, reproducible and user-friendly method.[8,9]

As myopia has been identified as the most prevalent refractive error all over the world,[10,11] the correlation between myopia and axial length of the eye was extensively discussed, revealing a positive correlation between the absolute value of myopia and axial length.[12,13]

The correlation between refractive error and corneal parameters has been previously studied in different regions and populations.[3,14–16] The purpose of this work is to find out if there is any correlation between corneal parameters (namely, central corneal thickness and corneal power) and the refractive error in the myopic adult Egyptian population.

Patients and Methods

This study is a retrospective study in which we analyzed the preoperative data of 1401 patients (1401 eyes) who underwent keratorefractive surgery (LASIK and photorefractive keratectomy (PRK) procedures) between 2016 and 2019 at Nour Eloyon Specialty Eye Center, Egypt. We only retrieved the data of the right eye of every patient. The study was performed according to the Declaration of Helsinki, and adhered to the regulations of the Institutional Review Board and ethical committee at Cairo University. The study was approved by the ethical committee of the Egyptian Society of Keratoconus and Corneal Transplants. Patient consent to review their medical records was not required by the ethical committee of the Egyptian Society of Keratoconus and Corneal Transplants in this retrospective study as patients' names were masked and their privacy respected.

Inclusion criteria were patients between 18–40 years old, with myopic error of spherical equivalent less than −8.00 D who had provided written informed consent to undergo the LVC procedure.

Exclusion criteria were previous corneal refractive procedure or intraocular surgery, corneal scarring, and definite or suspect keratoconus patients.

Data of these patients was retrieved from the hospital filing system; these data included age, sex, manifest and cycloplegic refraction, central corneal thickness,

keratometric measures and type of surgery performed. Data of patients revealed that manifest refraction was done using an automated refractometer (Topcon KR 8000, Japan). The patients were examined using a slit lamp for examination of the anterior segment. Manifest refraction was validated with trial correction using a lens set. Cycloplegic refraction was taken after instillation of Tropicamide drops (1% Mydriacyl; Alcon Inc., Switzerland) for 30 minutes to exclude any significant difference between manifest and cycloplegic refraction. Fundus examination was done using slit lamp biomicroscopy to exclude any retinal problems like myopic choroidal neovascular membranes or peripheral retinal holes or breaks.

Central corneal thickness and corneal power were measured using the Pentacam Scheimpflug system (Oculus Optikgerate GmbH, Germany). This system was designed with a camera that rotates 360 degrees around the optical axis of the examined eye to capture 25 Scheimpflug images per second and provide a three-dimensional image of the anterior segment with 25,000 height values. The printout included anterior and posterior corneal surface topography maps and a detailed pachymetric map.

We calculated the spherical equivalent (SE) value by adding the value of the sphere to the half of the refractive astigmatism value in diopters. Central corneal thickness was collected from the Pentacam images as the corneal thickness at the corneal apex. Keratometric measures were also retrieved from the Pentacam images as K1, the flat keratometric value, and K2, the steep keratometric value; the average K was used in the statistics and was calculated by the sum of flat and steep K divided by two. Keratometric astigmatism was calculated by the difference between the steep and the flat K.

Taking into consideration that we were dealing only with myopic refractive errors, we chose to use the absolute value of spherical equivalent and refractive astigmatism and to omit the negative sign in statistics to make it easier and to show real correlation between the refractive error and corneal parameters.

Statistics

Data were coded and entered using the Statistical Package for the Social Sciences (SPSS) version 26 (IBM Corp., Armonk, NY, USA). Data was summarized using means, standard deviations, median, minimum and maximum for quantitative variables and frequencies (number of cases) and relative frequencies (percentages) for categorical

variables. Comparisons between groups were done using unpaired *t*-tests.[17] Correlations between quantitative variables were done using the Pearson correlation coefficient.[18] P-values of less than 0.05 were considered to be statistically significant.

Results

Retrospective analysis of preoperative data of 1401 eyes of 1401 patients scheduled for LVC procedures was done. Mean age of patients was 28.1± 5.79 years (ranging from 18 to 40 years); 958 patients were aged between 18–30 years (68.38%), while 443 patients were aged between 30–40 (31.62%). Study subjects included 496 males (35.4%) and 905 females (64.6%); 1355 eyes (96.7%) underwent LASIK and 46 eyes (3.3%) underwent PRK.

