Original Article

Differences in Axial Length and Anterior Chamber Depth among Keratoconic, Myopic and Emmetropic Eyes

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ABSTRACT

Purpose: To report variation of the axial length (AL) and anterior chamber depth (ACD) among keratoconic (KC) eyes compared to myopic and emmetropic eyes in an African population sample.

Study Design: Cross sectional observational.

Place and Duration of Study: Al-Faisal Eye Hospital at Khartoum state of Sudan from January 2022 to September 2022.

Methods: One-hundred and twenty-four eyes of 62 patients were divided into KC group (n =17, eyes = 34), myopic group (n = 28, eyes = 56), and an age/gender matched emmetropic group (n = 17, eyes = 34). Central corneal thickness (CCT) was measured using ultrasonic pachymeter, AL, ACD and keratometry readings (K-reading) were recorded for each patient using non-contact partial coherence interferometry with an IOL Master.

Results: Mean age of the sample population was 22.27 ± 6.05 (range; 10 – 40 years). KC patients had the highest spherical equivalent of refraction (SER) (-6.19±3.91 dioptres), highest k-reading (48.98±5.68 dioptres) and the thinnest CCT. Myopic participants had a longer AL compared to other refractive error groups (AL = 24.99 ± 2.39, $p < 0.001$). KC patients exhibited a larger ACD in comparison to emmetropes and myopes (ACD=3.69 ± 0.26, $p < 0.001$). Among all participants, SER exhibited the highest correlation with AL ($r = -0.71$, $p < 0.001$) followed by a weaker correlation with ACD ($r= -0.26$, $p = 0.003$). However, among KC patients, SER exhibited a weaker correlation with AL compared to myopes ($r = -0.55$, $p = 0.001$), and a higher correlation with ACD compared to myopes ($r= -0.38$, $p = 0.03$).

Conclusion: ACD and corneal curvature were the most significantly detrimental parameters in KC. KC participants demonstrated a lower correlation between SER and AL and higher correlation between SER and ACD.

Key Words: Keratoconus, Axial length, Anterior chamber depth, Central corneal thickness, myopia, emmetropia.

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INTRODUCTION

Keratoconus is an asymmetric and usually bilateral disease of cornea which leads to its progressive thinning and steepening resulting in irregular astigmatism and reduction in visual acuity.[1,2]Most commonly observed histopathological changes in cornea that are associated with keratoconus include progressive thinning of stroma, rupture of the anterior limiting membrane and corneal ectasia.[3-5]

Majority of keratoconic eyes present with a progressive myopic astigmatism, where myopia could be attributed to changes in corneal dioptric power or changes in AL of the eye, or both.[6] Several reports have shown a negative relationship between AL and myopia. In other words, the longer the AL, the severer the myopia.[7,8] In addition, corneal curvature, anterior chamber depth (ACD) and vitreous chamber depth were reported to be linked to induce such refractive errors.[9,10,11] As keratoconus is a degenerative ocular condition associated with the development of refractive errors such as myopia and myopic astigmatism, it is expected that there are changes in AL and ACD.[12-14] Despite that AL is considered a major determinant of ocular refractive power, it has not been well studied in keratoconic eyes or has been investigated using ultrasonography techniques that use contact with the cornea.[12,13] Furthermore, these studies mainly employed Caucasians and did not consider ethnic variations in keratoconus in terms of ocular parameters.[2]

This study aimed to report the variation of the AL and ACD of keratoconic eyes compared to myopic and emmetropic eyes in an African population.

