Reference values of the central corneal thickness with different refractive errors for the adult Egyptian population

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Research article

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Abstract

**Background:** To generate reference values of the central corneal thickness (CCT) with different refractive errors for the adult Egyptian population.

**Methods:** A retrospective, observational, and cross-sectional study of 2200 eyes in 1166 subjects scheduled for LASIK, who came to private refractive eye center, Ismailia, Egypt. The study period was from January 2018 to January 2020. The subjects were divided into a broad range of myopia with spherical equivalent (SE) < -0.5D and hyperopia SE > +0.5D. Then, the myopic eyes divided into low (SE>-3.0D), moderate (SE-3.0D to >-6.0D), and high (SE<-6.0D). Similarly, the hyperopic eyes were divided into low (SE<+3.0 D) and moderate (SE+3.0D to <+6.0D) and high ≥+6.0D. The refractive error was measured by an auto-refractometer (Topcon, Tokyo Optical Co., Ltd., Japan), and CCT was measured using Sirius (CSO, Florence, Italy).

**Results:** The data of 1100 myopic eyes in 556 subjects (30.5% males and 69.5% females) and 1100 hyperopic eyes in 610 subjects (33.6% males and 66.4% females). The mean±SD of CCT for the total myopic subjects was 531.98±32.92μm, range (406 to 636 μm). The mean±SD of SE was -4.1±2.5D, range (-0.5 to -12.0D). The mean±SD of CCT for the total hyperopic subjects was 529±38.8 μm, range (448 to 619 μm). The mean±SD of SE was +3.65±1.97D, range (+0.5 to +8.5D).

**Conclusion:** In this study, the mean of CCT of the Egyptian population was 531.9 μm for myopic and 529μm for hyperopic subjects respectively. The myopic and hyperopic subjects show a reduction in CCT with age. Females have a thinner cornea than males, 23.6% of the myopic eyes, and 16.5% of the hyperopic eyes have CCT less than 500μm.

Introduction

Central corneal thickness (CCT) is a key indicator of a sound cornea; it helps to evaluate corneal diseases. Normal ordinary CCT is around 540μm and for the most part, consists of the corneal stroma which is estimated to be 450μm in the center. This stroma gives essential structural integrity and plays a significant function in keeping up corneal transparency [1].

Central corneal thickness usually is measured by ultrasonic pachymeter. With late advances, it is possible to measure this value by Pentacam, which maps the whole surface of the cornea [2]. It is an important factor to assess the suitability in refractive surgeries as it is used to exclude patients at risk of postoperative ectasia [3]. It is also a measure of the rigidity of the cornea and has an influence on the precision of intraocular pressure (IOP) estimation by Goldman applanation tonometry (thick comeas offer resistance to it, causing a falsely higher IOP) [4,5].

Current studies have indicated that age, sex, race, as well as ethnicity may affect CCT. It is reported to be thinner in elders and African-Americans than in whites [6,7]. Some studies showed that men had thicker
corneas [8,9]. So, this study aimed to give reference values of the central corneal thickness with different refractive errors for the adult Egyptian population.

**Methods**

A retrospective, observational, cross-sectional study in 2200 eyes of 1166 subjects scheduled for LASIK, who came to private refractive eye center, Ismailia, Egypt. The study period was from January 2018 to January 2020.

All the subjects experienced comprehensive ocular examinations, including slit-lamp examination, IOP by Goldmann applanation tonometry, direct and indirect ophthalmoscopy, both cycloplegic and subjective refractive error (presented in spherical equivalent) with auto-refractometer (Topcon, Tokyo Optical Co., Ltd., Japan), keratometry and corneal topography by Sirius (CSO, Florence, Italy). Schirmer's testing without anesthesia was used to exclude dry eyes.

The eligibility criteria included myopia and hyperopia, a minimum age of 21 years, a regular corneal topography pattern, both sex and free of any existing systemic pathology. All-female subjects were non-pregnant. The exclusion criteria included subjects with a history of current or recent contact lens wear (not worn contact lenses 2 weeks before examination), ocular trauma, ocular surgeries, glaucoma, and pregnancy. None of the subjects were at present utilizing any topical ophthalmic medications.

