ISSN: 2755-0184

Journal of Diabetes Research Reviews & Reports

SCIENTIFIC Research and Community

Research Article

Open Access

Corneal Thickness of Glaucoma Patients in Onitsha, Southeast Nigeria

Uzozie Chukwudi Charles[1], Apakama Uchenna Ogechukwu[2*], Onwuegbuna Arinze Anthony[1], Apakama Akunne Ijeoma[1], Isu Fidelis Nkama[1] and Chigbata Chigozie[1]

[1]Consultants Eye Clinic, Awka Road, Onitsha, Southeast Nigeria

[2]37 Military Hospital, Accra, Ghana

ABSTRACT

Background: The assessment of the Central Cornea Thickness (CCT) is crucial in the decision-making process in the management of glaucoma.

Objectives: The objectives of this study were to determine the mean CCT of glaucoma patients of Igbo descent, and to evaluate any relationship of CCT and the patients' demographics.

Materials and Method: This was a cross-sectional study done at a private eye specialist clinic in Onitsha, southeastern Nigeria. Participants were eligible glaucoma patients of Igbo ethnicity. The corneal thickness of each eye was measured using ultrasound pachymeter. The mean CCT was calculated and its relationship with gender and age was studied.

Results: A total of 155 eyes of 79 participants were studied; males constituted 57%. The mean age of the participants was 53.69±16.29years. The mean CCT for all eyes studied was 529.51±35.77µm (95% confidence interval (CI): 523.83 – 535.19µm), while the right and left eyes had mean CCT of 528.99 ±36.16µm (95% CI: 520.84 – 537.14µm) and 530.04 ±35.61µm (95% CI: 521.96 – 538.12µm) respectively. There was no significant difference in mean CCT with increasing age (P = 0.38). The mean CCT were thicker in males for both the right and left eyes, however, these differences were not statistically significant (P = 0.74, P = 0.86 respectively).

Conclusion: CCT values of glaucoma patients of Igbo ethnicity is similar to that of the non-glaucoma individuals. There is no significant relationship between age and CCT in both gender.

***Corresponding author**
Apakama Uchenna Ogechukwu, 37 Military Hospital, Accra, Ghana.

Received: February 28, 2025; **Accepted:** March 06, 2025; **Published:** April 28, 2025

Keywords: Cornea Thickness, Glaucoma, Southeast Nigeria

Introduction

The cornea, which is the transparent anterior part of the eye is important in the protection and overall health of the eye. The force necessary to flatten the cornea during tonometry can be influenced not only by the intraocular pressure (IOP) but also by corneal characteristics such as central corneal thickness (CCT), corneal shape and hydration, and rigidity of the sclera and globe [1]. The central region (4 mm from the optic area) is usually thinner than the middle of the corneal periphery (4-9 mm from the optic area), which is in turn thinner than the corneal periphery (9 mm from the optic area) The average thickness is 515µm in the center of the cornea. In the paracentral region, the thickness varies from 522µm to 574µm while the peripheral area thickness ranges from 633µm to 673µm [2-4].

There is a positive correlation between IOP readings and corneal thickness in the general population [5]. This fact stems from the principle upon which the Goldmann applanation tonometer (GAT), the most widely used and international gold standard of measuring IOP, is based. Hans Goldmann applied the Imbert–Fick principle which states: 'the existing pressure in a sphere containing a liquid, whose wall is constituted by a very thin and perfectly elastic membrane, can be measured by an external compression sufficient to transform a portion of spheric surface in a plain surface'. This theoretical sphere is dry, thin-walled, and readily flexible, all features not applicable to the cornea [1]. However, in describing some of the possible sources of measurement error Goldmann specifically outlined that the theoretical basis for his instrument was calculated for a mean CCT of 50µm and that the accuracy could vary if CCT was significantly different from this value [1].

