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Association Between Central Corneal Thickness and Axial Length in Patients with Refractive Anomalies and Emmetropes

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Abstract

Background: This study aimed to determine the correlation between central corneal thickness (CCT) and axial length (AL) in patients with refractive anomalies and emmetropes.

Methods and Results: The study included 330 respondents, with a total of 660 eyes, divided into two groups. The test group (TG) included 180 respondents with refractive anomalies (65 respondents with hypertropia, 65 with myopia, and 50 with astigmatism); the control group (CG) included 150 respondents with uncorrected visual acuity – 6/6 in both eyes.

The CCT values were higher in the hypermetropic group compared to the myopic group (561.5±25.3 vs. 517.9±37.3 mm, $P<0.001$), astigmatism group (561.5±25.3 vs. 528.3±35.3 mm, $P<0.001$) and the CG (561.5±25.3 vs. 553.3±18.5 mm, $P<0.001$).

From 360 eyes in the TG with refractive anomalies, the lowest AL values were found in the hypermetropic group (21.7±1.0 mm) compared to the myopic group ($P<0.001$), the astigmatism group ($P<0.001$), and the CG ($P<0.001$). Similar differences were also found for the right eyes (OD): hypermetrops tend to have shorter AL than the astigmatic group ($P<0.001$), myopic group ($P<0.001$), and the CG (emmetrope) ($P<0.001$).

Conclusion: The mean CCT value in the hyperopic group was higher than in the emmetropic group, while the CCT value of the myopic and astigmatic group was lower than that of the emmetropic group. AL values were the lowest in the hypermetropic group than in the myopic, astigmatic, and control groups.(**International Journal of Biomedicine. 2023;13(3):96-100.**)

Keywords: central corneal thickness • refractive anomaly • axial length

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Introduction

Central corneal thickness (CCT) is an important indicator of corneal health status. It is an essential tool in assessing and managing corneal diseases and helps estimate the corneal barrier and endothelial pump function.[1] Refractive errors refer to an optical defect in which the optical system cannot sharply focus parallel rays of light on the retina when the accommodation is at rest.[2-4]The most common refractive errors are myopia, hyperopia, and astigmatism.[5] The global magnitude of refractive errors is not reliably reported, but it is estimated that more than 2.3 billion people worldwide are affected by this ocular condition.[6]

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Experimental, epidemiological, and clinical research has shown that both environmental and genetic factors influence refractive development.[7] The axial length (AL) is known to be shorter in hyperopes and longer in myopes than in emmetropic eyes.[8] Compared with other ocular components, such as the cornea and crystalline lens, the AL is typically regarded as the primary determinant of refractive error.[9] The AL is the distance from the corneal surface to an interference peak corresponding to the retinal pigment epithelium/Bruch's membrane; this is expressed in millimeters,[10,11] and AL is one of the key variables determining the eye's refractive status. AL grows beyond the length at which emmetropia occurs, leading to myopia. Before emmetropia, short AL tends to keep hyperopia.[12] Among these components, AL received the most attention since it is a main parameter for both myopia and hypermyopia.[13]

This study aimed to determine the correlation between CCT and AL in patients with refractive anomalies and emmetropes.

Materials and Methods

The study included 330 respondents, with a total of 660 eyes, divided into two groups. The test group included 180 respondents with refractive anomalies (65 respondents with hypertropia, 65 with myopia, and 50 with astigmatism); the control group (CG) included 150 respondents with uncorrected visual acuity – 6/6 in both eyes.

All respondents included in the research were aged 18–40, with an average age of 22.9 years.

Data collection

Emmetropic respondents were selected after a detailed examination. Refractive anomalies were presented by the spherical equivalent refraction calculated as sphere plus half of the cylindrical error. The respondents were classified according to the spherical power into three major groups: emmetropic group (+0.25 to −0.25 D), myopic group (≥−0.50D), and hypermetropic group(≥+0.50D); furthermore, according to the cylindrical equivalent some respondents were classified into the astigmatism group (≥−0.5 DC to + ≥0.5 DC). The hypermetropia and myopia groups were divided into three subgroups based on refractive power: mild (≤3.00 DS), moderate (3.00-6.00 DS), and high (>6.00 DS).

