Original Article

Normal Central Foveal Thickness in a Thousand Eyes of Healthy Patients in Sub Saharan Africa Using Fourier Domain Optical Coherence Tomography

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ABSTRACT

Background: Optical coherence tomography provides high resolution *in vivo* images of the retina which are essential for diagnosis and follow up of patients with retina disorders like macula edema and exudative age-related macular degeneration. Establishing the normal range of central fovea values in our population provides vital baseline data for comparison. **Aim:** To report the range of normal central fovea thickness measurements in eyes of healthy hospital patients in sub-Saharan Africa using a commercially available Fourier domain optical coherence tomography (OCT) scan. **Patients and Methods:** A retrospective non-comparative review of case files of a thousand consecutive healthy patients who had retina OCT scans between January 2015 and December 2019 was done. **Results:** Data from 1000 consecutive eyes of 500 healthy patients were used for the study. There were 181 females and 319 males. The mean central foveal thickness was 239.48 microns (μm), with a minimum thickness of 200.0 μm and maximum thickness of 297.0 μm. Males had significantly ($P < 0.001$) thicker mean CFT (mean CFT = 241.77 μm) compared with females (mean CFT = 235.43 μm). The mean CFT increased with age of participants by 0.139 μm ($P < 0.001$) for every year of life below 70. **Conclusion:** The mean central foveal thickness (CFT) in eyes of healthy patients in our study was 239.48 μm with a range from 200 μm to 297.0 μm. Males had thicker mean CFT compared with females and there was a significant increase in mean CFT by 0.139 μm ($P < 0.001$) for every year of life below 70.

Keywords: *Central fovea thickness, mean central fovea thickness, optical coherence tomography, parafoveal retina thickness*

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Introduction

The Optical Coherence Tomography (OCT) is a noninvasive imaging technique that measures internal structures of biological systems. It is particularly useful for high resolution reproducible *in vivo* imaging of the retinal structure, making it a very useful tool for ophthalmologists.[1] For instance, high resolutions *in vivo* retinal images are essential for diagnosis and follow up of patients with macular edema (ME). This retina disorder may be secondary to several other retina diagnosis-like Diabetic Macula Edema (DME), Central Retina Vein Occlusion (CRVO), Branch Retina Vein Occlusion (BRVO), Irvin Gass Syndrome (IGS), and Posterior Uveitis. It is thus a commonly encountered disease in ophthalmology practice. The management of ME often requires repeated measurements of central foveal thickness to establish diagnosis and monitor treatment outcomes. Not having the right normative values may lead to wrong diagnosis, over or undertreatment and thus poorer outcomes than expected.[2]

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As a result of its accuracy and availability,[2] Optical Coherence Tomography (OCT) systems are now extensively used in ophthalmic practices in sub-Saharan Africa for both anterior and particularly posterior segment assessment. Several studies establish that there are racial differences in retina thickness measurements, with Asians reported to have thinner macula's than Caucasians.[2-4] These study results from other regions of the world make it important for us to establish normal parameters for our population, so this difference can be kept in mind when making diagnosis and monitoring macular diseases in sub-Saharan Africa. It is also important to note that traditionally normative data bases used by many OCT companies are gotten from a representative population within their area of influence. Most of these don't include data from sub-Saharan Africa.[5,6]

The OCT technology is dynamic and new innovations are introduced frequently. The split spectrum OCT (SS-OCT) technology is one of the latest developments in OCT technology. SS-OCT utilizes infrared (1050 nm) laser source, has less susceptibility to sensitivity roll-off, and has ultrahigh speed image acquisition often of 100,000 Hz A scans speed or higher for clinical systems and above 1 MHz in research systems. These characteristics of SS-OCT enable deeper penetration, excellent axial resolution, and fewer motion artifacts, to generate ultrahigh-definition B-scan images of the retinal microstructure.[7,8] The OCT Angiography (OCTA) has been recently introduced. It provides en face images of the retina giving access to the superficial and deep vascular plexus and has better imaging of the choroid and vitreous.[7] Wide and Ultrawide field imaging with the OCT and OCTA are also available[9,10] Our study, however, utilizes the Fourier domain OCT that is commonly available in African ophthalmology clinics.

In our study, we report a range of normal values for central foveal thickness among healthy individuals who attended our ophthalmology clinics for various reasons. We seek to provide information to help bridge the information gap and thus help improve diagnosis and treatment outcomes.