A corneal pachymeter measures corneal thickness, a sensitive indicator of endothelial physiology that correlates well with functional measurements. Techniques for measuring central corneal thickness (CCT) include optical pachymetry, ultrasound pachymetry, confocal microscopy, optical light ray passage

analysis, topography, and optical coherence tomography. Optical method for determining CCT consider the image projected onto the tear film or anterior corneal surface [2]. It is imprecise and rarely used today. Ultrasonic pachymetry, which is based on the speed of sound in the normal cornea (1640 m/sec), is both easier to perform and more accurate [6]. Values from the optical and ultrasound pachymetries are not interchangeable [7-9]. Corneal thickness affects the measurement of intraocular pressure (IOP), with thicker corneas producing falsely higher IOP readings and thinner corneas producing falsely lower readings. However, Liu and Roberts demonstrated that the biomechanical properties of the cornea, particularly stiffness, may have a greater impact on IOP measurement errors than does corneal thickness or corneal curvature. Adjustment for corneal biomechanical properties may lead to a more accurate measurement of the IOP. Despite these adjustments, low pachymetry measurements have been shown to be an independent risk factor for glaucoma even when the artificial lowering of IOP is accounted for [10,11]. CCT is considered as a possible explanation for glaucoma cases where clinical findings do not match [11]. Pachymetry is an important tool in the assessment of corneal hydration and the function of the corneal endothelium in its dual role as a barrier to aqueous humor and as a metabolic pump. Pachymetry measurements are important in the selection of patients for refractive surgery, contact lens wearing, keratoplasty, and detection of pathologies such as Keratoconus, Pellucid Marginal Corneal Degeneration, Fuchs Dystrophy [12].

The many devices available for measuring IOP can be influenced by variations in CCT. Although GAT was developed based on a 500-µm-thick cornea, however, with cannulation studies a CCT of 520 µm was found to be the most accurate with GAT [1,13]. There is a positive correlation between CCT and IOP in GAT [14, 15]. A deviation of 100 µm from the "ideal" CCT of 520 µm introduces an error of 7 mmHg [13]. To account for this deviation, several correction methods have been devised which unfortunately introduce other errors into the interpretation of the IOP results [16,17]. A thinner CCT was identified as an important independent predictive factor for development of primary open angle glaucoma (POAG) from ocular hypertension (OHTN) [18]. A patient with a CCT of 555 µm or less had a threefold increased risk of developing glaucoma within 5 years compared with someone with a CCT greater than 588 µm [18]. Likewise, with every 40 µm decrease in CCT associated with a twofold increased risk of developing glaucoma over 5 years [19].

Some factors are known to affect CCT. Twin studies have shown that the CCT phenotype is highly heritable with the genes also involved in collagen and extracellular matrix metabolism, collagen fibril organization, and myosin binding [20, 21]. Ethnicity should be considered when interpreting CCT, given the variations in the measured average CCT of different ethnic groups. Africans, African Americans and Japanese have thinner CCT consistently compared with Caucasian, Hispanic, Latino, Chinese, Filipino, Korean, Malay, and Iranian populations who have thicker CCT [22-31]. Age has a significant inverse correlation with CCT, decreasing ~2–10 µm per decade [14, 29, 32, 33]. There are variable correlations of sex and CCT wherein there is no difference between the sexes; males having thicker CCT than females and females having thicker CCT than males [14,22,24,29,34]. Certain systemic disorders are correlated with thicker CCT: diabetes mellitus, metabolic syndrome, an increased body mass index and chronic kidney disease [35, 36]. Topical anti-glaucoma medications can cause thinning, thickening, or no change to the CCT; the effects are mostly reversible [37-40]. In addition, glaucoma and OHTN patients with thicker CCT show significantly less decrease in IOP than those with thinner CCT following the use of anti-glaucoma medications or selective laser trabeculoplasty over time [41-44].

The southeast zone in Nigeria, populated by predominantly the Igbo ethnic group, was reported to have the highest prevalence of glaucoma (6.1%) according to a nationwide survey done more than 15 years ago [45, 46] without any data on CCT. Subsequently, several community and hospital based studies on CCT of Nigerians were on mixed ethnicities [23, 47, 48]. However, there was a recent study on CCT among the Igbo people but was focused only on the non-glaucomatous adults [22]. To the best of the authors' knowledge no research has been carried out in the southeastern Nigeria to determine the mean CCT of glaucoma patients.

This research aims to explore the central corneal thickness profiles of glaucoma patients in this region. The objectives include:

- To determine the mean CCT of glaucoma patients of Igbo descent,
- To evaluate any relationship of CCT and the patients' demographics.

Data generated from this study will contribute to a better understanding of the characteristics of glaucoma in the southeast, ultimately leading to improved diagnosis and treatment strategies for the local population.

Materials and Method

Study design: A cross-sectional prospective study

Study Population: The study was conducted among glaucoma patients of Igbo origin.

Study site: The study was carried out at a well-equipped private eye clinic in Onitsha which runs comprehensive outpatient and surgical services. Onitsha is the most populous city in the southeastern Nigeria.