Based on the focus of the main meridians in the astigmatic group, the respondents were classified into these subgroups: myopic astigmatism, hypermetropic astigmatism, compound astigmatism, and mixed astigmatism. Myopic astigmatism was determined in respondents who had a negative (sphere and cylinder) error of ≥-0.50DC, and hypermetropic astigmatism was determined in respondents who had a positive (sphere and cylinder) error of ≥+0.50DC.

In the subgroup of myopic compound astigmatism, respondents were classified into the group where both the sphere and cylinder had negative diopters (≥ −0.50D and ≥ −0.50DC), as well as the group of compound hypermetropic astigmatism (≥ +0.50D and ≥ +0.50DC). Meanwhile, the mixed astigmatism group included respondents with a positive sphere (+0.50D) and a negative cylinder (-0.50DC), or the opposite.

Inclusion criteria, respondents with the following: previously undiagnosed refractive anomalies, need for correction of refractive anomalies, normal corneal topography, no ocular disease, no previous eye surgery, and no previous correction with glasses.

Exclusion criteria, patients with the following: glaucoma and previous corneal refractive surgery procedures; IOP>21mmHg; evidence of other anterior segment pathology, including corneal opacities, keratoconus, corneal oedema, presbyopia, amblyopia, staphyloma; best visual acuity of 6/6 (also expressed as 20/20 or 1.0); diabetes mellitus or other acute or chronic diseases possibly affecting the corneal thickness; no history of contact lens wear; encroached pterygium; refusal to give consent.

Procedure

Data collected from respondents with refractive anomalies were retrospectively collected for 360 eyes examined over a period of two years, thereafter compared with data from normal eyes. After informed consent was obtained, the respondents underwent a complete ophthalmic examination and anterior segment evaluation biomicroscopy. Visual acuity was measured at 6 meters (20 feet) using a Snellen chart.

IOP measurement by Goldmann applanation tonometry (GAT): three measurements were taken, and the average was calculated, optic axis length measurement with ultrasound A scan, corneal curvature measurement with the automated keratometry, and 90D cycloplegia fundus exam.

CTT measurement was initially performed on all respondents with refractive anomalies as well as the CG. CCT was measured by ultrasonic pachymetry, five CCT measurements were taken, and the average was used for analysis. The visual acuity was determined using mydriatic points, then under the influence of the mydriatic, with Hydrochloride Cyclopentolate (one drop of 1% solution). A cyclopentolate drop was instilled two times at an interval of 10 minutes, and refraction was carried out after 45 minutes after the first instillation. Cycloplegia was considered complete if the pupil was dilated to 6 mm or more and no light reflex was present. On completion of testing the right eye, the acuity of the left eye was measured. Results were the same when the left eye was analyzed; thus, right-eye data were presented.

Statistical analysis was performed using the statistical software package SPSS version 22.0 (SPSS Inc, Armonk, NY: IBM Corp). For the descriptive analysis, results are presented as mean (M) ± standard deviation (SD). For data with normal distribution, inter-group comparisons were performed using Student's t-test. A non-parametric Kruskal-Wallis test was used to compare median values among ≥3 groups, followed by Dunn's test to identify which groups are different. Categorical variables were analyzed using the chi-square test with Yates' correction or, alternatively, Fisher's exact test. Spearman's rank correlation coefficient (r_s) was calculated to measure the strength and direction of the relationship between two variables. A probability value of $P<0.05$ was considered statistically significant.

Results

Most of the respondents in all groups were females, without significant differences between groups (P=0.824). In all groups, the respondents were younger than 40, although the control and astigmatism groups were younger than the others (P=0.0002), (Table 1).

We found a statistically significant difference between the CCT values of the three groups—hypermetropia, myopia, and astigmatism—and the CG ($P<0.001$) (Table 2). But we found no statistically significant difference between the CCT values in the hypermetropic and mixed astigmatism groups, compared with the CG ($P>0.05$).

