Original Article

Correlation of Axial Length, Lens Thickness, and Anterior Chamber Depth in Patients Undergoing Cataract Surgery

Ernest Ikechukwu Ezeh[1], Elijah Ndubuisi Chinawa[2], Roseline Nkeiruka Ezeh[3]

[1]Department of Ophthalmology, University of Calabar, Calabar, Cross River State, [2]Department of Ophthalmology, University of Uyo Teaching Hospital, Uyo, Akwa Ibom State, [3]Department of Ophthalmology, University of Calabar Teaching Hospital, Calabar, Cross River, Nigeria

Abstract

Background: Axial length, lens thickness and anterior chamber diameter are valuable parameters used in determining the refractive status of the eye. **Aim:** To determine the correlation between axial length (AL), crystalline lens thickness (LT), and preoperative anterior chamber depth (ACD) among patients undergoing cataract surgery. **Patients, Materials and Methods:** It was a cross-sectional study done over a one-year period. One hundred and fifty-one adults with cataract in both eyes were consecutively recruited. Using an optical biometer Ultrasound A/B Scan (Chong Qing Kang Hua S&T Co., Ltd, CAS-2000BER [Model A], China), ocular biometric data including AL, ACD, and LT were assessed for both eyes before cataract operation for either eye. Pearson's correlation and regression analyses were applied to determine relationships between the biometric variables. Statistically, significance was taken as $P < 0.05$. **Results:** One hundred and fifty-one (302 eyes) adult participants were studied, consisting of 77 (51.0%) males and 74 (49.0%) females. The age range was 12–88 years, with a mean age of 57.73 ± 14.87 years (95% confidence interval, 54.70–59.90). Correlation analysis revealed that AL and ACD were positively correlated ($r = 0.164$, $P = 0.002$). AL and LT demonstrated a statistically insignificant and very weak positive correlation ($r = 0.071$, $P = 0.217$). ACD was negatively correlated with LT ($r = -0.375$, $P = 0.000$). On multiple regression, AL (*z*-score = 0.191) and LT (*z*-score = −0.387) were significant predictor estimates of the regression model for ACD ($P = 0.000$); a hypothetical equation for ACD was generated: $ACD_{predicted} = 2.978 + (-0.522 \times LT \text{ in mm}) + (0.106 \times AL \text{ in mm})$. **Conclusion:** LT is an important biometric parameter that should be considered, along with other biometric parameters, in determining effective lens position in patients undergoing cataract surgery. The narrowing of ACD with age is largely due to increasing LT. Using an optical biometer, ACD is predominantly influenced by LT than the AL.

Keywords: Anterior chamber, axial length, effective lens position, lens thickness, ocular biometry

Introduction

Ophthalmic biometric parameters (axial length [AL], anterior chamber depth [ACD], lens thickness [LT], and keratometry [K]) are crucial factors determining the refractive status of the eye. The effective distance between the anterior surface of the cornea and the lens plane if the lens was infinitely thin, which is referred to as effective lens position (ELP), is estimated from the four generations of intraocular lens (IOL) power calculation formulae dependent on these parameters.[1-4] The postoperative ELP is predominantly determined by the postoperative ACD.[1,5,6] Different models utilize various ocular biometric parameters to predict postoperative ACD; however, the valuation of preoperative ACD constitutes the fundamental content in every IOL determining formula.[1]

Of note, the measurement of AL remains an indispensable step in IOL power calculation. Assuming normal eye dimensions, a 1 mm error in AL translates to an error of about 3 diopters (D).[1] It has been opined that AL is the most important factor in IOL calculation.[4] This may particularly be due to the documented robust scientific facts that postoperative ACD and AL are positively correlated.[1,4] Ning *et al*.[6] had reported that the postoperative ACD and refractive changes are significantly correlated with the preoperative ACD and AL. Thus, AL and preoperative ACD are very significant predictors in determining IOL power. However, with the advent of optical biometric techniques such as the IOL Master, the accuracy in AL measurements has remarkably

Access this article online

Quick Response Code:

Website: www.njmonline.org

DOI: 10.4103/NJM.NJM_9_21

Address for correspondence: Dr. Ernest Ikechukwu Ezeh, Department of Ophthalmology, University of Calabar, Calabar, Cross River State, Nigeria. E-mail: ezehiyk@yahoo.com

How to cite this article: Ezeh EI, Chinawa EN, Ezeh RN. Correlation of axial length, lens thickness, and anterior chamber depth in patients undergoing cataract surgery. Niger J Med 2022;31:208-11.