Sample size: A sample size of participants was determined using the formula

$N = z^2pq/d^2$

Where,

N = Minimum sample size.

Z = The standard normal deviate, usually set at 1.96 corresponding to 95% confidence interval

p = Assumed prevalence of glaucoma among the southeastern Igbo people taken from a study done in Nigeria which was 6.1% [45].

$q = 1.0 - p\ (1.0 - 0.061) = 0.939$

d = Precision level acceptable = 5% (0.05).

This gives a minimum sample size of approximately 88 participants.

Inclusion Criteria: Consenting glaucoma patients of Igbo ethnicity.

Exclusion Criteria: Patients less than 5 years, those with penetrative /perforative ocular injuries and those who did not give their consent.

Sample Technique: Simple random sampling technique was used. Consenting glaucoma patients were selected alternately from the list of patients present on each day. For any patient who declined consent the next alternate patient was recruited. For patients less than 18years consent was sought from a legitimate adult parent/ guardian.

Procedures Involved: Each selected patient underwent full clinical assessment including: biodata, clinical history and ocular examination. The average of three CCT readings were recorded for each patient into a pro forma (appendix 1). All CCT measurements were taken by the same qualified person.

Consent: The participants were duly informed of the aim and nature of the study, and the details of the various procedures that were involved. Patient information was obtained with no identifier, and confidentiality was maintained. All consenting patients were required to sign a consent form. A patient was free to withdraw his/her consent at any point.

Data Processing and analysis: All collected data were analyzed using Microsoft Excel spreadsheet (2013).

Result

There were more male participants 45 (57%) than females 34 (43%) out of a total of 79 participants in a ratio of 1.3:1 respectively. A total of 155 eyes were studied. An only eye was studied in a male while two female participants had each an only eye. The mean age of all participants was 53.69 years (SD ±16.29). The age range was from 9 to 82years. Table 1 shows that the mean CCT for all eyes studied was 529.51±35.77µm.

Table 1: Statistics of CCT Measured in all Participants

Variable	Count	Mean ± SD (µm)	95% CI (µm)
CCTRE	78	528.99 ±36.16	520.84 – 537.14
CCTLE	77	530.04 ±35.61	521.96 – 538.12
CCTCombined	155	529.51 ±35.77	523.83 – 535.19

CCTRE = central corneal thickness right eye; CCTLE = central corneal thickness left eye; CCTcombined = central corneal thickness of all eyes; SD = standard deviation; CI = confidence interval; µm = micron meter.

The CCT values for all eyes studied were not normally distributed as shown in figure 1.

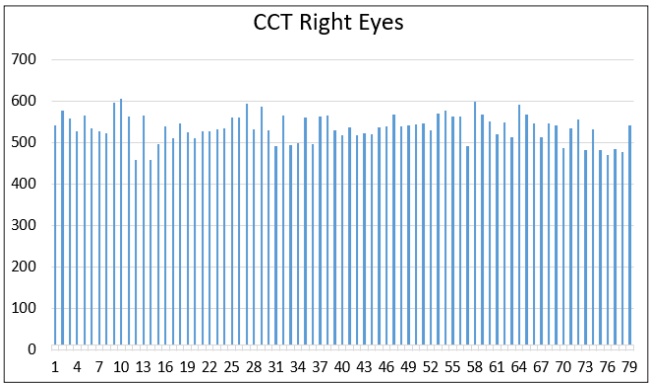

Figure 1: Distribution of CCT of Right Eyes

A summary of the descriptive statistics of the CCT of all eyes is shown in Table 2.

Table 2: Descriptive Statistics of CCT Combined

Mean	529.5084
Standard Error	2.873429
Median	532.3
Mode	564
Standard Deviation	35.7739
Sample Variance	1279.772
Kurtosis	-0.44673
Skewness	-0.04114
Range	173.3
Minimum	448.7
Maximum	622
Sum	82073.8
Count	155

The mean central corneal thickness (CCT) for RE was 528.99 ± 36.16µm (95% CI: 520.84 –537.14µm) and 530.04 ± 35.61µm for LE (95% CI: 521.96 – 538.12µm). Table 3 shows the mean CCT for the right and left eyes when discriminated into male and female groups.

Although, the mean CCT were higher in males for both the right and left eyes, however, these differences were not statistically significant (p=0.74, p=0.86 respectively).