Mean value and range of spherical equivalent (SE), refractive astigmatism, corneal power parameters and central corneal thickness (CCT) are shown in Table 1. Table 2 categorized patients' data into two age groups (18–30 years and 30–40 years).

Comparing the data of males and females, there was no statistically significant difference in SE, refractive astigmatism (RA), keratometric astigmatism (KA) or CCT. Only the corneal power parameters (flat K, steep K and average K) showed a statistically significant difference (p-value <0.001), as shown in Table 3.

By correlating the spherical equivalent of a myopic refractive error in its absolute value to different corneal parameters, we found a statistically significant but weak positive correlation with average K, meaning that the greater the myopic error, the steeper the cornea (r = 0.136, p-value <0.001), as shown in Figure 1. Also, a statistically significant but weak positive correlation was found with both refractive and keratometric astigmatism (r = 0.0957, p-value <0.001 and r = 0.089, p-value <0.001, respectively), as shown in Table 4.

The central corneal thickness showed a weak non-significant negative correlation with the absolute value of SE, meaning that the greater the myopic refractive error, the thinner the cornea (r = −0.027, p-value = 0.314), as shown in Table 4.

In addition to being correlated to SE, Table 4 shows a statistically significant and weak positive correlation of average K with the absolute value of refractive

Table 1 Statistical Values of Refractive Errors and Corneal Parameters

	Mean	Standard Deviation	Median	Minimum	Maximum
SE	−3.60	1.85	−3.25	−0.75	−8.0
Sphere value	−3.09	1.87	−2.75	0	−8.0
RA	−1.03	0.95	−0.75	0	−4.5
CCT	539.23	32.24	537.00	470.00	638.00
Flat K	42.89	1.59	42.84	38.09	47.86
Steep K	44.14	1.58	44.10	38.41	48.01
KA	1.25	1.08	1.02	0	5.25
Average K	43.52	1.49	43.46	38.25	47.935

Abbreviations: SD, standard deviation; SE, spherical equivalent; RA, refractive astigmatism; CCT, central corneal thickness; KA, keratometric astigmatism.

Table 2 Comparison of Patients' Data Between Two Age Groups

	18–30 Years					30–40 Years					p-value
	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	
SE	−3.71	1.84	−3.25	−0.75	−8.0	−3.44	1.7	−3.12	−0.75	−8.0	0.009
Sphere value	−3.2	1.83	−2.75	0	−8.0	−2.92	1.76	−2.75	0	−7.75	0.006
RA	−1.01	0.75	−0.75	0	−4.5	−1.06	0.97	−0.75	0	−4.5	0.42
CCT	541.08	30.76	541.00	470.00	625.00	535.51	34.18	528	470.00	638.00	0.004
Flat K	42.95	1.43	42.9	38.3	47.2	42.77	1.52	42.72	38.09	47.86	0.048
Steep K	44.19	1.54	44.15	38.7	47.2	44.05	1.64	44.00	38.41	48.01	0.15
KA	1.24	0.84	1.00	0	5.25	1.27	0.89	1.07	0.01	5.22	0.46
Average K	43.57	1.43	43.55	38.5	47.6	43.41	1.52	43.34	38.25	47.93	0.077

Abbreviations: SD, standard deviation; SE, spherical equivalent; RA, refractive astigmatism; CCT, central corneal thickness; KA, keratometric astigmatism.

Table 3 Comparison Between Data of Males and Females

	Male					Female					p-value
	Mean	SD	Median	Minimum	Maximum	Mean	SD	Median	Minimum	Maximum	
SE	−3.54	1.85	−3.25	−0.75	−8.0	−3.64	1.85	−3.25	−0.75	−8.0	0.347
Sphere value	−2.99	1.87	−2.75	0	−8.0	−3.14	1.86	−2.75	0	−8.0	0.149
RA	−1.09	0.98	−0.75	0	−4.5	−1.00	0.94	−0.75	0	−4.5	0.073
CCT	538.94	31.40	539.00	470.00	627.00	539.39	32.71	536.00	470.00	638.00	0.800
Flat K	42.61	1.43	42.58	38.09	46.60	43.05	1.66	43.00	39.11	47.86	<0.001
Steep K	43.86	1.60	43.82	38.41	47.87	44.30	1.54	44.25	40.02	48.01	<0.001
KA	1.25	0.91	1.00	0	5.22	1.26	1.17	1.04	0	5.25	0.867
Average K	43.24	1.45	43.23	38.25	47.13	43.67	1.49	43.63	39.56	47.93	<0.001