The subjects were divided into a broad range of myopia (SE < -0.5 D) and hyperopia (SE > +0.5 D). Then, the myopic eyes divided into low (SE > -3.0D), moderate (SE -3.0 to > -6.0D), and high (SE < -6D). Similarly, the hyperopic eyes were divided into low (SE < +3.0 D) and moderate (SE +3.0 to +6.0D) and high (> +6.0D).

This study follows the Declaration of Helsinki. The research ethics committee of the Faculty of Medicine, Suez Canal University accepted it. No informed consent was required to review the medical records of the subjects due to a number of the study sample and the retrospective nature of the study design. The confidentiality of the patients’ data was guaranteed.

**Statistical analysis:**

Statistical Package for the Social Sciences (SPSS version 25.0; IBM Corporation, Armonk, NY, USA) was used for data manipulation and statistical analysis. Baseline characteristics of the study populations were presented as frequencies and percentages (%) or mean values and standard deviations (SDs). To test for data normality Shapiro-Wilk's test was used. Differences between frequencies in the groups were compared by the Chi-square test or Fisher's exact test (if >20% of expected values were less than 5). The student's t-test was used to compare the differences between means in the groups. All graphs were performed by Graph Pad Prism (version 5.00 for Windows, Graph Pad Software, La Jolla California USA). To compare the difference in the mean measurements between the sub-groups of myopia and hyperopia, one-way ANOVA was performed. A $p$-value < 0.05 was considered statistically significant.
Results

General characteristics:

The data of 1100 myopic eyes in 556 subjects (30.5% males and 69.5% females) and 1100 hyperopic eyes in 610 subjects (33.6% males and 66.4% females) who came to private eye center, Ismailia, Egypt for refractive surgery were analyzed, Table (1).

Table 1: General characteristics of all patients.

| Characteristic          | Myopic subject n=556 | Hyperopic subjects n=610 | P-value |
|-------------------------|----------------------|--------------------------|---------|
| Eyes, n                 | 1100                 | 1100                     | ----    |
| Age (yrs):              |                      |                          |         |
| Mean+SD                 | 27.3±6.8             | 35.1±10.7                | <0.001* |
| Range                   | (21 to 53)           | (21 to 56)               |         |
| Age group (yrs), n (%)  |                      |                          |         |
| < 30                    | 774 (70.3%)          | 430 (39.1%)              | <0.001* |
| 30-39                   | 261 (23.7%)          | 280 (25.5%)              |         |
| ≥ 40                    | 65 (6.0%)            | 390 (35.5%)              |         |
| Sex:                    |                      |                          |         |
| Male, n (%)             | 336 (30.5%)          | 370 (33.6%)              | 0.1206  |
| Female, n (%)           | 764 (69.5%)          | 730 (66.4%)              |         |
| Laterality:             |                      |                          |         |
| Right, n (%)            | 554 (50.3%)          | 500 (45.5%)              | 0.0913  |
| Left, n (%)             | 576 (49.7%)          | 600 (54.5%)              |         |

SD: standard deviation; n: number; yrs: years. * Statistical significance

Myopic subjects:

The mean±SD of CCT for the total myopic subjects was 531.98±32.92 μm, range (406 to 636 μm). The mean±SD of spherical equivalent (SE) was -4.1±2.5D, range (-0.5 to -12.0D). The subjects with CCT<500μm were 23.6% of the total myopic subjects. The mean±SD of the CCT according to the different age groups, eye laterality, and sex are presented in Table 2. When further sub-classified the myopic subjects, those with low myopia >-3.0D the mean±SD of the CCT was 532.6±33.7 μm, range (426 to 636 μm). Moderate myopia -3.0 to >-6.0D the mean±SD of the CCT was 532±31.6 μm, range (406 to 627 μm). Those with high myopia ≤-6.0D the mean±SD of the CCT was 531.5±33.9μm, range (433 to 611μm). There were no statistically significant differences between myopic sub-groups regarding CCT (P=0.711).

Table 2, Figure 1.