Table 3: Gender Distribution of Mean CCT for Right and Left Eyes

	CCTRE (µm) ± SD (95% CI)	CCTLE (µm) ± SD (95% CI)
Males	530.22 ± 30.70 (520.89 – 539.55)	530.64 ± 29.73 (521.71 – 539.57)
Females	527.38 ± 42.63 (512.52 – 542.26)	529.19 ± 43.05 (513.67 – 544.71)
Combined	528.99 ± 36.16 (520.84 – 537.14)	530.04 ± 35.61 (521.96 – 538.12)
p value	0.74	0.86

Level of significance set at $p < 0.05$.

Figure 2 shows that the ages of the patients were not normally distributed. There was a consistent decrease in CCT with increasing age up to the fourth decade (Figure 3, Table 4). A one-way analysis of variance (ANOVA) test showed no statistically significant correlation (p=0.38) between the age categories and mean CCT (Table 5). Further analysis of the ranked ages and CCT using the Spearman's rank correlation test also showed no significant correlation (rs = -0.13, p= 0.11).

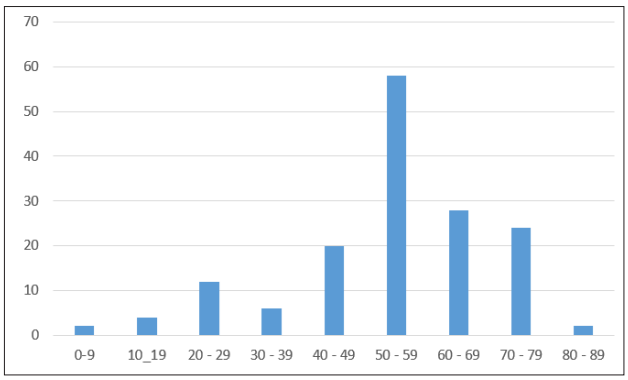

Figure 2: Age Frequency Distribution of the Patients (156 eyes)

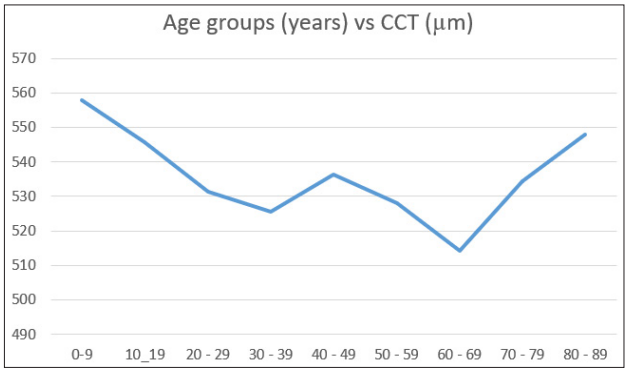

Figure 3: Age Groups vs CCT

Table 4: Age Frequency and Mean CCT

AGE Groups	Frequency (Eyes)	Mean CCT
0-9	2	557.8
10_19	4	545.75
20 – 29	12	531.4
30 – 39	6	525.6
40 – 49	20	536.23
50 – 59	58	528.18
60 – 69	28	514.36
70 – 79	24	534.51
80 – 89	2	548

Table 5: One-Way ANOVA test of Age Groups and Mean CCT

Summary						
Groups	Count	Sum	Average	Variance		
0-9	2	1115.6	557.8	612.5		
10_19	4	2183	545.75	344.8433		
20 - 29	12	6376.8	531.4	2243.078		
30 - 39	6	3153.6	525.6	67.832		
40 - 49	20	10724.5	536.225	935.5851		
50 - 59	54	28521.6	528.1778	1369.309		
60 - 69	27	13887.7	514.3593	1026.655		
70 - 79	24	12828.3	534.5125	1778.992		
80 - 89	2	1096	548	0.18		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Source of Variation	11238.48	8	1404.81	1.080509	0.380167	2.004177
Source of Variation	184619.6	142	1300.138			
Total	195858	150				

Diabetes mellitus was found in 12 (15.19%) of the participants. One participant has a history of tobacco smoking, and none had any previous eye surgery.