METHODS

The World Health Organization (WHO) sample size calculator with Finite Population correction (FPC) was used to determine the minimum sample size needed to perform this study. The population size was determined from all patients admitted for refractive error and correction and keratoconus management to Al-Faisal Eye Hospital at Khartoum state of Sudan between January, 2022 and September, 2022 and who were free of other eye diseases (except for keratoconus for the keratoconic group). Assumptions were made using a level of confidence of 95% and a margin of error of 5%. Once the design effect of 1.5 and adjustment for non-response using a 0.8 response rate, a minimum sample size of 59 subjects was calculated. The achieved sample size included in this cross-sectional, observational study was 62 subjects. The patients were divided into KC group (n = 17, eyes = 34), a myopic group (n =28, eyes =56), and an age/gender matched emmetropic group (n = 17, eyes = 34). All patients who visited Al-Faisal Eye Hospital at Khartoum state of Sudan between January 2022 and September 2022 and who matched the criteria of selection were consecutively recruited. Patients with any eye disease (besides keratoconus for the keratoconic group) or those who underwent any ocular surgery were excluded from this study.

Patients were subjected to a comprehensive eye examination that include uncorrected (UCVA) and best corrected visual acuity (BCVA), objective refraction using an autorefractometer (Topcon RM 89000, Japan) and CCT measurement using ultrasonic pachymeter (Accutome, AccuPach VI, USA). AL, ACD and K-readings were recorded for each subject using non-contact partial coherence interferometry with an IOL Master (Carl Zeiss, Oberkochen, Germany). Five readings were taken for AL, ACD and K-reading and average was calculated as per the manufacturer's instructions.

Data were analysed using IBM SPSS 24 (IBM Corp., Armonk, NY, USA) and P value of < 0.05 was taken as significant level in the inferential statistics.

All patients participated in this study showed their acceptance by signing a consent form that explained the research procedures and the purpose. Parents or legal guardians of children under the age of 18 years were requested to sign the consent form on behalf the children. All research procedures followed the principles of the Helsinki Declaration and were approved by the Ethics Committee.

RESULTS

A total of 62 patients (124 eyes) were recruited in this study. Among them, 17 patients had KC, 28 patients were myopic and 17 were emmetropic (control). Mean age of the sample population was 22.27 ± 6.05 (range; 10 – 40 years), which was 20.06 ± 4.39, 24.04 ± 6.43 and 21.59 ± 6.26 for keratoconus, myopic and control respectively. Table 1 illustrates the demographic and clinical profile of the patients.

Prior to conducting analysis, assumptions for each statistical test were checked and found not violated. One way between group ANOVA was used to find out any significant difference in AL between keratoconic

(M = 24.46, SD = 1.44), myopes (M = 24.99, SD = 2.39) and control eyes (M = 23.29, SD =1.02). The test showed statistically significant differences between the groups, F (2, 121) = 8.95, P < 0.001. Post hoc analysis indicated no significant difference in AL between keratoconic and myopic eyes, however, the AL of myopic and keratoconic eyes were found significantly higher than emmetropic eyes.

The ANOVA test also yielded significant differences between the study groups in term of ACD, F (1,121) = 11.97, P < 0.001. Pair wise comparisons indicated significant differences between keratoconic and myopic, keratoconic and control eyes, however, no significant difference was found between myopic and control eyes. The results showed that keratoconic eyes had significantly higher ACD compared to myopic and control eyes with no difference between myopic and control (refer to table 2).

Pearson's correlation coefficient showed no significant relation between AL (124 eyes) and mean keratometry readings (P = 0.17), however, strong negative correlation was detected between AL and SER (P < 0.001) (refer to figure 1).

Further correlation analysis was conducted between the parameters evaluated in each group. No significant correlations were found between axial length and Mean K (P = 0.06), and between axial length and CCT (P = 0.53) in keratoconus group, however, significant correlation was found between AL and SER (P =0.001) (figure 2) and between AL and ACD (P = 0.03) in the same study group. With regards to ACD, no significant correlations were detected between ACD and Mean K, SER and CCT with P values of 0.27, 0.09 and 0.77 respectively.

In myopic group, no significant correlations were detected between axial length and ACD, Mean K and CCT with P values of 0.75, 0.13 and 0.12 respectively, however, significant correlation was only found between AL and SER (P < 0.001) (see figure 3). ACD was found insignificantly correlated with SER, Mean K and CCT with P values of 0.38, 0.13 and 0.07 respectively.