Submitted: 08-Jan-2021 **Revised:** 16-Mar-2022
Accepted: 17-Mar-2022 **Published:** 29-Apr-2022

improved, and its influence on refractive error deficit is acceptably less than ACD.[4,7] ACD and AL may, respectively, account for the error in 42% and 36% of the cases.[7]

Importantly, the preoperative ACD is influenced by the LT.[2,8,9] LT is known to increase with aging,[7,10] and Hashemi *et al*.[7] had reported that LT increase with aging is largely due to the intensification in protein fiber layers underneath the anterior and posterior capsules. The crystalline lens growth with aging leads to both an increase in thickness and size of the lens, thereby resulting in narrowing of the anterior chamber and anterior chamber angle.[8] Furthermore, the shallower ACD with age has also been attributed to the forward shift of the lens with the lying down of lens fibers.[11] Based on this fact, the incorporation of LT in addition to other parameters in the 4th-generation formulas such as Holladay II, Olsen and Barret, was aimed at improving the precision of predicting the ELP.[1,2]

In determining the ELP, the first generation formulas such as the Binkhorst I formula used AL, SRK formula consider AL and K. The second-generation formula SRK II and the third-generation formulas Hoffer Q, SRK T, and Holladay 1 consider AL as well as K.[1,2] The fourth-generation formulas Haigis formula added on preoperative ACD, Oslen and Barrett formulas consider preoperative ACD, LT as well as white to white. In addition, Holladay II incorporates age and preoperative refraction.[1-3,5,6]

It is therefore evident that preoperative ACD, AL, and LT are critical parameters in the determination of ELP and IOL power, and establishing any relationship between these parameters in a given population is valuable. Several studies,[4,8,12-15] particularly among Asians and Caucasians, have examined the correlation between these parameters in normal/healthy eyes as well as in cataractous eyes. The outcomes were in some cases mixed and, in others, inconsistent. Notably, only a few studies[9,10,16] on correlation of these parameters have been done among Africans. Reportedly, these parameters vary between races and ethnicities. Facts of their correlation in any given race and ethnic group are essential for optimal ophthalmic care.[9,17] The data from other climes, in which the population is culturally, ethnically, and geographically diverse to Africa, cannot readily be extrapolated to Africans in general and Nigeria in particular if there are no sufficient comparable locally derived data to aid comparison and guide domestication of the available facts. It is therefore evident that geographic- and ethnic-based studies are timely. This study aimed at determining the correlation between AL, LT, and preoperative ACD among adult Nigerian patients with cataract scheduled for cataract surgery, in which optical biometry method was utilized to obtain ocular biometric parameters.

Patients, Materials and Methods

An analytical cross-sectional study was undertaken at Eye Centre of the Mercy Hospital, Abak, Akwa Ibom State, Nigeria, between July 2016 and June 2017. A total of 521 cataract patients were seen at the hospital within the study period, 183 with bilateral cataract and 338 with unilateral cataract. Within the study period, 151 patients with cataract in both eyes and scheduled for cataract surgery were consecutively recruited for the study. Patients with a history of ocular trauma or surgery, complicated cataract in either eye, secondary causes of cataract such as diabetes mellitus and uveitis, and those with anterior segment disorder, were excluded from the study.

Permission from the hospital ethical committee was obtained, and we kept to the ethical provisions of the Declaration of Helsinki. Biodata such as sex, age, ethnicity, and occupation were enquired. Using an optical biometer Ultrasound A/B Scan (Chong Qing Kang Hua S&T Co., Ltd, CAS-2000BER [Model A], China), ocular parameters such as AL, ACD, and LT were assessed for both eyes before cataract operation. AL was determined as the distance from the anterior corneal vertex to the retinal pigment epithelium along with fixation.[4] ACD was defined as the distance from the anterior corneal vertex to the anterior cataractous lens surface.[4] LT was assessed as the distance from the anterior lens surface to the posterior lens surface. All measurements were done by one experienced ophthalmic technician; this was to avoid interobserver error.