Abbreviations: SD, standard deviation; SE, spherical equivalent; RA, refractive astigmatism; CCT, central corneal thickness; KA, keratometric astigmatism.

astigmatism (r = 0.063, p-value = 0.018). Also, CCT was found to be negatively correlated to average K, to a weak statistically significant value, meaning that the steeper the cornea, the thinner the central corneal thickness (r = −0.089, p-value = 0.001) (Figure 2).

A non-statistically significant negative correlation was also found between average K and the keratometric astigmatism (r = −0.015, p-value =0.582).

Keratometric astigmatism showed a strong statistically significant positive correlation with the absolute value of refractive astigmatism (r = 0.651, p-value <0.001) (Figure 3) (Table 4).

By analyzing the age of the study subjects, a statistically significant but weak negative correlation was found with the CCT (r = −0.094, p-value <0.001), meaning that the older the patient, the thinner the cornea (Figure 4) (Table 4).

Age also showed a statistically significant correlation with keratometric astigmatism (r = 0.087, p-value = 0.001). But its correlations with spherical equivalent (r = 0.036, p-value =0.175) and average K (r = −0.018, p-value = 0.508) were not significant (Table 4).

Mean CCT in the Egyptian population in our study was 539.23± 32.24.
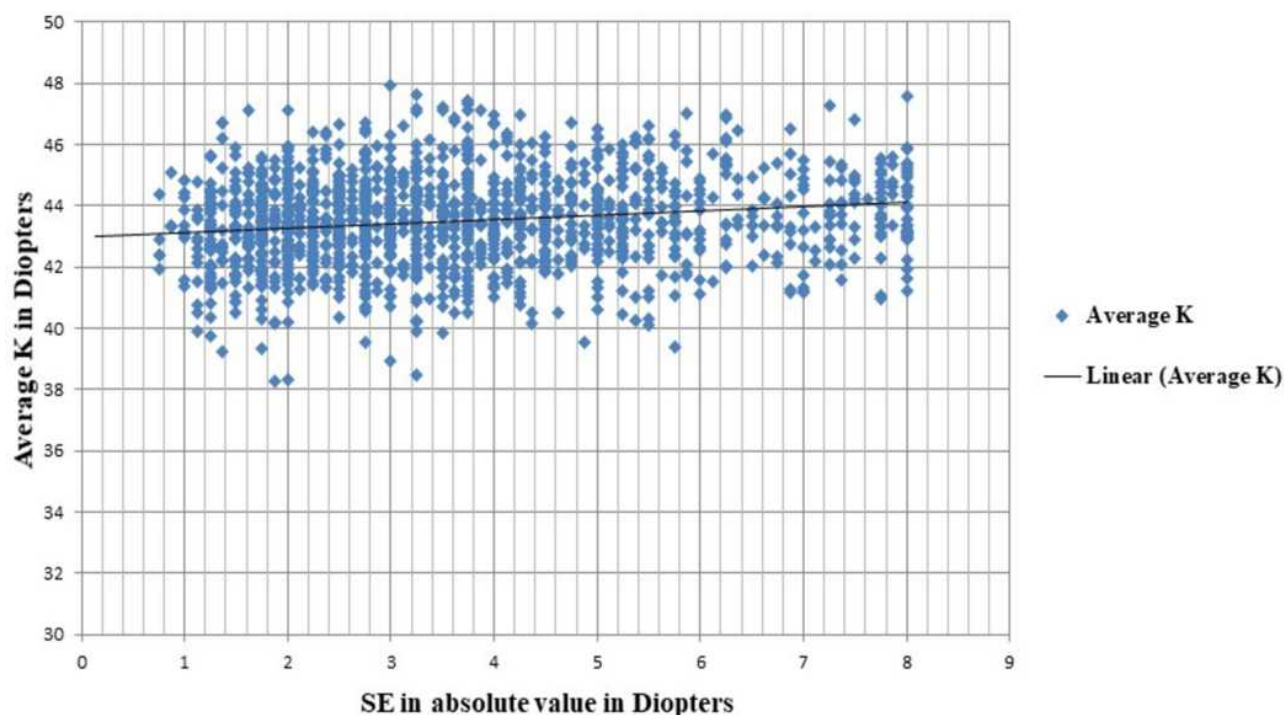

Figure 1 Correlation between spherical equivalent in absolute value and average K showing a statistically significant but weak positive correlation (r = 0.136, p-value <0.001).