The range of distribution of the central corneal thickness in myopic adult Egyptian subjects was presented in Figure 2.

Table (2): General characteristics of the myopia sub-groups.
|                  | Myopia total subjects | Myopia sub-groups n (Column %) | P-value |
|------------------|-----------------------|---------------------------------|---------|
|                  |                       | Low >-3.0D                       | Moderate -3.0 to >-6.0D | High ≤-6.0D |          |
| Number (%)       | 1100(100%)            | 512(46.5%)                      | 418(38%)                     | 170(15.5%) | ---     |
| Age (yrs):       |                       | 27.3±6.8 (21 to 53)             | 27.5±6.3 (21 to 51)         | 26.8±6.8 (21 to 53) | 27.5±8.4 (21 to 53) | 0.235 |
|                  |                       | Mean±SD                         | Range                          |           |
|                  |                       | Sex, n (%):                     |                                |           |         |
|                  |                       | Male 336(30.5%)                 | 190 (37.1%)                   | 100 (23.9%) | 46 (27%) | <0.001* |
|                  |                       | Female 764(69.5%)               | 322 (62.9%)                   | 335 (76.1%) | 132 (73%) |         |
|                  |                       | Eye, n(%):                      |                                |           |         |
|                  |                       | Right 554(50.4%)                | 258 (50.4%)                   | 206 (49.3%) | 90 (52.9%) | 0.723 |
|                  |                       | Left 546(49.6%)                 | 254 (49.6%)                   | 212 (50.7%) | 80 (47.1%) |         |
|                  |                       | SE (D):                         |                                |           |         |
|                  |                       | Mean±SD                         | Range                          |           | <0.001* |
|                  |                       | CCT (μm):                        |                                |           |         |
|                  |                       | Mean±SD                         | Range                          |           | 0.711   |
|                  |                       | K1 (D)                           |                                |           |         |
|                  |                       | Mean±SD                         | Range                          |           | <0.001* |
|                  |                       | K2                               |                                |           | <0.001* |

SE: spherical equivalent; n: number; yrs: years; SD: standard deviation; D: diopter; K min: minimum kertometric power; K max: maximum keratometric power.* Statistically significant.

**Hyperopic subjects:**

The mean±SD of CCT for the total hyperopic subjects was 529±38.8 μm, range (448 to 619 μm). The mean±SD of the refraction error was +3.65±1.97D, range (+0.5 to +8.5D). The subjects with CCT<500μm was 16.5% of the total hyperopic subjects. The mean±SD of the CCT according to the different age groups, eye laterality, and sex are presented in Table 3. When further sub-classified the hyperopic subjects, those with low hyperopia <+3.0D the mean±SD of the CCT was 525.3±35.7μm, range (468 to 616μm). Moderate hyperopia +3.0 to<+6.0D the mean±SD of the CCT was 525.3±42.6 μm, range (448 to 619μm). Those with high hyperopia ≥+6.0D the mean±SD of the CCT was 525.6±35.9μm, range (486 to 606μm). There is also no statistical significance differences between hyperopic sub-groups as regarding
CCT ($P=0.078$), Table 3, Figure 3. The range of distribution of the central corneal thickness in hyperopic adult Egyptian subjects was presented in Figure 4.