DISCUSSION

The current study investigated differences in AL and ACD among a group of emmetropes, myopes and persons with keratoconus from Sudan using non-contact partial coherence interferometry technique. In addition, corneal curvature and CCT were measured and compared among the various refractive groups. As far as the authors' knowledge, this is the first study to investigate these parameters among persons from African Continent in general and Sudan in particular. Participants with keratoconus exhibited significantly thinner CCT, steeper corneal curvature and higher myopic SER in comparison to other refractive groups. Myopic participants had a longer AL compared to other refractive error groups. However, participants with KC exhibited a larger ACD in comparison to

Table 1: *Mean ± SD of demographic and clinical data of all patients.*

Data	Groups with Mean Values			
	Keratoconic (n=17 Patients, 34 Eyes)	**Myopic (n=28 Patients, 56 Eyes)**	**Control (n=17 Patients, 34 Eyes)**	**Total (n=62 Patients, 124 Eyes)**
Age (years)	20.06± 4.39	24.04± 6.43	21.59±6.26	22.27± 6.05
UCVA(Decimal)	0.17±0.17	0.16±0.167	0.98±0.12	0.39±0.34
BCVA (Decimal)	0.54±0.27	0.91±0.22	1.00± 0.00	0.83±0.27
SER (Dioptre)	-6.19±3.91	-4.98±4.63	0.06±0.34	-3.93±4.48
Mean K (Diopter)	48.98±5.68	44.25±1.86	43.02±1.92	45.19±4.09
CCT (µm)	440.47±93.31	508.14±111.77	538.35±38.16	497.87±98.61

UCVA; uncorrected visual acuity, BCVA; best corrected visual acuity, Mean K; mean keratometry reading, SER; spherical equivalent of refraction, CCT; central corneal thickness.

Table 2: *Mean differences of axial length and anterior chamber depth among the study groups.*

Parameter	Groups			P value
	Keratoconus (n =34 Eyes)	**Myope (n =56 Eyes)**	**Control (n = 34 Eyes)**	
AL (mean ± SD)	24.46±1.44	24.99±2.39	23.29±1.02	<0.001
ACD(mean ± SD)	3.69±0.26	3.46±0.39	3.30±0.28	<0.001

AL; Axial length ACD; anterior chamber depth

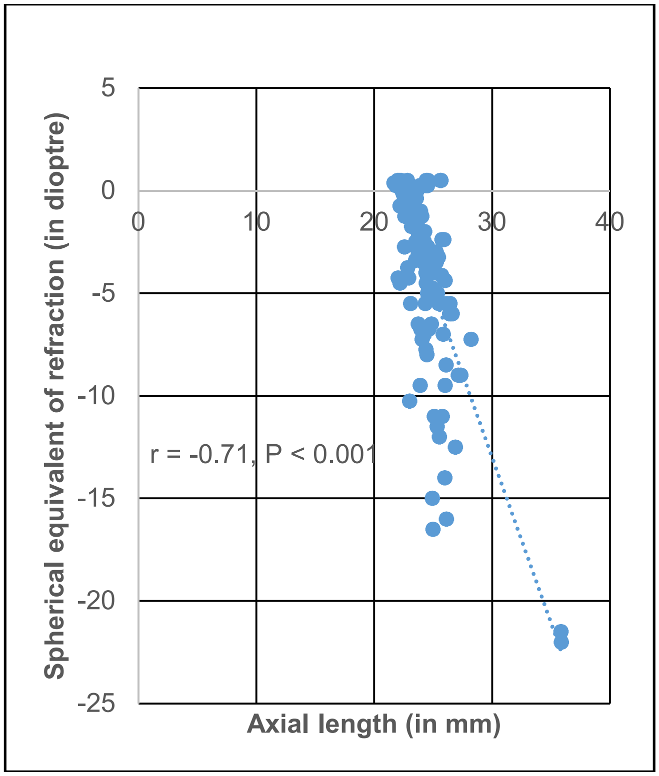

Figure 1: Correlation between axial length and spherical equivalent of refraction of all 124 eyes.

