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Original Research Article

Relationship between axial length, keratometry and central corneal thickness in patients with refractive errors at a teaching hospital in Southwest, Nigeria

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ABSTRACT

Background: Aim of the study was to determine the relationship between axial length (AL), keratometry and central corneal thickness (CCT), and refractive errors in adult patients attending the Guinness eye centre (GEC), Lagos university teaching hospital (LUTH) Idi-Araba, Lagos.
Methods: A descriptive cross-sectional study conducted among consecutive patients aged 16 years and above with refractive errors attending the GEC, LUTH. Ocular parameters measured included AL, anterior corneal curvature, CCT and refractive errors. AL and keratometry were measured with IOL master and CCT with ultrasonic A scan pachymeter. Refraction was done with auto-refractor-keratometer. Data analysis was done with statistical package for social science (SPSS) 20.
Results: A total of 394 patients were studied, 157 males and 237 females. The age range was 16-65 years, mean -37.9±13.3 years and median -36.5 years. There were more myopic patients 215 (54.6%) than hyper-metropes 179 (45.4%). The mean AL was 23.9±1.1 mm and eyes with longer AL were more likely to be myopic (r=-0.676, p<0.001); to have flatter cornea (r=0.519, p<0.001) and thicker cornea (r=0.149, p=0.003). The mean CCT was 520.3±31.0 µm. There was a weak negative correlation between CCT and refractive error (r=-0.111, p=0.027).
Conclusions: The mean CCT was lower than the mean CCT of other Nigerian studies. Hypermetropic patients were more likely to have thinner corneas**.** This may lead to underestimation of intraocular pressure (IOP) in these patients**.** Significant correlation was seen between AL and refractive error, CCT and keratometry. AL correlated with less spherical equivalent refractive error, flatter and thicker cornea. It is therefore important to measure the CCT of all patients going for refractive surgery to detect those at risk of developing corneal ectasia following refractive surgery.

Keywords: AL, Keratometry, CCT, Refractive error

INTRODUCTION

Refractive errors constitute one of the commonest causes of visual impairment affecting all age groups.[1] Refractive error occurs when there is failure of the eye to correctly focus rays of light from an object onto the retinal plane. The resultant image perceived by the individual is blurred, and refractive correction is required to see clearly. Refractive error can be divided into myopia, hyperopia and astigmatism.[2] Refractive errors are not preventable but can easily be treated with corrective eye glasses, contact lenses or in some cases, corrective surgery.[3]

Refractive errors are the commonest cause of visual impairment and the second commonest cause of visual loss worldwide as 43% of visual impairments are attributed to refractive errors.[4] Holden and colleagues reported that an estimated 2.3 billion people have refractive errors worldwide but only 1.8 billion had access to affordable correction, leaving about 500 million people mostly in developing countries with uncorrected refractive errors.[5] Naidoo et al showed that uncorrected refractive errors were responsible for visual impairment in 101.2 million people and blindness in 6.8 million people in 2010.[6] In Nigeria, it accounts for 77.9% of mild visual impairment, 57.1% of moderate visual impairment, 11.3% of severe visual impairment, and 1.4% of blindness among Nigerian adults in a national survey conducted from 2005 to 2007. The crude prevalence of myopia (≤0.5 D) and high myopia (≤5.0 D) were 16.2% and 2.1%, respectively.[7,8] Ajayi and colleagues reported that refractive error occurred in 21.4% of total new cases in an observational study in Ekiti State.[9] The most common refractive error was myopia in 64.3%.

The refractive state of the eye is determined by the corneal power, the lens power, the anterior chamber depth, and the AL of the eye all of which are interdependent variables. The refractive power of the eye is dependent on the balance of change in the overall eye size and refractive components, namely, the cornea and the crystalline lens.