Discussion

CCT is a dynamic parameter. The ocular and systemic factors known to influence CCT are varied, and include age, gender, ethnicity, diurnal variation, contact lens wear, topical medication, corneal disease, ocular surgery, systemic disease (e.g. DM) as well as the technical factors (instrument, observer or technique related) [49]. In this study the CCT of 79 (155eyes) confirmed POAG patients of Igbo ethnicity were measured. The participants had a mean age of 53.69 ±16.28 years and a male to female ratio of 1.3:1 (57% males, 43% females). The average CCT of 529.51 ± 35.77µm for all the eyes is similar to 527.57 ± 37.42µm recorded in a study

done in Enugu among non-glaucomatous Igbos with similar mean age (50.29 ± 16.58years) [22], but thicker than that measured (523.10µm ±SD 41.3) for glaucoma eyes in Zaria, northern Nigeria [48]. This may be due to the greater proportion of females (M/F = 1:3) and mixed ethnicity in their study. In a study done in a larger sample size in southwestern Nigeria there were no significant differences between glaucoma and non-glaucoma in the CCT measurements. The mean for both groups was 530µm for both eyes [25]. However, another study in southwestern Nigeria, which compared mean CCT between POAG and normal control for both myopes and hypermetropes showed statistically no significant difference [50]. The mean CCT in the index study is also similar to that documented by La Rosa for African Americans (531 ± 37µm) in a comparative study of Whites and African Americans with glaucoma [28]. In contrast, the mean CCT in this study is higher than the mean CCT (521µm) recorded in another African American study by Aghaian et al in a glaucoma clinic [29]. It was suggested that a higher mean age accounted for this. Compared with non-Black racial groups the mean CCT of this study is thinner: in the European Glaucoma Prevention Study the mean CCT was 574.2µm ± 38.48 for OHT patients on dorzolamide and 571.0µm ± 36.21 for the control. There was no statistically significant difference in the mean CCT of the groups [51].

In this study, females had numerically thicker CCT (530.04 ± 35.61 (95% CI: 521.96 – 538.12)) than males (528.99 ± 36.16 (95% CI: 520.84 – 537.14)) for both left and right eyes (p=0.86, p=0.74 respectively) although with no significant difference. The gender difference in CCT is tripodal, with some studies reporting thicker male CCT, or thicker female CCT or no difference at all. The Enugu study reported a significantly thicker CCT among males ((533.59µm vs 522.38µm, p=0.004 and p=0.007 for right and left eyes respectively) in contrast to the present study [22]. Similarly, marked significantly thicker mean CCT in males was found by Mercieca and co-workers in a hospital-based study in Port Harcourt, South south Nigeria (males 541.0µm vs females 522.0µm) [23]. Consistent with this study several studies also documented thicker mean CCT in females which are not statistically significant [25, 29, 48]. These were attributed to higher proportion of female participants. The relationship of age and CCT is controversial. The present study showed a non-significant negative correlation between age and CCT whereby the CCT decreased with increased age up to the fourth decade in both male and females. This may be a result of the non-normal distribution of the data. However, employing the Spearman rank correlation test also failed to show a significant correlation. This trend was also reported by Prasad and co-workers in New Jersey in their study (r = 0 .00645) of the relationship of CCT with age and refraction [52]. In addition, The Rotterdam Study similarly reported that CCT did not significantly correlate with age in normal controls, OHT and POAG [53]. Although Siu and Herse in Auckland, New Zealand reported no significant correlation of age and CCT in their 108-sample study, however, power analysis may help explain the conflicting reports available in literature. They posited that diversity in data interpretation may be due to the statistically small sample sizes used in most studies [54]. In their study power analysis shows that at least 80 subjects are needed in each age group (480 subjects in total) before a statistically reliable test of the null hypothesis is possible thus emphasizing the importance of power analysis in calculating an adequate sample size [54]. Some authors have reported definite negative relationship between age and CCT in both gender [22, 23, 25, 51, 54]. According to Hahn et al, the probable cause supported by histologic evidence is the decline in the density of keratocytes and a breakdown in the collagen fibres in the aging cornea. In addition, there is a probable environmental factor that older individual may have been exposed to longer than younger ones that could have affected the structure or the integrity of the cornea [54].

Conclusion

This study has found that the CCT values in the glaucoma patients of Igbo ethnicity, a group with the reported highest prevalence of glaucoma in Nigeria, are similar to that reported for the non-glaucoma individuals. It also shows that there is no significant relationship between age and CCT as seen in some studies for both gender.

Limitation

The small sample size and non normal distribution of the data set. CONSENT Informed consent was obtained from each patient.

Ethical Approval

Study approval was obtained from the ethics committee of the Chukwuemeka Odumegwu Ojukwu University Teaching Hospital Awka.

Competing Interests

Authors have declared that no competing interests exist.