Table 4 Correlation Value Between Different Parameters

		Spherical Equivalent (SE) by Absolute Value	Refractive Astigmatism (RA) by Absolute Value	Average K	Keratometric Astigmatism (KA) by Absolute Value	CCT
Refractive astigmatism (RA) by absolute value	r p-value N	0.0957 <0.001 1401				
Average K	r p-value N	0.136 <0.001 1401	0.063 0.018 1401			
Keratometric astigmatism (KA) by absolute value	r p-value N	−0.089 0.001 1401	0.651 <0.001 1401	−0.015- 0.582 1401		
CCT	r p-value N	−0.027 0.314 1401	0.035 0.187 1401	−0.089 0.001 1401	−0.018 0.512 1401	
Age	r p-value N	0.036 0.175 1401	0.018 0.491 1401	−0.018 0.508 1401	−0.087 0.001 1401	−0.094 <0.001 1401

Abbreviations: SD, standard deviation; SE, spherical equivalent; RA, refractive astigmatism; CCT, central corneal thickness; KA, keratometric astigmatism.

Discussion

The primary outcome of our work is evaluating the correlation between corneal parameters measured with Pentacam and the myopic refractive error in the adult Egyptian population.

Although correlation between axial length and myopic refractive error has been thoroughly studied and proven by different studies showing a positive correlation between the absolute value of myopia and axial length,[12,13] the
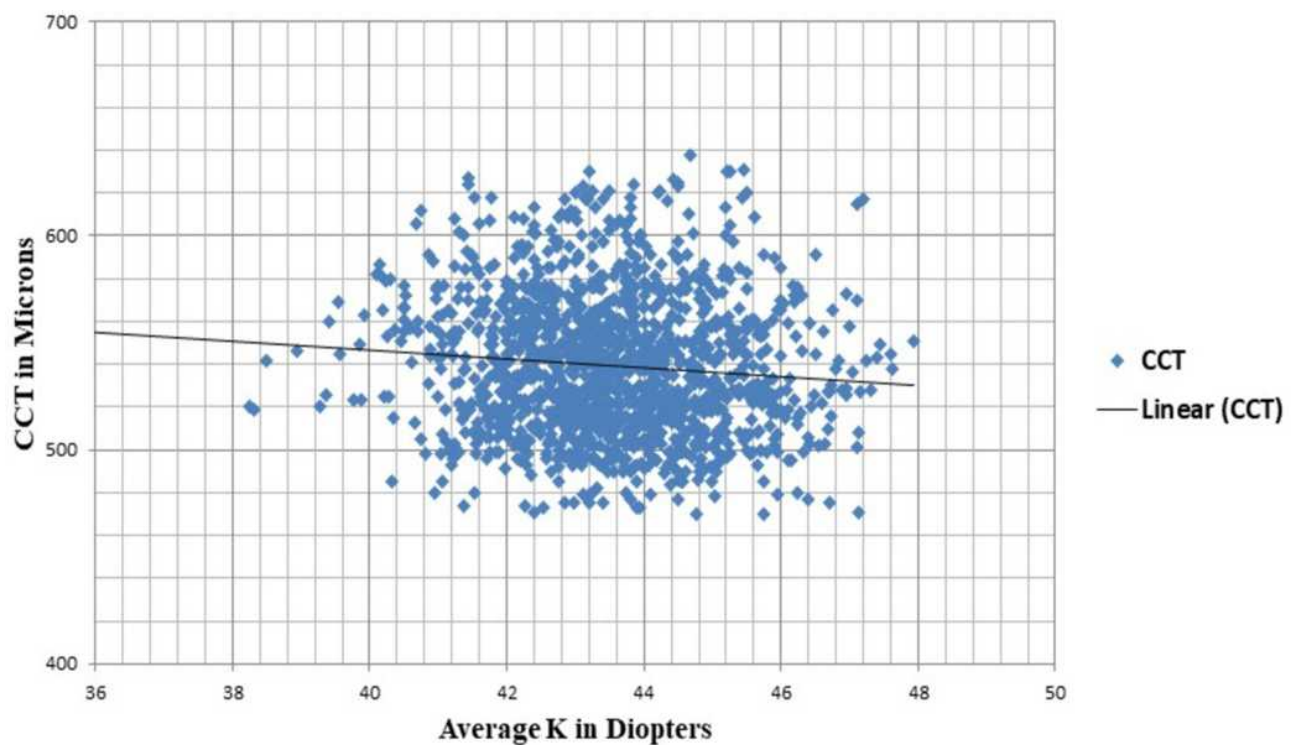