**Table (3):** General characteristics of the hyperopia sub-groups.

| Hyperopia Total subjects | Hyperopia sub-groups n (Column %) | $P$-value |
|--------------------------|----------------------------------|-----------|
|                         | Low $<-+3.0D$ | Moderate $+3.0 to <-+6.0D$ | High $\geq+6.0D$ |
| Number (%)              | 1100(100%) | 480(43.6%) | 380(34.5%) | 240(21.8%) | — |
| Age (yrs):              | 35.1±10.7 (21 to 56) | 35.6±10.1 (21 to 56) | 38.9±11.9 (21 to 56) | 28.1±5.8 (21 to 42) | $<0.001^*$ |
| Sex, n (%):             | Male 370 (39.4%) | Female 570 (60.6%) | Male 170 (41.5%) | Female 240 (58.5%) | Male 100 (30.3%) | Female 230 (69.7%) | Male 100 (50.0%) | Female 100 (50.0%) | 0.340 |
| Eye, n (%):             | Right 460 (43.4%) | Left 600 (56.6%) | Right 180 (39.1%) | Left 280 (60.9%) | Right 160 (44.4%) | Left 200 (55.6%) | Right 120 (50.0%) | Left 120 (50.0%) | 0.676 |
| SE(D): Mean±SD Range   | $+3.65\pm1.97$ (+0.5 to +8.5) | $+0.87\pm1.02$ (+0.5 to +2.75) | $+3.44\pm1.08$ (+3.0 to +5.75) | $+5.92\pm0.67$ (+6.0 to +8.5) | $<0.001^*$ |
| CCT(μm): Mean±SD Range | 529±38.8 (448 to 619) | 525.3±35.7 (468 to 616) | 525.3±42.6 (448 to 619) | 525.6±35.9 (486 to 606) | 0.999 |
| K1 Mean±SD Range        | 42.63±1.57 (46.4 to 39.7) | 42.6±1.8 (39.7 to 46.4) | 42.7±1.2 (40.1 to 46.1) | 42.5±1.6 (39.89 to 44.98) | 0.296 |
| K2 Mean±SD Range        | 44.31±1.72 (40.1 to 48.6) | 44.4±1.7 (40.6 to 48.0) | 44.2±1.6 (41.4 to 48.5) | 44.3±1.95 (40.11 to 47.18) | 0.758 |

SE: spherical equivalent; n: number; yrs: years; SD: standard deviation; D: diopter; K min: minimum keratometric power; K max: maximum keratometric power.* Statistically significant.

**Age, sex, and eye laterality:**

The subjects were divided into 3 age sub-groups <30years, 30 to 39years, and ≥ 40years. The mean±SD of CCT of these sub-groups found to be thinner with age, with statistically significant differences in both myopic subjects ($P_2=0.0316$) and hyperopic subjects ($P_2= 0.0022$). There were no statistically significant differences between right and left eyes in myopic subjects ($P_3=0.3521$) and hyperopic subjects.
(P3=0.1042). Male has thicker cornea than females with statistically significant differences (P4=0.034 and P<0.0001) for the myopic and hyperopic subjects respectively, Table 4.

Table (4): Central corneal thickness by age groups, eye laterality and sex in myopic and hyperopic subjects.

| Age groups (yrs): | Central corneal thickness Mean±SD Range | P1-value |
|-------------------|----------------------------------------|---------|
| < 30              | Myopia 536.4±23.4 (467 to 617) | 0.193   |
|                   | Hyperia 534.0±41.5 (468 to 619)    |         |
| 30 – 39           | Myopia 532.9±20.7 (426 to 622)     | 0.252   |
|                   | Hyperia 530.4±29.8 (490 to 591)    |         |
| ≥ 40              | Myopia 531.3±26.9 (406 to 636)     | 0.192   |
|                   | Hyperia 524.5±41.7 (448 to 597)    |         |
| P2-Value          | 0.0316*                             | 0.0022* |

| Eye               | Central corneal thickness Mean±SD Range | P3-value |
|-------------------|----------------------------------------|---------|
| Right             | Myopia 532.9 ± 32.5 (433 to 636)       | 0.4337  |
|                   | Hyperia 531.2 ± 38.9 (448 to 616)      |         |
| Left              | Myopia 531.1 ± 33.3 (406 to 622)       | 0.2200  |
|                   | Hyperia 528.5 ± 39.0 (450 to 619)      |         |
| P3-value          | 0.3521                                 | 0.1042  |

| Sex               | Central corneal thickness Mean±SD Range | P4-value |
|-------------------|----------------------------------------|---------|
| Male              | Myopia 535.3 ± 31.9 (462 to 617)       | 0.691   |
|                   | Hyperia 536.4 ± 39.5 (448 to 606)      |         |
| Female            | Myopia 531±3.4 (433 to 636)            | 0.0298* |
|                   | Hyperia 526.3 ± 38.3 (468 to 619)      | <0.0001*|

* Statistically significant.