Methodology

A retrospective review of case files of 1000 consecutive eyes of 500 patients with healthy eyes who had retina OCT scans in Eye Foundation Hospital Ikeja Lagos, Nigeria between January 2015 and December 2019 was done. Inclusion criteria were normal eyes with good quality OCT scans as well as normal clinical findings on slit lamp examination, pupillary light reaction and fundoscopy. Approval for the study was granted by Eye Foundation Hospital Research Ethics Committee (EFH-HREC/2022/001).

Exclusion criteria for eyes included any history or evidence of retinopathy from diabetes mellitus or other systemic diseases, glaucoma, intraocular pressures higher than 21 mm Hg, abnormal visual fields and previous intraocular surgery, as well as best-corrected visual acuity worse than 6/12, and any refractive error greater than 6.00 diopters.

All scans were done with the Fourier Domain RTVue-100 (Optovue, Fremont, CA) machine. Six radial scans, 6 mm in length and centered on the fovea, were obtained and retinal thickness was automatically calculated by OCT mapping software. Measurements were displayed as the mean and standard deviation for each of the 9 regions defined in the Early Treatment Diabetic Retinopathy Study.

The imaging protocol followed for all included healthy eyes was the same. Images were taken after pharmacological pupillary dilatation by either of two experienced ophthalmic technicians, well versed with the operation of the machine. Only images with signal strength index (SSI) >50 with the full extent and depth of the retina distinguishable were included.

Data was collected in an excel sheet format. Analysis was done using IBM SPSS Statistics Version 22 (IBM Corp. Armonk, NY, USA). Frequency and percentages were used to summarize socio-demographic variables. Measurements of central foveal thickness (CFT) and parafoveal thickness were summarized as means and standard deviations. Independent t test was used to find variation between CFT and gender, one-way ANOVA was used to find variations between CFT and age and refractive error. Paired t test was used to determine inter-eye CFT variation, linear regression, and the generalized estimating equation was used to determine the relationship between variables and CFT. Test for statistical significance was calculated and values < 0.05 was considered significant.

The spherical equivalent of a lens is the algebraic sum of the value of the sphere and half the cylindrical value. This value was used to classify refractive errors in our patients into myopia, emmetropia, and hyperopia. Only distant vision was used for this classification. An eye was considered emmetropic when the error was within ± 0.50 diopters.

Results

Data from 1000 consecutive eyes of 500 healthy patients who had OCT in Eye Foundation Hospital Ikeja Lagos

Table 1: Table showing mean central foveal thickness across age groups

Age range in years	Mean	Frequency	Percentage	95% Confidence Interval for Mean		*P*
				Lower Bound	Upper Bound	
10-19	232.1	21	4.2	226.3	237.7	= 0.001
20-29	238.9	82	16.4	235.8	242.1	
30-39	241.9	54	10.8	237.9	246.0	
40-49	240.1	131	26.2	237.9	242.4	
50-59	241.0	118	23.6	238.2	243.9	
60-69	244.8	68	13.6	241.2	247.0	
70-79	239.7	17	3.4	232.4	246.9	
80-89	244.2	9	1.8	236.6	251.8	
Total		500	100.0			

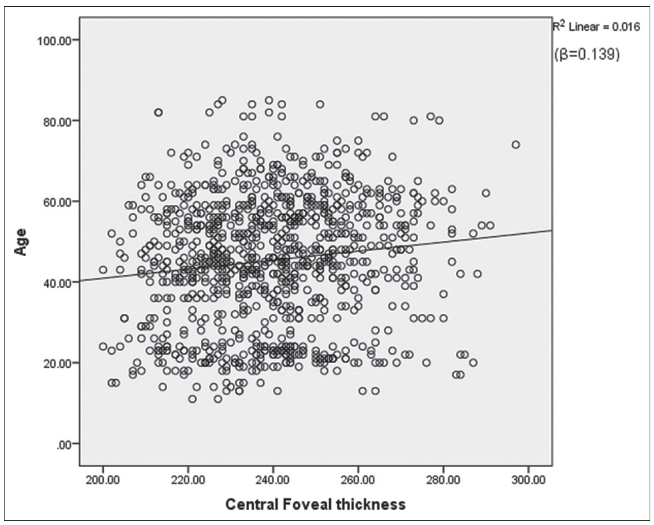

Figure 1: Scatterplot showing linear correlation of mean age of participants' eyes with mean central foveal thickness

Nigeria between January 2015 and December 2019 were used for the study. Only eyes that met the inclusion criteria were analyzed. Age range was from 11 years to 85 years and a mean age 45.7 years ± 15.6 years, there were 181 females and 319 males. The mean central foveal thickness was 239.48 µm ± 17.78 µm, with a minimum thickness of 200.0 µm and maximum thickness of 297.0 µm.