Figure 2 Correlation between average k and central corneal thickness showing a statistically significant but weak negative correlation (r = −0.089, p-value = 0.001).
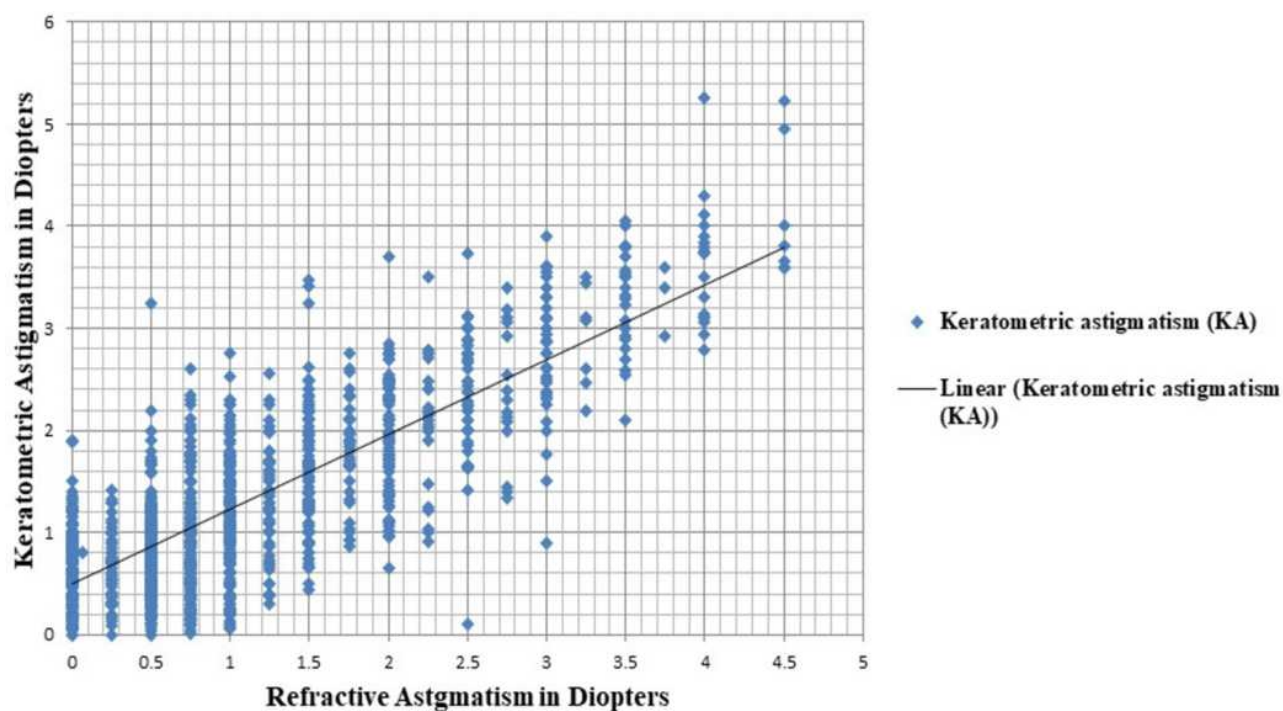
Figure 3 Correlation between absolute value of keratometric and refractive astigmatism showing a statistically significant strong positive correlation (r = 0.651, p-value <0.001).
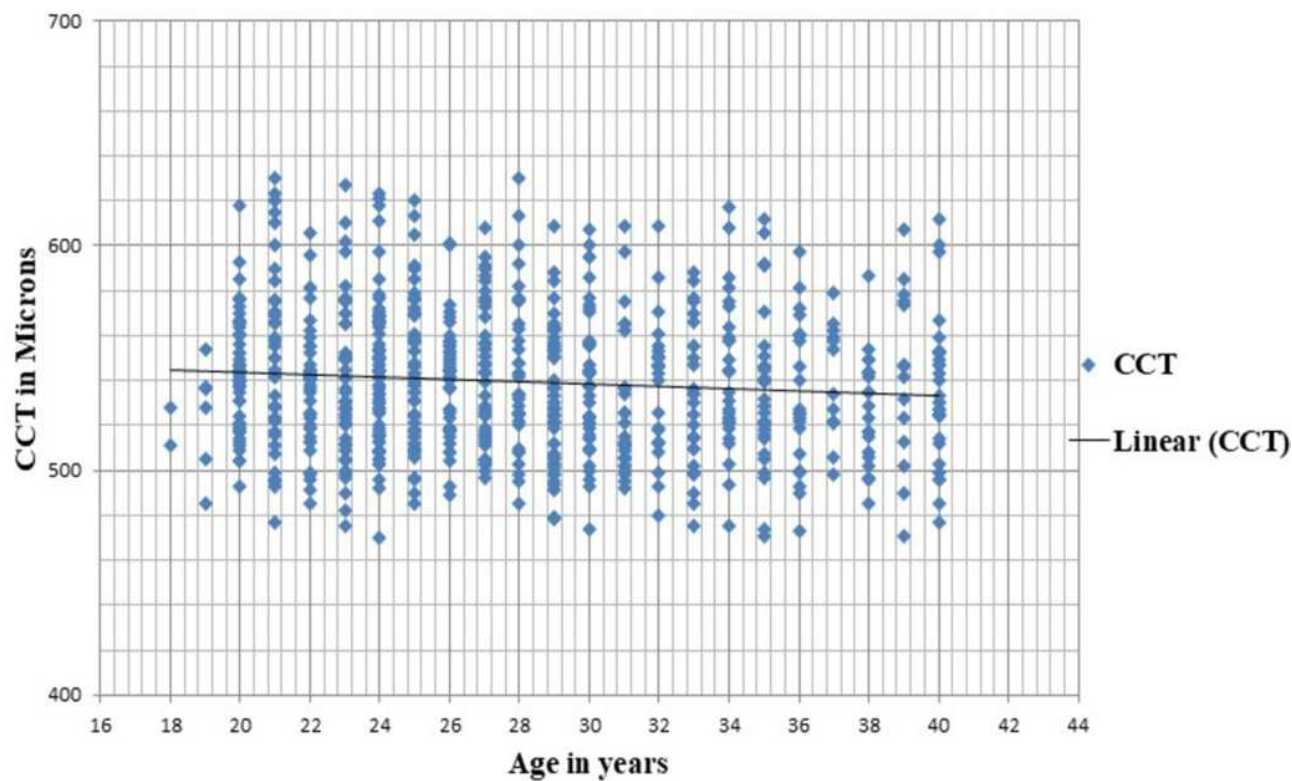