In the group of respondents with hypermetropia, we found a statistically significant difference in the CCT values in the subgroups of high, moderate, and low hypermetropia, compared to the CG (569.5±23.2 vs. 553.3±18.5 mm [$P<0.05$], 577.1±40.2 vs. 553.3±18.5 mm [$P<0.001$], and 559.7±21.5 vs. 553.3±18.5 mm [$P<0.001$], respectively). In the group with myopia, we found statistically significant differences

in the CCT values in the subgroups of high, moderate, and low myopia, compared to the CG (507.3±50.8 vs. 553.3±18.5 mm [*P*<0.001], 499.3±41.8 vs. 553.3±18.5 mm [*P*<0.001], and 526.0±34.5 vs. 553.3±18.5 mm [*P*<0.001], respectively) (Table 2). In the group with astigmatism, we found a statistically significant difference between the CCT values in the myopic and compound subgroups of astigmatism, compared with the CG (518.2±24.6 vs. 553.3±18.5 mm and 514.1±36.0 vs. 553.3±18.5 mm, *P*<0.001 in both cases) (Table 2). About 24.5% of the myopic eyes and 16% of the astigmatic eyes had CCT less than 500 µm.

Table 1.

General characteristics of study patients

	Hypermetropic group n=65	Myopic group n=65	Astigmatism group n=50	Control group n=150	*P*-value
Gender. n (%)					
F	45(69.2)	41(63.1)	32(64.0)	94(62.7)	0.824
M	20(30.8)	24 36.9)	18(36.0)	56(37.3)	
Age (year)					
Mean ± SD	23.8±4.9	24.2±5.6	21.6±2.1	22.3±2.7	0.0002
Rank	18-40	18-39	17-28	18-30	

Table 2.

Central corneal thickness by groups

CCT (µm)	n	Mean ±SD	*P*-value
Hypermetropia	65	561.5±25.3	Hypermetropia
high	7	569.5±23.2	High vs.Con., *P*<0.05
moderate	15	577.1±40.2	Moderate vs.Con., *P*<0.001
low	43	559.7±21.5	Low vs.Con., *P*<0.001
Myopia	65	517.9±37.3	Myopia
high	5	507.3±50.8	High vs. Con., *P*<0.001
moderate	9	499.3±41.8	Moderate vs. Con., *P*<0.001
low	51	526.0±34.5	Low vs. Con., *P*<0.001
Astigmatism	50	528.3±35.3	Astigmatism
hypermetropic	10	547.8±27	Hypermetrop.vs. Con., *P*>0.05
myopic	21	518.2±24.6	Myopic vs. Con., *P*<0.001
mixed	11	549.4±41.5	Mixed vs. Con., *P*>0.05
compound	8	514.1±36	Compound vs. Cont., *P*<0.001
Control (Con.)	150	553.3±18.5	
Kruskal Wallis test		*P*<0.001	

Dunn's test

Hypermetropia vs. Myopia [*P*<0.001];
Hypermetropia vs. Astigmatism [*P*<0.001];
Hypermetropia vs. Control [*P*>0.05];
Myopia vs. Astigmatism [P>0.05];
Myopia vs. Control [*P*<0.001];
Astigmatism vs.Control [*P*<0.001].

Table 3.

AL (OD) values in groups with refractive anomalies

AL (mm)	Group			
	Hypermetropia	Myopia	Astigmatism	Control
n	65	65	50	150
Mean	21.6	23.2	23.0	23.1
SD	0.9	1.1	1.1	0.3
Min	19.0	21.0	20.8	22.0
Max	23.3	26.3	25.2	24.9
Kruskal Wallis test P<0.0001				

Dunn's test

Hypermetropia vs. Myopia [*P*<0.001]; Hypermetropia vs. Astigmatism [*P*<0.001]; Hypermetropia vs. Control [*P*<0.001]; Myopia vs. Astigmatism [*P*>0.05]; Myopia vs. Control [*P*>0.05]; Astigmatism vs. Control [*P*>0.05]

From 360 eyes in the TG with refractive anomalies, the lowest AL values were found in the hypermetropic group (21.7±1.0 mm) compared to the myopic group (*P*<0.001), the astigmatism group (*P*<0.001), and the CG (*P*<0.001). Similar differences were also found for the right eyes (OD) (Table 3): hypermetrops tend to have shorter AL than the astigmatic group (*P*<0.001), myopic group (*P*<0.001), and the CG (emmetrope) (*P*<0.001) (Table 3).

Moreover, we found a significant correlation between CCT and AL in the hypermetropic and astigmatism groups but no significant correlation between the myopic group and the CG (Figures 1-4).