The age group within 10-19 years had the least mean CFT (232.1 µm ± 18.35 µm, 95% CI = 226.3 µm – 237.7 µm), while the thickest was in the 60-69 age group (244.1 µm ± 17.21 µm, 95% CI = 241.2 µm – 247.0 µm). This differences in the mean CFT between the groups was statistically significant (F = 3.501, $P = 0.001$) [Table 1]. There was a progressive increase in CFT with age of participants up until 69 years before a decline was noticed, this difference was, statistically significant (F = 3.501, $P = 0.001$), with an average increase in mean CFT by 0.139 µm ($\beta = 0.139$, $P < 0.001$) for every year of life below 70. Figure 1 is a scatter plot showing the

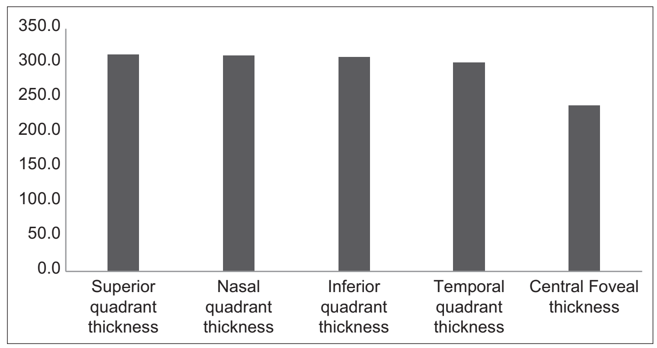

Figure 2: Bar chart showing mean parafoveal retinal thickness and central foveal thickness of patients in the study

linear relationship between age of patients and mean CFT.

Males had thicker CFT (mean CFT = 241.77 µm ± 17.48 µm) compared with female participants (mean CFT = 235.43 µm ± 17.60 µm). The difference in mean CFT between male and female participants was statistically significant (t = 5.493, 95%CI = 4.077 – 8.613, $P < 0.001$).

Three hundred and seventy-six eyes (39.6%) of eyes were emmetropes while 364 eyes (36.4%) had myopia and 260 eyes (26%) had hypermetropia. Differences in CFT among patients with refractive errors were not significant ($P = 0.192$ and 0.863), myopes had a mean CFT of 239.47 µm ± 17.36 µm, while hyperopes had a mean CFT 239.03 µm ± 18.26 µm, and emmetropes had mean CFT of 239.81 µm ± 17.87 µm.

Averagely the parafoveal region was thicker than the central fovea. The mean parafoveal retinal thickness was thickest in the superior quadrant, 312.64 µm ± 13.25 µm, followed by the nasal quadrant, 311.17 µm ± 14.08 µm, then the inferior quadrant, 309.47 µm ± 13.31 µm, and thinnest in the temporal quadrant, 300.94 µm ± 13.76 µm [Figure 2].

Discussion

The emergence of Optical Coherence Tomography (OCT) as a major tool for high-resolution cross-sectional images of the macula raises the requirement for normal values to be established. The fovea in particular needs more attention because small changes in its thickness can significantly affect vision, since it is the vital seeing area of the macula.[2] The mean CFT in our patients was 239.48 μm ± 17.78 μm, with a minimum thickness of 200.0 μm and maximum thickness of 297.0 μm. This measurement is higher than the mean central foveal thickness of 208.62 ± 21.71 μm reported by Huang J *et al*.[11] but similar to the values reported by Wolf-Schnurrbusch UE *et al*.[12] where average central foveal thickness was 245 ± 28 μm and 249 ± 24 μm in the right and left eyes, respectively, using the same Optovue RTVue. This difference can be attributed to the version of OCT used for these studies. Differences as high as 65 to 70 μm have been reported by Grover S *et al*.[14] when comparing measurements by Spectralis OCT with Stratus OCT. Using 6 different commercially available OCTs (Stratus OCT [Carl Zeiss Meditec, Inc. Dublin, CA], SOCT Copernicus [Reichert/Optopol Technology, Inc., Depew, NY], Spectral OCT/SLO [Opko/OTI, Inc., Miami, FL], RTVue-100 [Optovue Corp., Fremont, CA], Spectralis HRA + OCT [Heidelberg Engineering, Inc., Heidelberg, Germany], and Cirrus HD-OCT [Carl Zeiss Meditec, Inc.]) Wolf-Schnurrbusch UE *et al*.[12] reported that measurements with the Stratus OCT showed the lowest thicknesses, whereas those with the Cirrus HD-OCT and Spectralis HRA+OCT yielded the highest ones. These discrepancies might be the due to differences in the retinal segmentation algorithms used by the various OCT systems. The more recent OCT systems also have greater resolution, less movement artifacts, and faster scanning times allowing patients to be more stable during the scanning process thus resulting in better quality scans.