The AL is the distance between the cornea and retina of the eye. The majority of AL elongation takes place in the first three to six months of life although a slower rate of growth continues to occur over the next two years.[10] By three years the adult size eye is attained.[11] The changes in AL appear to outweigh the progressive corneal flattening with age in normal eyes. The AL has been shown to strongly correlate with the degree of refractive error and measurement of AL can be used to study the difference between myopes and hypermetropes.[12]

The CCT has an important bearing on IOP measurement and it has been shown to influence true IOP measurement.[13,14] CCT plays a vital role in the management of glaucoma, as thin CCT is a relative risk factor in the disease process. Corneal thickness is also an important measurement in patients screening before refractive surgeries.

Keratometry is measurement of anterior radius of curvature of cornea. It can also be represented in dioptres. A mean keratometry greater than 47.00 DS is a risk factor for development of corneal ectasia post refractive surgery.

With the recent surge in corneal refractive surgeries, there is a renewed interest in understanding the correlation between AL, keratometry and CCT with refraction. The correlation between these parameters remains a subject of debate as these parameters are interdependent and yield varying results according to populations being studied. Therefore, this study aimed at further determining the relationship between refractive errors and these ocular parameters and the correlation between these parameters in Nigerian Africans.

METHODS

This descriptive cross-sectional study was conducted among 421 consecutive and consenting patients aged 16 years and above with refractive error attending the GEC, LUTH, Idi-Araba, Lagos State through a systematic random sampling technique. Subjects with refractive error and IOP≤ 21 mmHg and patients with no other ocular diseases, previous history of contact lens use, ocular trauma or surgery and co-morbidities (such as diabetes, hypertension, haemoglobinopathy) were included in the study. Subjects with previous history of contact lens use, corneal diseases, visible lens opacity, ocular trauma or surgery and glaucoma were excluded from the study.

Ethical approval was obtained from the LUTH health research and ethics committee. Informed consent was also obtained from each of participants prior to the examination.

An interviewer administered questionnaire and examination proforma were used to elicit information from respondents. Every third consecutive consenting patient from the out-patient clinic that met the inclusion criteria was recruited into the study between January and June 2014 till the required number of participants was obtained. Old and newly diagnosed patients with only refractive error were recruited into the study. Ocular history was taken and ocular examination was carried out on each patient by the principal researcher and the ophthalmology resident doctor. Blood pressure and random blood sugar tests were done to exclude hypertension as well as the diabetes.

Ophthalmic assessment included visual acuity test, slit lamp examination, IOP measurement, dilated fundoscopy, cycloplegic refraction, pachymetry, keratometry and AL measurements. IOP was measured using Perkins's hand held applanation tonometer. Patients' eyes were dilated with 1% cyclopentolate eye drops and a cycloplegic refraction was carried out using an auto-refractor-keratometer. The refractive error was calculated in diopters as the spherical equivalent of spherical refractive error plus half the cylindrical refractive error. Measurement of ocular parameters was done in the right eye of each participant. All measurements were taken between 9.00 AM and 12 noon. Subjective refraction was done at a later date and prescription was given to the patient.

AL and keratometry (anterior radius of curvature) measurements were obtained using IOL master. The two major keratometry readings separated by 90° were averaged to give mean keratometry value. CCT was measured using ultrasonic SUOER ophthalmic A scan pachymeter SW 100 (model no GI 090760982 SN/0037CP) at 55Hz. All the measurements were performed by the researcher and the mean of three readings for each ocular parameter was used for analysis. To avoid using a patient more than once, the patient's case note was tagged.

A descriptive analysis and Pearson's bivariate correlation of studied ocular parameters was done using the statistical package for social sciences (SPSS) software version 20 (IBM Corp, Armonk, NY, US).

RESULTS

Sociodemographic characteristics

A total of 394 participants were analysed in study. There were more female patients 237 (mean age, 37.5±13.6 years) than male patients 157 (mean age, 38.3±12.8 years) in this study. The male to female ratio was 2:3.

Table 1: Sociodemographic characteristics of respondents.