**Discussion**

Reference values are a significant base for clinical decisions throughout patient examinations and diagnosis of different ocular diseases. The diagnostic criteria for those diseases depended on the differences between those reference values and clinical observations [10]. In this study, reference values for the central corneal thickness of the Egyptian population with different refractive errors were 531.9 μm for myopic and 529μm for hyperopic subjects, respectively. These values are relatively higher compared to that recorded in other studies (other ethnic groups) [11-15]. Also, it reports that the myopic and hyperopic subjects show a statistically significant reduction in CCT with aging, females have thinner corneas than males, with no significant differences between the right and left eyes in all the subjects as recorded in other studies [12,16,17]. Also, about 23.6% of the myopic eyes and 16.5% of the hyperopic eyes (in the investigated sample) have CCT less than 500μm and this means that those patients are not suitable for LASIK.
Normal reference values represent an essential base of clinical judgment for the patients. Once the normal range of CCT is specified in a population, applicable studies can be completed without the necessity for a control group, and patients’ pachymetry analyses can be adjudicated with more certainty [18-21]. Still, most ophthalmic diagnostic instruments produced in America and Europe use normal reference values of their populations. In this manner, it may not be effective to assess the Egyptian population utilizing normal values from Americans and Europeans. Gathering normal values of the corneal thickness in a large population of adult Egyptians will help in precise diagnoses of keratoconus and keratoconus suspect, besides other corneal diseases, where these reference values of Egyptians CCT are important also in glaucoma diagnosis and treatment.

Principally in successful corneal refractive surgery, corneal thickness is an important factor for the preoperative screening of keratoconus and for pre-surgical assessment of the precise ablation profile to maintain post-surgical corneal stability. This reduces the incidence of post-LASIK corneal ectasia [22].

Increased care on the corneal thickness has brought about its description in a considerable number of studies from different regions and countries [23-28]. For the contrasts in ethnicity, geography, and other environmental variables, there is a wide-extending variety within these records; in this way, reference values of the corneal thickness-related parameters should not be utilized imprecisely and should be sensitive to variations within each population.

To the best of my knowledge, this is the first study with a relatively large sample size, which reports the reference values for central corneal thickness in an Egyptian population with different refractive errors. Some restrictions must be considered while reading this study. First, the study was led in one city, and hence, the environmental effects could not be evaluated. Second, it is a retrospective study, and in this way, all related restrictions must be thought of. Third, the unequal distribution of age groups between the myopic and hyperopic subjects. Finally, factors affecting female central corneal thickness, like the menstrual cycle, lactation, oral contraceptive pills, and hormonal therapy, were not associated.

In conclusion, reference values for central corneal thickness in the Egyptian population with myopia and hyperopia were generated, quantified, and presented in this study. These values offer tools for interpreting many clinical situations and evaluating changes in physiology and corneal biology in response to systemic diseases among the Egyptians. This also will help for accurate diagnoses of suspected keratoconus, early keratoconus, and other corneal diseases.

Abbreviations

CCT: Central corneal thickness.

IOP: Intraocular pressure.

SE: Spherical equivalent.
K min: minimum kertometric power.

K max: maximum keratometric power.

D: diopter.

SD: standard deviation.

SPSS: Statistical Package for the Social Sciences

**Declarations**

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**Availability of data and materials:**

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

**Author's contributions:**

(AAG) designed the work, collected the data, analyzed it, writing the manuscript and submitting the manuscript.

**Ethics approval and consent to participate:**

The research ethics committee of the Faculty of Medicine, Suez Canal University accepted it. No informed consent was required to review the medical records of the subjects due to a number of the study sample and the retrospective nature of the study design. The confidentiality of the patients’ data was guaranteed.

**Consent for publication:**

Not applicable.

**Competing interests:**

No competing of interest.

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Figures
Figure 1

Mean+SD of the central corneal thickness of myopia sub-groups.

Figure 2

Histogram showing the distribution of central corneal thickness values in myopic adult Egyptian subjects.
Figure 3

Mean of the central corneal thickness of hyperopia sub-groups.

Figure 4

Histogram showing the distribution of central corneal thickness values in hyperopic adult Egyptian subjects.