The study by Abdu L and Sani R Y[13] in 100 normal Nigerian patients using the Carl Zeiss Stratus OCT model 3000 with software version 4.0 gave a mean central foveal thickness (MCFT) of 149.58 ± 32.47 μm which is significantly different from our values, these findings suggest that measurements obtained with different devices are not interchangeable. The RTVue SD-OCT (Optovue, Fremont, CA) used in our study is the first FDA approved SD-OCT, it has a 5-μm axial resolution and scans at 26,000 A-scans per second. It allows the option of a 5-by-5 line raster scan, sampled five times each for noise reduction, a 6-by-6 mm grid scan, or en-face 3D scanning capability, all of which are automatically registered to an ETDRS chart. This allows for easy localization of the fovea, the scans are repeatable and have a large (>1,000 patients) normative database for macular thickness and ganglion cell complex/RNFL analysis. The accuracy and repeatability of the scans are very high.[14]

A recent systematic review of evaluating 49 studies that looked at the effect of age on macula thickness and volume using the OCT concluded that "aging seems to increase the thickness of the central point fovea."[15] This was the finding among our group of patients, there was a progressive increase in CFT with age of participants up until 69 years before a decline was noticed, this difference was, statistically significant ($F = 3.501$, $P = 0.001$). An average increase in mean CFT by 0.139 μm ($\beta = 0.139$, $P < 0.001$) for every year of life below 69 was established. A significant difference (t=5.493, 95%CI= 4.077 – 8.613, p<0.001) in CFT between males and females was seen in our study as reported by other authors.[16] Males had thicker CFT (mean CFT = 241.77 μm ± 17.48 μm) compared with female participants (mean CFT = 235.43 μm ± 17.60 μm). Our data shows that the differences in CFT between genders reported among Caucasians and Asians[16,17] is equally present in our patients in sub-Saharan Africa.

Differences in CFT among patients with refractive errors were not significant ($P = 0.192$ and 0.863), myopes had a mean CFT of 239.47 μm ± 17.36 μm, while hyperopes had a mean CFT 239.03 μm ± 18.26 μm, and emmetropes had mean CFT of 239.81 μm ± 17.87 μm. Similarly, Song *et al*.[16] reported no significant changes in macula thickness with refractive errors. It must also be noted that eyes with high refractive errors above 6D were not included in our study.

Average parafoveal thickness values in our study patients were thicker than the central fovea. The mean parafoveal retinal thickness was thickest in the superior quadrant, 312.64 μm ± 13.25 μm, followed by the nasal quadrant, 311.17 μm ± 14.08 μm, then the inferior quadrant, 309.47 μm ± 13.31 μm, and thinnest in the temporal quadrant, 300.94 μm ± 13.76 μm [Figure 1]. These values were larger than values from Al Saad MM *et al*.[1] in an Asian population. The superior value of 299.71 (±23.67) um ($P = 0.001$), inferior value of 296.46 (±28.85) um, ($P = 0.001$) and nasal 293.63 (±26.86) um. ($P = 0.001$). Like our study and despite different values, the temporal had the thinnest value of 293.43 (±30.78) um ($P = 0.001$).

In view of the technical nature of OCTs,[7,18] more studies will be required to fully establish the relation between age, gender, refractive errors, and central fovea thickness. We, however, believe our study provides a much need information base for further investigations.