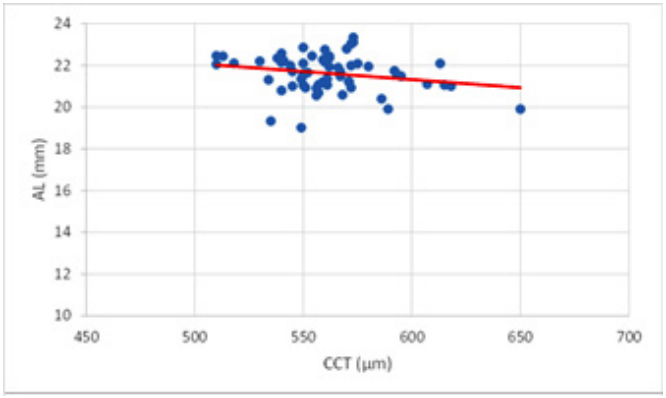

Fig. 1. *Correlation between CCT and AL in the hypermetropic group.*

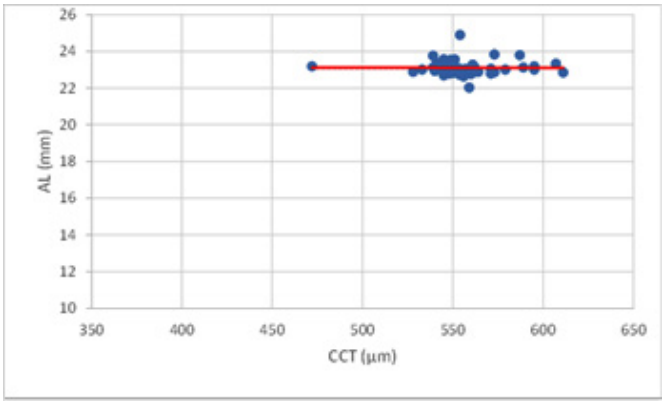

Fig. 2. *Correlation between CCT and AL in the myopic group.*

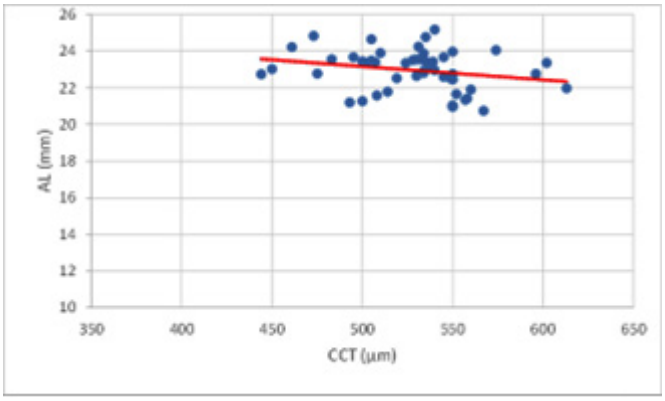

Fig. 3. *Correlation between CCT and AL in the astigmatism group.*

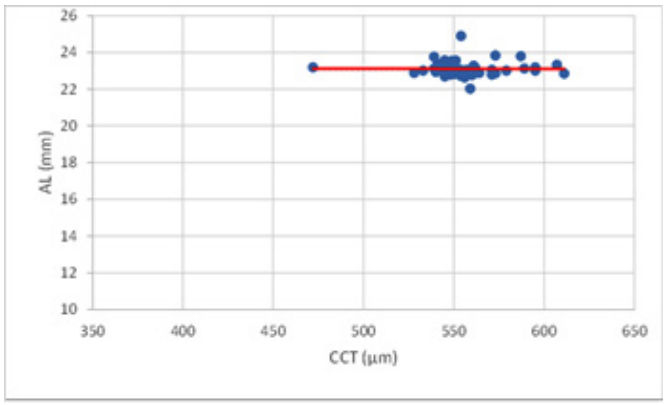

Fig. 4. *Correlation between CCT and AL in the control group.*

Discussion

In this study, the mean age was 22.9 years, ranging from 18 to 40 years, because people of these ages represent refractive stability. The respondents were distributed into three age subgroups:18-40 years in the hypermetropic group, 18-39 years in the myopic group, 17-28 years in the astigmatic group, and 18-30 years in the emmetropic group. Respondents with astigmatism were younger than the hypermetropic (P<0.01) and myopic (P<0.01) groups. In all groups, females dominated, without a significant difference between the groups.