Variables	Frequency	Percentage (%)
Age (Years)		
<20	26	6.6
20-29	116	29.4
30-39	71	18.0
40-49	87	22.1
50-59	74	18.8
60 and above	20	5.1
Sex		
Male	157	39.8
Female	237	60.2
Educational status		
No formal education	17	4.3
Primary	46	11.7
Secondary	131	33.2
Tertiary	200	50.8
Occupation		
Student	107	27.2
Skilled labour	79	20.0
Professional	68	17.3
Unskilled labour	65	16.5
Unemployed	54	13.7
Semi-skilled labour	21	5.3

As shown in Table 1, the age range of participants was 16-65 years while the mean age of patients was 37.9±13.3 years and the median age was 36.5 years. Nearly one-third of the respondents (29.4%) were between 20 and 29 years, 50.8% had tertiary education while 27.2% were students.

Table 2: Values of ocular parameters of patients with refractive errors at GEC, LUTH.

Variable*	Mean	Range
AL (mm)	23.9±1.1	21.11 to 27.06
K (mm)	7.8±0.3	7.04 to 8.85
CCT (µm)	520.3±31.00	434 to 614
SE (D)		
Hypermetropia	1.2±1.0	0.13 to 6.13
Myopia	-1.7±1.7	-0.13 to -7.38

*Data presented as means ± standard deviation. AL=Axial length, K=Keratometry, CCT=Central corneal thickness, SE=Spherical equivalent.

Table 2 shows the values of the various ocular parameters. The mean AL was 23.9±1.1 mm and the AL ranged between 21.1 mm and 27.06 mm. The mean keratometry was 7.8±0.3 mm and the keratometry range was between 7.04 mm and 8.85 mm.

The CCT range was between 434 µm and 614 µm and mean CCT was 520.3±31.00 µm. The spherical equivalent refractive error ranged between -7.38 to 6.13D. The spherical equivalent refractive error means in the hypermetropic and myopic groups were 1.2±1.0 D and -1.7±1.7 D respectively.

As shown in Table 3, the means of the ocular parameters were compared between the two refractive groups. The myopic eyes had longer AL and thicker cornea than the hypermetropic eyes. The mean AL in myopic eyes was 24.4±1.1 mm while in hypermetropic eyes it was 23.3±0.8 mm. The difference in means was statistically significant (p<0.001).

The mean keratometry reading for both refractive groups were almost the same. The mean CCT was 520.0±31.3 µm in myopic eyes and 518.3±30.6 µm in hypermetropic eyes. However, the difference in mean was not statistically significant.

Table 3: Values of ocular parameters of patients with refractive errors at GEC, LUTH stratified by type of refractive error.

Variables	Hypermetropia		Myopia		T test	Df	P value
	Mean	Range	Mean	Range			
AL (mm)	23.3±0.8	21.21 to 25.15	24.4±1.1	21.11 to 27.06	-10.302	392	<0.001*
K (mm)	7.8±0.3	7.04 to 8.85	7.8±0.3	7.34 to 8.68	-0.312	392	0.755
CCT (µm)	518.3±30.6	434 to 593	522.0±31.3	438 to 614	-1.184	392	0.237
SE (D)	1.2±1.0	0.13 to 6.13	-1.7±1.7	-0.13 to -7.38	19.646	392	<0.001*

Data presented as mean ± standard deviation, p value based on Student's t-test, *statistically significant, AL=Axial length, K=Keratometry, CCT=Central corneal thickness, SE=Spherical equivalent

Table 4: Correlation analysis between ocular parameters of patients with refractive error at GEC, LUTH.