Data analysis

The data were entered into Statistical Package for the Social Sciences (SPSS) for Windows (version 20, SPSS Inc., Chicago, IL, USA) and analyzed. Descriptive statistics are reported as frequency and percentage, where necessary. Inferential statistics such as Pearson's correlation analysis was applied to determine relationships between the biometric variables (i.e., AL and ACD, AL and LT, and ACD and LT). Mathematical model to estimate ACD using AL, LT, and age was derived via multiple regression model. $P < 0.05$ was taken as statistical significance.

Results

A total of 151 (302 eyes) participants, consisting of 77 (51.0%) males and 74 (49.0%) females, were studied. The male: female ratio is approximately 1:1. The age range was 12–88 years, with a mean age of 57.73 ± 14.87 years (95% confidence interval [CI], 54.70–59.90). The mean age of males and females was 57.31 and 57.16 years, respectively [$P = 0.910$, Table 1].

The mean values of AL, ACD, and LT were 23.51 ± 0.96 mm (95% CI: [23.33–23.64]), 3.22 ± 0.53 mm (95% CI: [3.12–3.30]), and 4.23 ± 0.39 mm (95% CI: [4.17–4.29]).

Correlation analysis

Correlation analysis of axial length and anterior chamber depth

A statistically significant positive correlation was observed between AL and ACD ($r = 0.164$, $P = 0.002$). After controlling for age, partial correlation analysis revealed a similar statistically significant positive correlation between AL and ACD ($r = 0.162$, $P = 0.005$). On controlling for LT, partial correlation analysis revealed a statistically significant slightly increased positive correlation between AL and ACD (r = 0.206, P = 0.000).

Correlation analysis of axial length and lens thickness

On correlation analysis, AL and LT demonstrated a statistically insignificant very weak positive correlation (r = 0.071, P = 0.217). After controlling for ACD, AL was then weakly, positively correlated with LT (r = 0.145, P = 0.012). After controlling for age, AL was still very weakly, positively correlated with LT (r = 0.074, P = 0.201).

Correlation analysis of anterior chamber depth and lens thickness

A negative correlation was observed between ACD and LT (r = −0.375, P = 0.000). After controlling for AL, partial correlation analysis revealed a marginal increased negative correlation between ACD and LT (r = −0.393, P = 0.000). After controlling for age, a negative correlation was still sustained between ACD and LT (r = −0.372, P = 0.000). After controlling for LT, a partial correlation analysis revealed that ACD was negligibly, negatively correlated with age (r = −0.031, P = 0.297).

Multiple regression analysis

Table 2 displays the correlations between ACD and AL, LT, and age, on multiple regression analysis. AL and LT were significant predictor estimates of the regression model (P = 0.000). Age was not a reliable predictor estimate of the model (P = 0.675). The standardized coefficients (beta) reveal that LT with z-score = −0.387 is a more powerful predictor of ACD, though in the negative direction, than AL which had z-score = 0.191. A hypothetical mathematical equation for predicting ACD was generated thus:

$ACD_{predicted}$ = 2.978 + (−0.522 × LT in mm) + (0.106 × AL in mm). For every 1 mm rise in LT, ACD decreases by 0.522 mm, and every 1 mm rise in AL, ACD increases by 0.106 mm.

Table 1: Age and gender distribution of study participants (n=151)

	Gender		Total	P
	Male	Female		
Mean age±SD (years)				
57.73±14.87	57.31±15.84	58.16±13.88		0.910
Age group (years)				
<30	4	2	6	0.647
30-49	14	16	30	
50-69	41	38	79	
70-89	18	18	36	
Total	77	74	151	

SD: Standard deviation

Table 2: Correlations between anterior chamber depth and axial length, lens thickness, and age, on multiple regression analysis (n=151)

Model 1	Coefficients[a]			t-test	Significant (P)
	Unstandardized coefficients		Standardized coefficients, β		
	B	SE			
Constant	2.978	0.742		4.015	0.000*
LT	−0.522	0.071	−0.387	−7.317	0.000*
AL	0.106	0.029	0.191	3.617	0.000*
Age	−0.001	0.002	−0.022	−0.419	0.675