Funding

No funding was received for conducting this study.

APPENDIX 1
NAME—
AGE
SEX
SMOKING/TOBACCO HABITS
SYSTEMIC ILLNESS
DURATION OF SYSTEMIC ILLNESS
FAMILY HISTORY OF GLAUCOMA
FAMILY HISTORY OF OTHER OCULAR DISEASES
HISTORY OF OCULAR TRAUMA YES NO
LATERALITY OF OCULAR TRAUMA (R) (L);

PROCEDURE/FINDINGS:
VA AIDED (R) (L)
VA UNAIDED (R) (L)
PUPILLARY EXAMINATION/REACTION
IOP (R) (L)
SLIT-LAMP FINDINGS
FUNDUS FINDINGS (UNDILATED)
CORNEAL THICKNESS (R) (L)
USE OF ANAESTHETIC DROPS YES NO
ANY ASTIGMATISM YES NO
POWER OF ASTIGMATISM & AXIS
ANY OTHER OCULAR PATHOLOGIES
HISTORY OF EYE SURGERIES YES NO
TYPE OF SURGERY
USE OF TOPICAL MEDICATIONS YES NO
TYPES OF TOPICAL MEDICATIONS

References

1. Goldmann H, Schmidt T (1957) Applanation tonometry. Ophthalmological 134: 221.
2. Binnawi KH, Elzubeir H, Osman E, Abdu M, Abdu M (2019) Central corneal thickness measurement using ultrasonic pachymeter, optical coherence tomography, and TMS-5 topographer. Oman J Ophthalmol 12: 15-19.