Figure 4 Correlation between age and central corneal thickness showing a statistically significant but weak negative correlation (r = −0.094, p-value <0.001).

correlation between SE and corneal power has not been fully studied yet.

In the current study we retrieved data from a large sample which included 1401 eyes of 1401 patients. To our knowledge, this is the largest sample among all the studies that assessed the correlation of corneal parameters with myopic refractive error. AlMahmoud et al, in 2011, used the same retrospective pattern with a larger sample of 3395 eyes but they included all types of emmetropia with a wide range of refractive errors from +6.75 to −14.0 diopters.[14] Arora et al, in 2015, studied 1000 eyes of 500 candidates with different types of refractive errors.[15]

The mean age of our study subjects was 28.1± 5.79 years, with a range from 18 to 40 years. In contrast, the study by AlMahmoud et al included patients with a mean age of 40±10 years, ranging from 19 to 84.[14] Kadhim et al, in 2016, recruited patients with a mean age of 40.1±14.6 years, ranging from 20 to 75 years.[16]

In our study we used the Pentacam (Oculus Optikgerate GmbH, Germany) for assessment of corneal power and CCT; AlMahmoud et al and Ucakhan et al used the same instrument.[14,19] Kadhim et al used the autorefracto-keratometry (RC-5000; Tomey Corporation) for assessment of corneal power and the contact ultrasound pachymeter (SP-3000; Tomey Corporation, Nagoya, Japan) for CCT measurement.[16] Arora et al also used the autokeratometerfor assessment of corneal power.[15] The use of Pentacam made it easier to assess all the corneal parameters needed, in a rapid, reproducible non-contact way.[8,9]