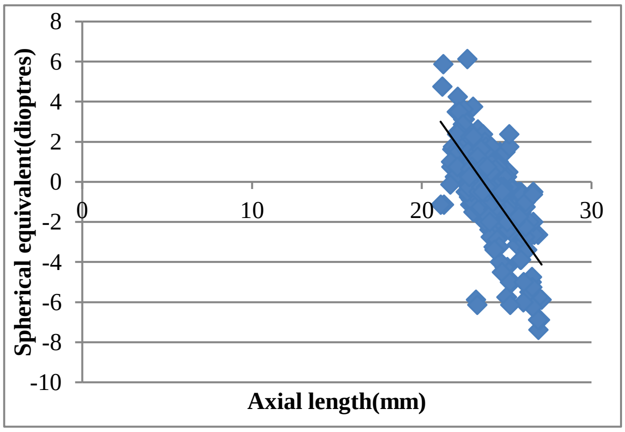
Variables	SE vs AL	SE vs K	SE vs CCT	AL vs K	AL vs CCT	K vs CCT
Whole group						
R	-0.676	-0.036	-0.111	0.519	0.149	0.049
P value	<0.001*	0.479	0.027*	<0.001*	0.003*	0.334
Hypermetropes						
R	-0.447	0.088	-0.022	0.682	0.034	0.025
P value	<0.001*	0.243	0.769	<0.001*	0.650	0.738
Myopes						
R	-0.597	-0.102	-0.138	0.53	0.199	0.068
P value	<0.001*	0.137	0.043*	<0.001*	0.003*	0.321

r=Pearson's correlation coefficient, p value based on Pearson's correlation, *statistically significant, AL- Axial length, SE- Spherical equivalent, CCT-Central corneal thickness, K-Keratometry.

Table 4 shows data from whole group showed a moderate positive correlation between AL and keratometry (r=0.519, p<0.001). There is also a moderate negative correlation between AL and spherical equivalent (r=-0.676, p<0.0001). However, positive correlation between AL and CCT is weak (r=0.149, p=0.003). Hence, eyes with longer AL had greater radius of curvature, thicker corneas and more myopia. There is a weak negative correlation between spherical equivalent and CCT. Hence, more myopic eyes had thicker corneas (r=-0.111, p=0.027).

In the myopic group, there was moderate positive correlation between AL and keratometry (r=0.530, p<0.001). There is a weak positive correlation between AL and CCT (r=0.199, p=0.003). However, there is a moderate negative correlation between AL and spherical equivalent (r=-0.597, p<0.001). Hence, eyes with longer AL also had greater radius of curvature, thicker cornea and more myopia in the myopic group.

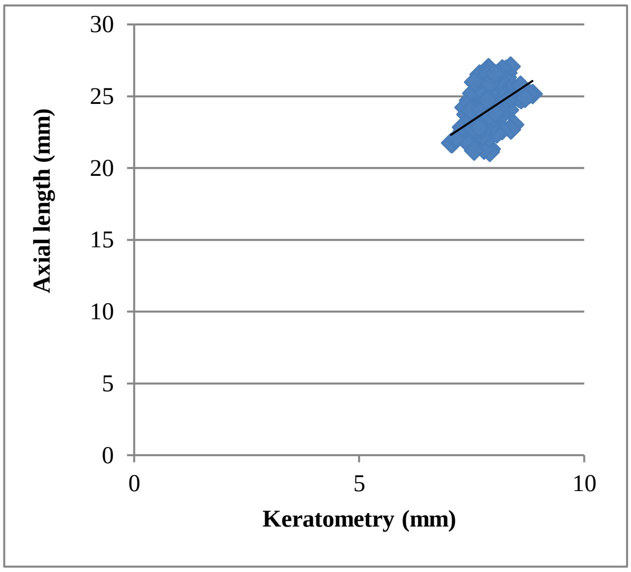
In the hypermetropic group, moderate positive correlation was seen between AL and keratometry (r=0.682, p=<0.001). But a weak negative correlation was seen between AL and spherical equivalent (r=-0.447, p<0.001).



Correlation coefficient=-0.676; p=<0.001; Y=-1.2X+28.60; r^2=0.46

Figure 1: Regression and correlation between the spherical equivalent refractive error and AL of patients with the refractive errors at GEC, LUTH.

As shown in Figure 1, the regression analysis between spherical equivalent refractive error and AL yielded: Y=-1.2X+28.60, r^2=0.46, Pearson's correlation coefficient=-0.676; p≤0.001. This shows a negative correlation between spherical equivalent refractive error and AL.