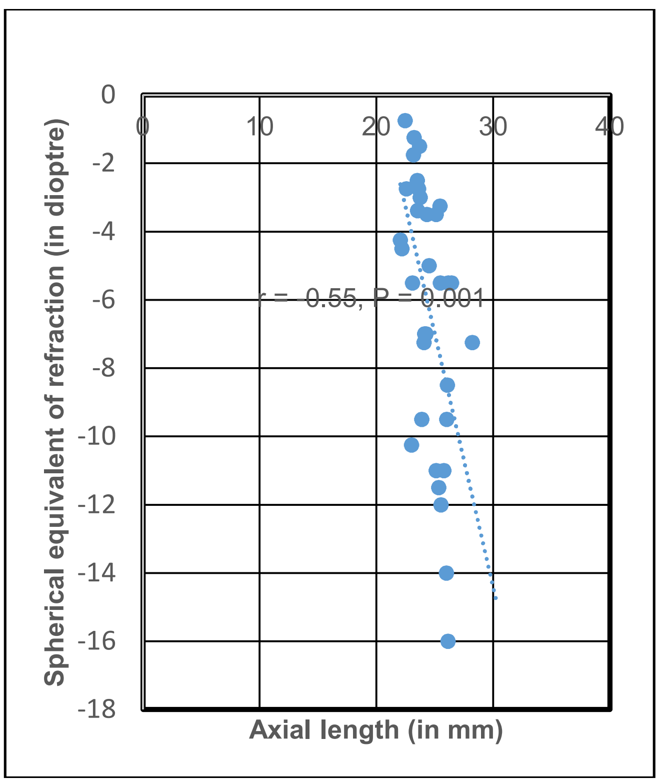

Figure 2: Correlation between axial length and spherical equivalent of refraction in eyes with keratoconus (34 eyes).

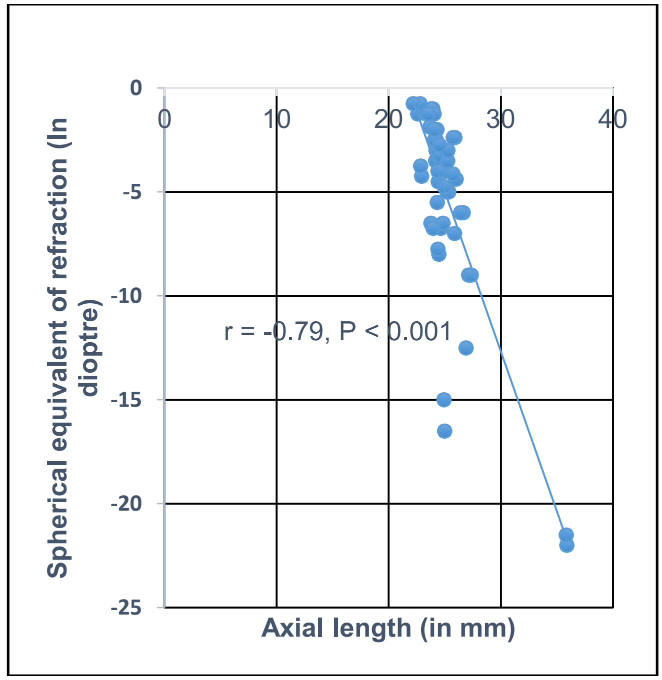

Figure 3: Correlation between axial length and spherical equivalent of refraction in eyes with myopia (56 eyes).

emmetropes and myopes. In the whole sample, especially among myopes, SER exhibited the highest correlation with AL followed by a weaker correlation with ACD. However, among patients with keratoconus, SER exhibited a weaker correlation with AL compared to myopes and a higher correlation with ACD compared to myopes.