Regarding the correlation between myopic refractive error in its absolute value and corneal power, we found a weak statistically significant correlation in the present study (r = 0.136, p-value <0.001). AlMahmoud et al studied this correlation in a large sample with different types of refractive errors and, in the whole study sample, found a weak correlation between average K and SE; in the myopic group, the correlation was also weak but statistically significant (r = −0.185, p-value <0.001). They stated that there was a 0.11 diopter change in average K for every diopter change in SE in the whole study sample. AlMahmoud et al also found that the cornea in males was significantly flatter than that in females (average K: males 43.54; females 44.21, p-value <0.001). This finding was consistent with our results in this point (average K: males 43.24; females 43.67, p-value < 0.001), even though there was no statistically significant difference in SE between males and females in either study.[14]

In a sample of 500 eyes, from subjects aged between 20 and 40 years, Arora et al, in 2015, found a statistically significant correlation between SE and corneal curvature (CC) (r = 0.159, p <0.01 and r = 0.184, p <0.01) in the right eye and left eye, respectively.[15]

Mashige et al, in 2017, studied the corneal parameters and their correlations with refractive error in a sample of 600 black South African participants. Their mean age was 28.15 ±13.1 years, which was close to the mean age in our study. They found no correlation between SE and corneal power (referring to it as anterior corneal curvature (ACC) (r = −0.03, p-value = 0.48).[20]

In addition, Chen et al, in 2009, found no significant correlation between SE and corneal power (r = −0.016, p-value = 0.723) in a sample of 500 Taiwanese Chinese patients aged 40–80 years (mean age = 60.9±11.2 years).[21]

In 2019, Krishnan et al identified no significant correlation between SE and corneal power in terms of base curve (BC) (r = 0.070, p = 0.383) in a sample of 156 subjects in South India with an average age of 29.27 years.[22]

In the present study, we found a statistically significant but weak correlation between average K and the absolute value of refractive astigmatism (r = 0.063, p-value = 0.018); however, the correlation between average K and keratometric astigmatism was not significant (r = −0.015, p-value = 0.582). Keratometric astigmatism showed a strong statistically significant correlation with the absolute value of refractive astigmatism (r = 0.651, p-value <0.001).

AlMahmoud et al found in the myopic group of their study a significant correlation between corneal power and keratometric astigmatism (r = 0.082, p-value = 0.0003) but not with refractive astigmatism (r = 0.039, p-value = 0.103). However, like our study, they found a strong correlation between KA and RA (r = 0.784, p-value <0.001).[14]

Multiple studies tried to describe the relationship between the SE and the central corneal thickness. In our work we found the mean SE (−3.6± 1.85) and the mean CCT (539.23± 32.24), the correlation between absolute value of SE and CCT was non-significant negative correlation meaning that the more the myopic refractive error the thinner the cornea (r= −0.027, p value =0.314).

In a study by Lazreg and Colin, in 2011, Pentacam pachymetry was performed in refractive surgery centers in Algeria, Tunisia and Morocco on 1615 eyes of patients originating from North Africa. Most of the patients (70%)

were aged between 20 and 35 years. Thirty-eight percent had a CCT between 450 and 500 microns and 40% between 500 and 550 microns.[3]

In agreement with the present study, AlMahmoud et al described a non-significant correlation between SE and CCT in their myopic group dataset (r = −0.018, p-value = 0.427), while this correlation was statistically significant in the whole study dataset (r = −0.067, p-value = 0.003).[14] In addition, Chen et al found a non-significant correlation between SE and CCT in Taiwanese Chinese people (r = −0.034, p-value = 0.445).[21] In another study on Chinese people, Fam et al studied CCT in a sample of 714 myopic patients with a mean age of 32.9 years (range 15–59 years) and found the mean CCT to be 534.5± 38.1 μ; they found no significant correlation between CCT and SE (r = −0.13, p-value = 0.72).[23]

In South India, Krishnan et al found a negative weak correlation between SE and CCT (r = −0.172, p-value = 0.03) and, in a black South African population, Mashige et al found a non-significant correlation between SE and CCT (r = 0.05, p-value = 0.25).[20]