Pearson's correlation coefficient=0.519; p≤0.001; Y=2.074X +7.71; r^2=0.27

Figure 2: Regression and correlation between AL and keratometry of patients with refractive errors at GEC, LUTH.

As shown in Figure 2, regression analysis between AL and keratometry yielded: Y=2.074X+7.71; r^2=0.27, Pearson's correlation coefficient=0.519; p≤0.001. This shows a positive correlation between AL and keratometry.

DISCUSSION

In the present study, myopia was commoner than hypermetropia. However, myopia cannot be assumed to be commoner than hypermetropia because this is a clinic-based study with selection bias. Similarly, in the studies by Adefule-Ositelu and Adegbehingbe et al myopia was the commonest refractive error seen.[15,16]

The mean AL in this study was 23.9±1.1 mm which is slightly higher than the mean AL in the study by Chen et al (23.3±1.2 mm).[17] The authors measured AL in Taiwanese Chinese with A scan ultrasound and this may be responsible for the slight difference. However, the mean AL in the present study is lower than the mean seen by Chang et al in their study.[18] The participants were Chinese and mainly myopic patients and the mean age was 22.2 years which is lower than the mean age in this present study. This may have contributed to the longer AL seen in their study. The racial difference may also be responsible for the different mean ALs obtained. Another reason may be the use of different instruments by the other researchers.[18] In the present study, AL was measured with IOL master while A scan ultrasound was used by Chen et al and Chang et al.[17,18] Sachis Gimeno et al demonstrated that ALs measured with IOL master were higher than those with applanation ultrasound.[19]

In the present study, there was a weak negative correlation between AL and age. However, other studies showed a positive correlation between AL and age.[20,21] The present study was carried out among patients with refractive errors and this may be responsible for the different findings. AL was also seen to be longer in males than females and this is consistent with other studies.[17,18]

Myopes had longer ALs while hypermetropes had shorter ALs in the present study which is similar to other studies.[10,22] AL has been shown to be related to refractive error and myopia progression.[18] The present study further confirmed this relationship when it showed significant correlation between AL and spherical equivalent refractive error. Hence, increasing AL was related to increasing myopia while short AL was related to more hypermetropia. This is consistent with results from other studies.[17,23] In the present study, regression analysis showed that spherical equivalent refractive error was mainly predicted by AL. Unlike the present study where a wide range of refractive error was seen, Chang et al investigated myopic patients only and this may be responsible for the stronger correlation seen in their study.[18] Also, the number of patients in the Chang et al study was fewer than the present study.[18]

The AL correlated positively with keratometry value in the present study (r=0.519, p<0.001). The positive correlation between AL and keratometry value seen in the study was more in the hypermetropia group. Eyes with longer AL had a higher radius of corneal curvature hence flatter cornea. This finding is consistent with results from previous studies.[18,23] Increased flattening of the cornea was also seen as AL increased in Chen et al.[17] The normal anterior radius of curvature of the cornea is 7.8 mm which is similar to the mean anterior radius of curvature observed in the present study. The present study showed that males had flatter corneas than the females. This was also demonstrated by previous related studies.[17,18.24]

Keratometry value did not correlate with refractive error in the present study (r=-0.036, p=0.479) and similar finding was seen in the study by Chen et al.[17] In contrast, Al Mahmoud et al found a weak correlation between keratometry power in dioptres and spherical equivalent refractive error.[25] In that study, the mean keratometric power increased as mean spherical equivalent decreased.[25] The keratometric power was found to increase by 0.11 D for every dioptric decrease in spherical equivalent. The different correlations may be due to the different instrument used in measuring corneal curvature in these studies.[25,26] Al Mahmoud et al used the Zeiss Humphrey automatic refractor/keratometer 599 and Topcon KR-3000 auto-refractor-keratometer to measure the corneal curvature. The number of patients analysed was higher than the present study.[25] An earlier study by Sheridan et al. also showed that mean corneal radius of curvature was longer in hypermetropes than emmetropes.[27] Hypermetropes had flatter corneas than emmetropes in that study. The small number of hypermetropes in that study may make comparison difficult.[27]