*Statistically significant, [a]Dependent variable: ACD. ACD: Anterior chamber depth, SE: Standard error, LT: Lens thickness, AL: Axial length

Discussion

The positive correlation between AL and ACD suggests that longer eyes are likely to have deeper ACD, while smaller eyes are likely to have shallower ACD. This positive correlation has been the consistent finding in previous studies in Africa,[9,16] Asia,[14,15,18] South America,[19] and the United Kingdom.[20] On partial correlation analysis, age did not significantly affect this relationship; however, once the effect of LT was removed, the correlation between AL and ACD positively increased slightly and was statistically significant. Whereas the relationship between AL and LT was equivocal, ACD and LT were clearly negatively correlated. This finding may suggest that LT may be an effect modifier in the association of AL and ACD, particularly in patients with cataract. To the best of our knowledge, this effect of LT on AL and ACD relationship has not been widely reported. We recommend that this phenomenon be explored in future studies.

We are of the opinion that the impact of LT on the association of AL and ACD, as seen in our study, may provide some explanation for the varied correlation outcome reported in a few studies[3,4,15] that considered this association in various eye sizes. The finding in this study on the role of LT as an effect modifier may suggest that the variation may additionally be explained by LT other than the size of the eyeball alone. This reaffirms the need to consider LT in IOL power calculation as one of the predictor variables in the determination of ELP, as have been acknowledged by some studies.[21-23] Quite interestingly, 4th-generation formulas such as Oslen, Barrett and Holladay II incorporates LT in the prediction of ELP.

In accordance with previous studies,[3,6,8-10,14] this study found that ACD and LT were negatively correlated. This finding suggests that ACD significantly decreases with increasing LT but does not significantly decrease with age. This corroborates that narrowing of ACD with age is largely due to increasing LT. Furthermore, on regression analysis, it was evident that LT (z-score = −0.387, P = 0.000) is a more significant predictor of ACD, though in the negative direction, than AL (z-score = 0.191, P = 0.000). As earlier stated, growth of the crystalline lens with aging leading to both an increase in thickness and size of the lens, and the intensification in protein fiber layers underneath the anterior and posterior capsules, are responsible for increasing LT. These factors are further accentuated in cataractous lens, as may have been seen in our study participants. The accentuated increase in LT in cataract patients as well as the forward shift of the lens with the lying down of lens fibers, as seen in cataractous lens and with advancing age, will lead to narrowing of the anterior chamber angle, leading to aqueous flow resistance at the angle with resultant increase in intraocular pressure that could lead to optic nerve damage and development of secondary glaucoma. More so, considering that preoperative ACD is reported as the fundamental concept in all the IOL determining formula;[1] contributing up to 42% of residual refractive error,[5] it will be plausible to be mindful of all factors that influences ACD such as LT. This may have informed the use of anterior segment optical coherence tomography by some clinicians to further reliably estimate the ACD and LT.[2] Therefore, we unequivocally agree that LT is invaluable in the assessment and care of ocular diseases.[17]

There are some limitations to our study. First, given that it was a hospital-based study, its generalizability to the general population may be limited. Second, the enrolment of participants into the study was by consecutive recruitment; evidently, there was a preponderance of adult participants; thus, the findings in the study may not adequately reflect the actual picture in the pediatric age group.