Ucakhan et al, in 2008 in Turkey, prospectively evaluated corneal elevation and thickness in relation to the refractive status measured with the Pentacam Scheimpflug system. They examined 215 patients with different types of refractive errors. They found no correlation between SE and CCT in the whole study sample (r = 0.149, p-value >0.05). However, when comparing the high myopia group to other groups (low myopia, myopic astigmatism, hyperopia and emmetropia), they found CCT to be significantly lower in this group than in other groups.[19]

In 2010, Nangia et al evaluated CCT and its association with ocular and general parameters in Indians (the Central India Eye and Medical Study). This study included 9370 eyes of 4711 participants. Mean CCT was 514±33μ, mean age was 49.1±13.2 years (range = 30–100 years) and mean refractive error was 0.19±1.50 diopters (rang = 20.0 to +6.00 diopters). In contrast to our results, they stated that, according to univariate analysis, there was a significant correlation between CCT and SE (r = 0.07, p-value <0.001); following multivariate analysis (including CCT, age, gender, and body mass index), CCT was no longer significantly correlated with SE (p-value = 0.54).[24]

In contrast, Kadhim et al studied the distribution of CCT and its relation to age, SE and corneal power in a sample of the Iraqi population. They studied 418 eyes from 209 subjects ranging in age from 20 to 75 years and with different types of refractive errors. They found a statistically significant correlation between CCT and SE (r = 0.153, p-value = 0.002), which they attributed to the inclusion of a wide range of refractive errors in their study.[16]

An earlier study by Mourad et al, in 2019, found that CCT was significantly lower in myopic and hyperopic patients (means = 531 and 523.5, respectively) than in emmetropic people (mean = 555) in a sample of 84 eyes in Egyptian people.[25]

In our work, CCT was found to be negatively correlated to average K to a weak statistically significant value, meaning that the steeper the cornea, the thinner the central corneal thickness (r = −0.089, p-value = 0.001). This was consistent with AlMahmoud et al's results in their myopic group (r = −0.113, p-value <0.001) and the whole dataset (r = −0.105, p-value <0.001).[14] Kadhim et al also reported a significant negative correlation in the Iraqi population (r = −0.097, p-value = 0.048).[16] In contrast, Mashige et al reported no significant correlation between CCT and average K in South African people (r = 0.16, p = 0.08).[20] Chen et al also reported a non-significant correlation in Taiwanese Chinese patients (r = 0.013, p = 0.77).[21]

Wirbelauer et al, in 2009, studied the influence of corneal curvature on central and paracentral pachymetry using Optical Coherence Tomography (OCT). That prospective study included 77 eyes of 77 patients with a mean age of 61±17 years (range 14–87 years) and reported that the correlation between corneal thickness and corneal power was non-significant in the center (r = −0.009, p = 0.935). However, it became significant in the paracentral areas measured in 4 points (r = 0.131, p = 0.021).[26]

Age in our study was significantly correlated with CCT and non-significantly correlated with average K, in agreement with AlMahmoud et al regarding the myopic group in their study.[14]

To conclude, among the myopic adult Egyptian population, the greater the myopic error measured, the steeper the cornea, with a weak positive correlation between refractive error and corneal power.

Limitations of this work include its retrospectiveness and its lack of assessment of axial length to differentiate between axial and index myopia. However, the fact that our study subjects were young candidates for refractive corneal surgery means that there was no place for index myopia. Also,

the age range from 18–40 years did not offer a chance for other age groups to be represented in the study.

A multi-continental study on a larger number of patients must be conducted in order to confirm the relationship between CCT and ethnic origin.

Data Sharing Statement

All the data included in this study are available on request.

Ethics Approval

The study was performed according to the Declaration of Helsinki, and adhered to the regulations of the Institutional Review Board and ethical committee of Cairo University. The study was approved by the ethical committee of the Egyptian Society of Keratoconus and Corneal Transplants.

Patient Consent to Review Their Data

Patient consent was not required by the ethical committee of the Egyptian Society of Keratoconus and Corneal Transplants in this retrospective study as patients' names were masked and their privacy respected.

Consent to Participate

Written consent was gained from all patients undergoing LASIK and PRK procedures after the surgical techniques and indications had been thoroughly explained to them.

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Disclosure

Mohamed S. Kotb states no conflicts of interest. Sherif A. Eissa states no conflicts of interest.

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