In conclusion, normative values for central foveal thickness in our hospital-based population of healthy patients were obtained using commercially available RTVue SD-OCT (Optovue, Fremont, CA). Mean central foveal thickness (CFT) in participants was 239.48 μm, this was similar to mean values reported by authors using the same Fourier domain OCTs. Males, had significantly thicker CFT (mean CFT = 241.77 μm) when compared with female participants (mean CFT = 235.43 μm), while the relationship between age and CFT showed that with increasing age mean CFT increased by 0.139 μm for every year of life below 70.

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Conflicts of interest

There are no conflicts of interest.

References

1. AlSaad MM, Shatarat AT, AlRyalat SA. Normative values of the retinal macular thickness in a middle eastern population. BMC Ophthalmology 2020;20:137.
2. Pilat A, Frank A, Sarim P, Gottlob AI. Normal macular structure measured with optical coherence tomography across ethnicity. Br J Opthalmol 2014;98941-5.
3. Adhi M, Aziz S, Mohammad K, Adhi MI. Macular thickness by age and gender in healthy eyes using spectral domain optical coherence tomography. PloS One 2012;7:e37638.
4. Asefzadeh B, Cavallerano AA, Fisch BM. Racial differences in macular thickness in healthy eyes. Optom Vis Sci 2007;84:941-5.
5. Mehta N, Waheed KW. Commentary: Diversity in optical coherence tomography normative databases: Moving beyond race. Int J Retin Vitr 2020;6:5. doi: 10.1186/s40942-020-0208-5.
6. Nieves-Moreno M, Martinez de la Casa JM, Cifuentes-Canorea P, Sastre Ibanez M, Santos Bueso E, Sáenz-Francés F, *et al*. Normative database for separate inner retinal layer thickness using spectral domain optical coherence tomography in Caucasian population. Plos One 2017;12:e0180450. doi: 10.1371/journal.pone.0180450.
7. Li Y, Xia X, Paulus YM. Advances in retinal optical imaging. Photonics 2018;5:9. doi: 10.3390/photonics5020009.
8. Kang J, Feng P, Wei X, Lam EY, Tsia KK, Wong KK. 102-nm, 44.5-MHz inertial-free swept source by mode-locked fiber laser and time stretch technique for optical coherence tomography. Opt Express 2018;26:4370-81.
9. Klein T, Wieser W, Eigenwillig CM, Biedermann BR, Huber R. Megahertz OCT for ultrawide-field retinal imaging with a 1050 nm fourier domain mode-locked laser. Opt Express 2011;19:3044-62.
10. Poddar R, Migacz JV, Schwartz DM, Werner JS, Gorczynska I. Challenges and advantages in wide- field optical coherence tomography angiography imaging of the human retinal and choroidal vasculature at1.7-MHz a-scan rate. J Biomed Opt 2017;22:1-14.
11. Huang J, Liu X, Wu Z, Xiao H, Dustin L, Sadda S. Macular thickness measurements in normal eyes with time-domain and Fourier-domain optical coherence tomography. Retina 2009;29:980-7.
12. Wolf-Schnurrbusch UE, Ceklic L, Brinkmann CK, IIieve M, Frey M, *et al*. Macular thickness measurements in healthy eyes using six different optical coherence tomography instruments. Invest Ophthalmol Vis Sci 2009;50:3432-7.
13. Abdu L, Sani RY. Macular volume and central foveal thickness measurements in normal eyes of healthy Nigerian adults using optical coherence tomography. Ann Afr Med 2014;13:134-7.
14. Grover S, Murthy RK, Brar VS, Chalam KV. Comparison of retinal thickness in normal eyes using stratus and spectralis optical coherence tomography. Invest Ophthalmol Vis Sci 2010;51:2644-7.
15. Subhi Y, Forshaw T, Sørensen TL. Macular thickness and volume in the elderly: A systematic review. Ageing Res Rev 2016;29:42-9.
16. Wagner-Schuman M, Dubis AM, Nordgren RN, Lei Y, Odell D, Chiao H, *et al*. Race- and sex-related differences in retinal thickness and foveal pit morphology. Invest Ophthalmol Vis Sci 2011;52:625-34.
17. Song WK, Lee SC, Lee ES, Kim CY, Kim SS. Macular thickness variations with sex, age, and axial length in healthy subjects: A spectral domain-optical coherence tomography study. Invest Ophthalmol Vis Sci 2010;51:3913-8.
18. Yu S, Lu J, Cao D, Liu R, Liu B, Li T, *et al*. The role of optical coherence tomography angiography in fundus vascular abnormalities. BMC Ophthalmology 2016;16:107.