Conclusion

LT is an important biometric parameter that should be considered, along with other biometric parameters, in determining ELP in patients undergoing cataract surgery. The narrowing of ACD with age is largely due to increasing LT. ACD is predominantly influenced by LT than the AL.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Olsen T. Calculation of intraocular lens power: A review. Acta Ophthalmol Scand 2007;85:472-85.
2. Lenses I. Effective ocular biometry and intraocular lens power calculation. Eur Ophthalmic Rev 2016;10:94-100.
3. Sedaghat MR, Azimi A, Arasteh P, Tehranian N, Bamdad S. The relationship between anterior chamber depth, axial length and intraocular lens power among candidates for cataract surgery. Electron Physician 2016;8:3127-31.
4. Dong J, Zhang Y, Zhang H, Jia Z, Zhang S, Wang X. Comparison of axial length, anterior chamber depth and intraocular lens power between IOLMaster and ultrasound in normal, long and short eyes. PLoS One 2018;13:e0194273.
5. Miraftab M, Hashemi H, Fotouhi A, Khabazkhoob M, Rezvan F, Asgari S. Effect of anterior chamber depth on the choice of intraocular lens calculation formula in patients with normal axial length. Middle East Afr J Ophthalmol 2014;21:307-11.
6. Ning X, Yang Y, Yan H, Zhang J. Anterior chamber depth – A predictor of refractive outcomes after age-related cataract surgery. BMC Ophthalmol 2019;19:134.
7. Hashemi H, Khabazkhoob M, Miraftab M, Emamian MH, Shariati M, Abdolahinia T, *et al.* The distribution of axial length, anterior chamber depth, lens thickness, and vitreous chamber depth in an adult population of Shahroud, Iran. BMC Ophthalmol 2012;12:50.
8. Zeng Y, Liu X, Wang T, Zhong Y, Huang J, He M. Correlation between lens thickness and central anterior chamber depth. Eye Sci 2012;27:124-6.
9. Mashige KP, Oduntan OA. Axial length, anterior chamber depth and lens thickness: Their intercorrelations in black South Africans. Afr Vis Eye Health 2017;76:1-7.
10. Chinawa E, Ezeh E. The distribution of ocular biometrics among patients undergoing cataract surgery. Niger J Ophthalmol 2018;26:40.
11. Knox Cartwright NE, Johnston RL, Jaycock PD, Tole DM, Sparrow JM. The Cataract National Dataset electronic multicentre audit of 55,567 operations: When should IOLMaster biometric measurements be rechecked? Eye (Lond) 2010;24:894-900.
12. Chang JS, Lau SY. Correlation between axial length and anterior chamber depth in normal eyes, long eyes, and extremely long eyes. Asia Pac J Ophthalmol (Phila) 2012;1:213-5.
13. Chen H, Lin H, Lin Z, Chen J, Chen W. Distribution of axial length, anterior chamber depth, and corneal curvature in an aged population in South China. BMC Ophthalmol 2016;16:47.
14. Sathyan S. Correlation between ocular axial length and anterior chamber depth and a differential analysis in same-sized eyes. Kerala J Ophthalmol 2017;29:160-7.
15. Aziz JH, Elghazawy RM, Elawamry AI, Zaki RG. Correlation between axial length and anterior chamber depth in eyes with high, low and average axial length. QJM An Int J Med 2020;113 Suppl 1:9-10.
16. Ejimadu C. Analysis of ocular axial length and anterior chamber depth in port harcourt, Nigeria. World J Ophthalmol Vis Res 2019;2:1-7.
17. Yoon JJ, Misra SL, McGhee CN, Patel DV. Demographics and ocular biometric characteristics of patients undergoing cataract surgery in Auckland, New Zealand. Clin Exp Ophthalmol 2016;44:106-13.
18. Yin G, Wang YX, Zheng ZY, Yang H, Xu L, Jonas JB, *et al.* Ocular axial length and its associations in Chinese: The Beijing Eye Study. PLoS One 2012;7:e43172.
19. Pereira GC, Allemann N. Ocular biometry, refractive error and correlation with height, age, gender and years of formal education. Arq Bras Oftalmol 2007;70:487-93.
20. Foster PJ, Broadway DC, Hayat S, Luben R, Dalzell N, Bingham S, *et al.* Refractive error, axial length and anterior chamber depth of the eye in British adults: The EPIC-Norfolk Eye Study. Br J Ophthalmol 2010;94:827-30.
21. Olsen T, Thorwest M. Calibration of axial length measurements with the Zeiss IOLMaster. J Cataract Refract Surg 2005;31:1345-50.
22. Norrby S, Lydahl E, Koranyi G, Taube M. Clinical application of the lens haptic plane concept with transformed axial lengths. J Cataract Refract Surg 2005;31:1338-44.
23. Norrby S. Using the lens haptic plane concept and thick-lens ray tracing to calculate intraocular lens power. J Cataract Refract Surg 2004;30:1000-5.