3. Wang M, Kugler LJ (2014) Atlas and Clinical Reference Guide for Corneal Topography. SLACK Incorporated.
4. Garg A (2010) Instant Clinical diagnosis in Ophthalmology Anterior Segment Diseases. Jaypee Brothers Medical Publishers LTD.
5. Shah S, Chatterjee A, Mathai M, Kelly SP, Kwartz J, et al. (1999) Relationship between corneal thickness and measured intraocular pressure in a general ophthalmology clinic. Ophthalmology 106: 2154-2160.
6. Khaja WA, Grover S, Kelmenson AT, Ferguson LR, Sambhav K, et al. (2015) Comparison of central corneal thickness: ultrasound pachymetry versus slit-lamp optical coherence tomography, specular microscopy, and Orbscan. Clin Ophthalmol 12: 1065-1070.
7. Bao F, Wang Q, Cheng S, Savini G, Lu W, et al. (2014) Comparison and evaluation of central corneal thickness using 2 new noncontact specular microscopes and conventional pachymetry devices. Cornea 33: 576-581.
8. Nam SM, Im CY, Lee HK, Kim EK, Kim T-i, (2010) Accuracy of RTVue optical coherence tomography, pentacam, and ultrasonic pachymetry for the measurement of central corneal thickness. Ophthalmology 117: 2096-2103.
9. Garcia-Medina JJ, Garcia-Medina M, Garcia-Maturana C, Zanon-Moreno V, Pons-Vazquez S, (2013) Comparative study of central corneal thickness using fourier-domain optical coherence tomography versus ultrasound pachymetry in primary open-angle glaucoma. Cornea 32: 9-13.
10. Liu J, Roberts CJ (2005) Influence of corneal biomechanical properties on intraocular pressure measurement: quantitative analysis. J Cataract Refract Surg 31: 146-155.
11. European Glaucoma Society (2003) Terminology and Guidelines for Glaucoma, European Glaucoma Society 2: 2-5.
12. Garg A (2014) Anterior and Posterior Segment OCT: Current Technology and Future Applications. First Ed. Jaypee Brothers Medical Publishers LTD.
13. Ehlers N, Bramsen T, Sperling S (1975) Applanation tonometry and central corneal thickness. Acta Ophthalmol 53:34-43.
14. Sng C, Barton K, Kim H, Yuan S, Budenz DL (2016) Central corneal thickness and its associations with ocular and systemic factors in an urban West African population. Am J Ophthalmol 169: 268-275.
15. Carbonaro F, Hysi PG, Fahy SJ, Nag A, Hammond CJ (2014) Optic disc planimetry, corneal hysteresis, central corneal thickness, and intraocular pressure as risk factors for glaucoma Am J Ophthalmol 157: 441-446.
16. Bao F, Huang Z, Huang J, Wang J, Deng M, et al. (2016) Clinical evaluation of methods to correct intraocular pressure measurements by the goldmann applanation tonometer, ocular response analyzer, and corvis ST tonometer for the effects of corneal stiffness parameters. J Glaucoma 25: 510-519.
17. Orssengo GJ, Pye DC (1999) Determination of the true intraocular pressure and modulus of elasticity of the human cornea in vivo. Bull Math Biol 61: 551–572.
18. Gordon MO, Beiser JA, Brandt JD, Heuer DK, Higginbotham EJ, et al. (2002) The Ocular Hypertension Treatment Study—Baseline factors that predict the onset of primary open-angle glaucoma. Arch Ophthalmol 120: 714-720.
19. Gordon MO (2007) Ocular Hypertension Treatment S, European Prevention Study G. Validated prediction model for the development of primary open-angle glaucoma in individuals with ocular hypertension. Ophthalmology 114:10-19.
20. Toh TY, Liew SHM, MacKinnon JR, Hewitt AW, Poulsen JL, et al. (2005) Central corneal thickness is highly heritable: the twin eye studies. Invest Ophthalmol Vis Sci 46: 3718-3722.
21. Zheng Y, Ge J, Huang G, Zhang J, Liu B, et al. (2008) Heritability of central corneal thickness in Chinese: the Guangzhou twin eye study. Invest Ophthalmol Vis Sci 49: 4303-4307.
22. Uche NJ, Kizor-Akaraiwe N, Okeke S, Shiweobi J (2023) Profile of central corneal thickness in an adult non-glaucomatous population in Enugu, Southeast Nigeria. International Journal of Medicine and Health Development 28: 263-269.
23. Mercieca K, Odogu V, Fiebai B, Arowolo O, Chukwuka F (2007) Comparing central corneal thickness in a sub-Saharan cohort to African Americans and Afro-Caribbeans. Cornea 26: 557-560.
24. Oladigbolu K, Abdullahi H, Abdulsalam H, Gana O, Kadala N, et al. (2018) Central corneal thickness measurement of non-glaucomatous adults in Ahmadu Bello University Sick Bay, Samaru, Zaria. Sub-Saharan African Journal of Medicine 5: 6-25.
25. Adegbehingbe SA, Olusanya BA, Ajayi BGK, Ashaye AO, Bekibele CO (2016) Central Cornea Thickness in Glaucoma and Non-Glaucoma African Population. Ophthalmology Research: An International Journal pp: 1-8.
26. Baboolal SO, Smit DP (2018) South African Eye Study (SAES): ethnic differences in central corneal thickness and intraocular pressure. Eye 32: 749-756.
27. Mostafa EM (2014) Central corneal thickness in southern Egypt. International ophthalmology 34: 809-815.
28. La Rosa FA, Gross RL, Orengo-Nania S (2001) Central corneal thickness of Caucasians and African Americans in glaucomatous and non - glaucomatous populations. Archives of ophthalmology 119: 23-27.
29. Aghaian E, Choe JE, Lin S, Stamper RL (2004) Central corneal thickness of Caucasians, Chinese, Hispanics, Filipinos, African Americans, and Japanese in a glaucoma clinic. Ophthalmology 111: 2211-2219.
30. Lee ES, Kim CY, Ha SJ, Seong GJ, Hong YJ (2007) Central corneal thickness of Korean patients with glaucoma. Ophthalmology 114: 927-930.
31. Pakravan M, Javadi MA, Yazdani S, Ghahari E, Behroozi Z, et al. (2017) Distribution of intraocular pressure, central corneal thickness and vertical cup-to-disc ratio in a healthy Iranian population: the Yazd Eye Study. Acta Ophthalmol 95:144-151.
32. Wang D, Huang W, Li Y, Zheng Y, Foster PJ, et al. (2011) Intraocular pressure, central corneal thickness, and glaucoma in Chinese adults: The Liwan Eye Study. Am J Ophthalmol 152:454-462.
33. Vijaya L, George R, Arvind H, Ramesh SV, Baskaran M, et al. (2010) Central corneal thickness in Adult South Indians: the Chennai Glaucoma Study. Ophthalmology 117: 700–704.
34. Brandt JD, Beiser JA, Kass MA, Gordon MO (2001) Central corneal thickness in the Ocular Hypertension Treatment Study (OHTS) Ophthalmology 108: 1779–1788.
35. Su DHW, Wong TY, Foster PJ, Tay WT, Saw SM, et al. (2009) Central corneal thickness and its associations with ocular and systemic factors: the Singapore Malay Eye Study. Am J Ophthalmol 147: 709.
36. Hawker MJ, Edmunds MR, Vernon SA, Hillman JG, MacNab HK (2009) The relationship between central corneal thickness and the optic disc in an elderly population: the Bridlington Eye Assessment Project. Eye 23: 56-62.
37. Panos GD, Konstantinidis A, Mendrinos E, Kozobolis V,

Perente I, Gatzioufas Z. (2013) Effect of Tafluprost 0.0015% on central corneal thickness in patients with primary open-angle glaucoma. Curr Eye Res 38: 977–982.