The CCT is an important ocular parameter especially due to its influence on IOP. It is also an indicator of corneal endothelial function. The CCT has been noticed to vary with ethnicity and nationality.[28,29] In these studies, blacks had thinner cornea than Caucasians. Iyamu et al found a mean CCT of 548 µm when 130 adults Nigerians were examined.[30] They also noticed that CCT decreased with advancing age. Decrease in CCT with age may be due to a reduction in density of keratocytes and breakdown of collagen seen in aging cornea.[31]

The mean CCT in the present study (520.3µm) was lower than the mean in other Nigerian studies.[30,32] However, it is similar to mean CCT of blacks (521.0 µm) reported by Aghaian et al.[29] Selection bias may be responsible for the lower mean CCT found in the present study since only patients with refractive errors were examined. In the present study, there was no significant association between gender and CCT. This is similar to the findings of Iyamu et al.[30] The thinner corneas of patients in the present study suggest that many of these patients' IOP would have been underestimated. How CCT varies with AL, keratometry and spherical equivalent remain controversial. No consensus has been reached on how CCT relates to these ocular parameters.

As the eyeball elongates, the sclera (especially the posterior sclera) becomes predisposed to posterior staphyloma formation. The cornea may also thin with elongation of the eyeball but this is controversial.[17,18,21,33] The CCT in the present study had weak positive correlation with AL in the whole group and myopia group. As AL increased, the CCT also increased. This is similar to what Yin et al found in their study.[21] Chang et al noticed that eyes with longer AL had thinner corneas but there was no significant correlation in their study.[18] They thought that as AL increases corneal stroma becomes thinner. Other authors like Chen et al. and Oliveira et al. did not find any correlation between AL and CCT.[17,33] In the present study, CCT had a weak negative correlation with spherical equivalent refractive error. It was observed that increasing CCT tended towards decreasing spherical equivalent refractive error. Al Mahmoud et al found a very weak positive correlation between CCT and spherical equivalent refractive error.[25] CCT increase tended to occur with increasing spherical error. Fam et al and Chen et al however, found no correlation between CCT and refractive error.[34,17] A possible explanation for different findings could be variation in the populations studied.

Al Mahmoud et al using a large sample size of predominantly Caucasians found a weak correlation between corneal power and CCT.[25] There may not be a reasonable explanation for this finding since different results were seen in different studies.[17,25,30,34] However, ethnicity may be considered. Also, the sample size in those other studies were much smaller than sample size in the study by Al Mahmoud et al.[17,25,34]

The study may be limited by the clinic setting which may introduce selection bias. Hence, mean values of the ocular parameters must be interpreted with caution especially when comparing with population-based studies. However, the strength of the present study is that only one investigator measured the ocular parameters to reduce inter-observer errors. Cycloplegic refraction was also done which will reduce the variability that may occur with accommodation during refraction.

CONCLUSION

This study has been able to demonstrate a relationship between AL and keratometry, CCT and refractive error. As AL increased spherical equivalent refractive error decreased, the cornea became flatter and thicker. No correlation was seen between keratometry and CCT or refractive error. Males appeared to have longer mean AL, and flatter cornea. Age was also observed to have an association with refractive error. As age increased refractive error increased. The mean CCT was lower than the mean seen in other studies in Nigeria. The presence of the relationship between refractive error, corneal thickness and keratometry and AL may help to improve preoperative assessment of patients for cataract and refractive surgeries. This study further adds to previous knowledge on how these ocular parameters relate. Therefore, recommended that the CCT should be measured in all patients to prevent underestimation of IOP in these patients since the mean CCT is lower in our patients. This will also help to identify the patients at risk of primary open angle glaucoma. All patients going for refractive surgery should have pachymetry. This will help to prevent excessive corneal thinning in patient willing to have refractive surgery.

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