In a study by Juwayli et al.,[14] the average age of the myopic study group was 32.3± 5.61years, while in the hypermetropic group - 35± 6.59 years, ranging from 20 to 40 years. Women dominated in both groups. Their results are similar to those of our study. The results of a study by Mourad et al.[15] with the mean age for all patients of 33.75 years, most of them females, were also similar to our study results. However, the mean age in our study group was 22.9.

In a study by Iyamu et al.,[16] there was a statistically significant negative correlation between CCT and age, and that was a 5.0µm decrease in CCT for every 10-year increase in age. Their finding does not correspond with our study.

Our results confirmed our initial hypotheses. The first hypothesis is that the value of CCT in hypermetropic respondents is higher than in the emmetropic group. The second hypothesis is that CCT's value in myopic respondents is lower than in the emmetropic group. The third hypothesis, the value of the CCT in respondents with astigmatism depends on the type of astigmatic equivalents.

Our findings showed that the median CCT in the hypermetropic group was 564.8 µm, in the myopic group - 521.3 µm, and in the astigmatism group - 530.3 µm, compared to the emmetropic group with 552.3 µm. As a result, a correlation was found between CCT and refractive anomalies, as CCT was statistically higher in the hypermetropic group than in the myopic and astigmatism groups (P<0.001). About 24.5% of myopic and 16% of astigmatic eyes had CCT less than 500 µm.

The correlation between the CCT and refractive anomalies is questionable. Thus, as in our study, Shisheng et al.[17] suggested a positive correlation between these two parameters; but Liu et al.[18] found no significant correlation.

Bradfield et al.[19] found that the CCT is 1µm thinner than average for every degree of increased myopic refractive anomaly. In our study, we found such a correlation, but we did not determine the degree of the anomaly. A study by Kadhim et al.[20] that measured the CCT by ultrasound pachymeter found significantly thinner corneas in myopia (539.5 nm) than emmetropia (550.47 nm). Our study had similar results. Saxena et al.,[21] who used the same CCT evaluation methodology, found a thinner CCT in myopic individuals than in hyperopic. We had the same finding in our study.

A study by Nomura et al.[22] found a median CCT for hyperopia of 512.5 nm and for emmetropia of 516 nm. Their conclusion is contrary to our study results because we found CCT to be thicker in the hypermetropic group than in the emmetropic one. According to a study by Hashmani et al.,[23] astigmatism significantly correlates with CCT. These findings are in accordance with our study.

Mourad et al.[15] studied the association between CCT and axial errors of refraction, but unlike our study, the CCT was obtained by pentacam. They found the CCT is higher in the emmetropia than in myopia and hypermetropia groups. This result does not correspond with our study outcome because we found a higher CCT value in a hypermetropic group than in other study groups.

The other findings of our study were related to the correlation between CCT parameters and AL in respondents with refractive anomalies. In our study, AL values for both eyes were the lowest in the hypermetropic group, with an average of 21.7±1.0 mm statistically significant difference (P<0.001) than in the myopic group (23.3 mm), astigmatism group (23.1 mm), and the CG (23.1 mm), (P<0.001). So far, there is no consensus in terms of CCT correlation with other ocular parameters, including the AL.[16]

Chang et al.[24] found that the mean CCT in myopic adults was 533µm and is thinner in more myopic eyes with longer AL. Our results showed that CCT values were lower in the myopic group, with longer AL, but not in more myopic eyes. According to Bhardwaj et al.,[25] myopes tend to have longer AL, and hypermetropes tend to have a shorter AL than emmetropes and astigmatics up to particular age. This is in accordance with our results, although in different study age groups.

Unlike other studies, Iyamu et al.[16] found no correlation between CCT and AL in adult Nigerians. Neither did Shimmyo et al.,[26] who studied the ocular parameters of 1084 eyes. Meanwhile, we found a significant correlation between CCT and AL in the myopic and astigmatism groups, but no significance in the hypermetropic group and the CG.

In conclusion, the mean CCT value in the hyperopic group was higher than in the emmetropic group, while the CCT value of the myopic and astigmatic group was lower than that of the emmetropic group. In about 24.5% of the myopic eyes and 16% of the astigmatic eyes, the CCT was lower than 500 μm. AL values were the lowest in the hypermetropic group than in the myopic, astigmatic, and control groups.

Ethical Approval

This study was approved by the Health Research Ethics Committee at the University of Pristina (Ref. Nr.12072). Informed consent was obtained from all participants before collecting the data.

Competing Interests

The author declares that there is no conflict of interest.

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