38. Zhong Y, Shen X, Yu J, Tan H, Cheng Y (2011) The comparison of the effects of latanoprost, travoprost, and bimatoprost on central corneal thickness. Cornea 30:861-864.
39. Iester M, Telani S, Brusini P, Rolle T, Fogagnolo P, et al. (2013) Central corneal thickness and glaucoma treatment: an Italian multicenter cross-sectional study. J Ocul Pharmacol Ther 29: 469-473.
40. Lass JH, Khosrof SA, Laurence JK, Horwitz B, Ghosh K, Adamsons I. (1998) A double-masked, randomized, 1-year study comparing the corneal effects of dorzolamide, timolol, and betaxolol. Dorzolamide Corneal Effects Study Group. Arch Ophthalmol 116:1003–1010.
41. Johnson TV, Toris CB, Fan S, Camras CB (2008) Effects of central corneal thickness on the efficacy of topical ocular hypotensive medications. J Glaucoma 17:89-99.
42. Birt CM, Buys YM, Kiss A, Trope GE (2012) Toronto Area Glaucoma Study. The influence of central corneal thickness on response to topical prostaglandin analogue therapy. Can J Ophthalmol 47: 51-54.
43. Martinez-de-la-Casa JM, Rayward O, Saenz-Frances F, Santos-Bueso E, Mendez-Hernandez C, et al. (2012) Effects of corneal thickness on the intraocular penetration of travoprost 0.004% Eye 26: 972-975.
44. Shazly TA, Latina MA, Dagianis JJ, Chitturi S (2012) Effect of central corneal thickness on the long-term outcome of selective laser trabeculoplasty as primary treatment for ocular hypertension and primary open-angle glaucoma. Cornea 31: 883-886.
45. Dineen B, Gilbert CE, Rabiu M, Kyari F, Mahdi AM, et al. (2008) The Nigerian national blindness and visual impairment survey: Rationale, objectives and detailed methodology. BMC ophthalmology 8: 17.
46. Kyari F, Abdull MM, Wormald R, Evans JR, Nolan W, et al. (2016) Risk factors for open-angle glaucoma in Nigeria: results from the Nigeria National Blindness and Visual Impairment Survey. BMC Ophthalmology 16: 78.
47. Nzelu-Egwuonwu NN (2012) Central Corneal Thickness in Nigerians: A Population-Based Study in Lagos State. Investigative Ophthalmology & Visual Science 53: 5044-5044.
48. Abah ER, Mahmud-Ajeigbe AF, Sharief S, Chinda D, Jiya PY, et al. (2018) Central Corneal Thickness and Intraocular Pressure of Adult Nigerians: An Assessment of Zaria Community. West African Journal of Medicine 35: 158-161.
49. Doughty MJ, Zaman ML (2000) Human corneal thickness and its impact on intraocular pressure measures: A review and meta-analysis approach Surv Ophthalmol 44: 367-408.
50. Oluwaniyi AT, Olawoye O, Sarimiye TF, Ajayi BGK (2023) Comparison of Ocular Biomery in Primary Open Angle Glaucoma and Non-glaucoma in South West Nigeria. J West Afr Coll Surg 13: 37-44.
51. Pfeiffer N, Torri V (2007) Central cornea thickness in the European glaucoma prevention study. Ophthalmology 114: 454-459.
52. Prasad A, Fry K, Hersh PS (2011) Relationship of age and refraction to central corneal thickness. Cornea 30: 553-555.
53. Siu A, Herse P (1993) The effect of age on human corneal thickness. Statistical implications of power analysis. Acta Ophthalmol (Copenh) 71: 51-56.
54. Hahn S, Azen S, Ying-Lai M, Varma R (2003) Central corneal thickness in Latinos. Investigative Ophthalmology & Visual science 44: 1508-1512.