A previous study conducted on predominantly Caucasian population sample using similar methodology to the current study has shown that AL was significantly higher in persons with keratoconus compared to emmetropes and lower compared to myopes.[15] In addition Caucasian participants with keratoconus exhibited a steeper corneal curvature and a deeper anterior chamber. Furthermore, regression analysis has shown a higher correlation between SER and ACD, and a lower correlation between SER and AL amongst keratoconic participants in comparison to the rest of the sample. This is in agreement with the current study which employed participants of African ethnicity, which shows that despite the variations in prevalence of keratoconus among ethnicities, ACD and corneal curvature remained the most significantly detrimental parameters in Keratoconus.[2,15]

A study conducted on Australian population of European ethnicities and utilizing a similar methodology to the current study had shown that CCT was the most significantly different ocular parameter between KC and other refractive groups while AL was not significantly different among the refractive groups.[16] The current study also demonstrated that participants with KC exhibited thinnest CCT. While there was no statistically significant difference in AL between myopic and keratoconic participants in the current study, AL was different between the control group (emmetropes) and other refractive groups. The difference in AL between emmetropic and keratoconic persons have also been demonstrated in another study.[14]

The variation in findings among the current study and previous studies can be attributed to the differences in the refractive error groups including participants with sub-clinical KC.[14,16]

In contrast to the findings of the current study and that of Rozema and colleagues[15] and Sahebjada et al,[16] Ernst et al, concluded that AL elongation in the posterior chamber rather than ACD elongation and corneal steeping[14] was mainly responsible for the refractive changes in African American participants with keratoconus. However, the results of this study should be taken with caution as AL measurements vary significantly among various techniques which would account for the discrepancy in conclusions in published literature.[17,18] It is of importance that clinicians employ the latest techniques in biometry measurement such as non-contact partial coherence interferometry technique for accurate AL measurements, especially if no ocular media opacity exists that would impede the utilization of optical biometry.[17-19]

In addition to keratometry readings and biometric measurements of cornea, AL and its components are also important in management and estimation of treatment outcomes and follow-up of KC patients. This is especially important when keratoplasty is performed as the surgery is expected to affect the AL of the eye and the post-surgical axial myopia would affect the optical outcomes of the surgery.[20,21] Thus, it is important for clinicians to be aware of the role of ocular parameters in KC to provide the best treatment outcomes for patients with KC.

A limitation of this study is the cross-sectional nature of the study design, which would not allow understanding of long-term changes in ocular parameters in KC compared to other refractive errors. It is recommended that a longitudinal study be conducted. Despite that the sample population size is similar to previous studies, it is recommended that a larger sample size should be considered as the range of AL in KC is wide.[13,14,20]

Data available from literature which practitioners rely on to manage KC patients of African descents should be considered with caution as it relied on methods of data capturing that are less accurate than the instruments used in the current study. Practitioners should consider; measure and monitor anterior chamber parameters more closely among African KC patients.

CONCLUSION

The current study investigated differences in ocular parameters among myopic, emmetropic and keratoconic participants of African ethnicity. SER, CCT and corneal curvature showed the highest variation among the refractive groups. AL was significantly different between the emmetropes and the participants with keratoconus. On the other hand, there was no significant difference in AL between the keratoconic and myopic participant's despites significant difference in SER between these two groups. While SER demonstrated a significant correlation with AL among the whole sample population, keratoconic participants demonstrated a lower correlation between SER and AL. On the other hand, keratoconic participants demonstrated a higher correlation between SER and ACD in comparison to other participants which support the role of the anterior segment parameters in keratoconus.

Conflict of Interest: Authors declared no conflict of interest.

Ethical Approval: The study was approved by the Institutional review board/Ethical review board **(FEC 0039).**

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Authors' Designation and Contribution

Mustafa Abdu; Associate Professor: *Concepts, Design, Data Acquisition, Data Analysis, Manuscript Preparation, Manuscript Review.*

Yazan Gammoh; Associate Professor: *Concepts, Design, Manuscript Editing, Manuscript Review.*

Hiba Abd Alla; Optometrist: *Concepts, Design, Data Acquisition, Manuscript Review.*

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