African Vision and Eye Health
ISSN: (Online) 2410-1516, (Print) 2413-3183

A review of African studies on central corneal thickness

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Dates:
Received: 18 Dec. 2015
Accepted: 31 Mar. 2016
Published: 03 Nov. 2016

How to cite this article:
Rampersad N, Hansraj R. A review of African studies on central corneal thickness. Afr Vision Eye Health. 2016;75(1), a341. http://dx.doi.org/10.4102/aveh.v75i1.341

Recently, there has been increasing interest in understanding central corneal thickness (CCT) measurements in various populations. This may be related to the influence of CCT in the diagnosis, classification and management of glaucoma. In addition, CCT measurements are also important for monitoring corneal diseases and contact lens wear, indicating the overall health of the cornea and assessing eligibility for refractive surgery. This article reviews studies that have reported CCT measurements in non-glaucomatous African sub-populations. The CCT measurements, gender associations and limitations of these studies are highlighted. The findings of these studies and their implications are discussed in relation to global studies reporting on CCT measurements.

Introduction

Central corneal thickness

Central corneal thickness (CCT) measurements have been widely researched with studies appearing in the literature for over a century. Assessing CCT has diagnostic and therapeutic applications such as monitoring corneal diseases and contact lens wear, indicating the health of the cornea and endothelial pump, assessing eligibility for refractive surgery and interpreting intraocular pressure (IOP) measurements.[1] The first documented report on CCT measurements in the human eye, obtained using an optical device, appeared in 1880.[2] Since then, there have been several advancements in measurement techniques, and currently, a wide range of contact and non-contact devices are available for measuring CCT.[1] Although ultrasound devices are regarded as the gold standard,[3] devices based on the principles of Scheimpflug photography,[4,5,6] specular microscopy,[7,8,9] ultrasound biomicroscopy,[10,11] slit-scanning topography[12,13,14] and optical coherence tomography[15,16,17] are increasingly being used for clinical CCT measurements. Furthermore, studies conducted in countries such as China, India, Japan, United States of America and Australia suggest that CCT measurements vary widely between ethnic groups and geographical areas.[6,9,18,19,20]

Central corneal thickness measurements are known to influence IOP measurements recorded with applanation tonometers.[21,22] Several studies[16,18,19,23,24,25] have reported that IOP is overestimated in thicker corneas and underestimated in thinner corneas. Goldmann applanation tonometry, the clinical gold standard for IOP,[26] is calibrated on a theoretical assumption of a 520 µm CCT measurement.[21,27,28] Thus, any variation in CCT will alter the balance between the corneal resistance to indentation and the surface tension of the tear film.[29] In an early study, Ehlers[28] concluded that any deviation of 70 µm on either side of 520 µm would alter the IOP by 5 mmHg. It was further noted that IOP may be incorrectly interpreted by as much as 7 mmHg for every 100 µm deviation in CCT.[30] More recently, Eballe et al.[31] suggested that IOP would change by 2.8 mmHg per 100 µm change in mean CCT. Despite several researchers acknowledging the influence of CCT on IOP measurements, there is little agreement as to how the measured IOP should be adjusted to account for the CCT measurement.[32] This has resulted in several correction algorithms being posited[21,33,34] but none have been widely used or accepted.[35,36]

Glaucoma and central corneal thickness

Glaucoma is the second leading cause of global blindness and results in irreversible visual impairment.[37] Primary open angle glaucoma is the most common type of glaucoma.[37] There is a higher prevalence of primary open angle glaucoma among African populations[35,38] with 19.4% of the total global population affected living in sub-Saharan Africa.[39] Several studies[40,41,42,43] have identified primary open angle glaucoma as an important cause of irreversible blindness in African countries including Ghana, Nigeria, Gambia and Ethiopia. Moreover, primary open angle glaucoma presents at an earlier age and progresses more rapidly among African populations than non-African populations.[35,44,45,46]

Accurate measurements of IOP are essential in the screening, diagnosis and management of glaucoma.[33,47] Previous studies have highlighted the role of CCT as an independent risk factor for glaucoma.[48,49] Moreover, Kaushik et al.[50] suggested that thinner CCT measurements are related to greater susceptibility for glaucomatous changes. As a result, assessment of CCT has become an important part of an ocular examination since it provides information about the risk and clinical characterisation of the various glaucoma disorders.[48,51,52] Since IOP is the only known risk factor that can be pharmacologically manipulated in the treatment of glaucoma,[53,54] accurate IOP measurements are essential to assess the response and effectiveness of glaucoma management strategies.[55]

The literature shows that considerable CCT data have been collected in several American, Asian and European populations.[4,6,7,8,9,12,17,18,19,23,53] In contrast, only a few studies have investigated CCT in African populations living within the African continent. Considering the consequences of glaucoma and its prevalence in the African continent, it is important to understand the distribution of CCT measurements in African sub-populations. The purpose of this article is to review CCT measurements reported in normal (non-glaucomatous) populations from African countries including Nigeria, Cameroon, South Africa, Ghana, Ethiopia and Sudan.

African studies on central corneal thickness

Table 1 shows the various studies that have investigated and reported on CCT measurements in normal African sub-populations.[31,32,35,54,55,56,57,58,59,60,61,62] Half of the studies (n = 6) have been undertaken in West-Africa (Nigeria). The instrument used to measure CCT is an important consideration when mean CCT measurements are compared across different studies. All studies, with the exception of the two involving South African samples,[61,62] used ultrasound devices to measure CCT. As seen in Table 1, differences in mean CCT measurements are apparent even when ultrasound devices are used since values of ~550 µm were found in some studies[56,57,58,60] while values closer to ~530 µm were reported in other studies.[31,32,55]

Overall, there is a broad distribution (range: 519 µm – 550 µm) of CCT measurements in the various African sub-populations. The highest and lowest CCT measurements were reported in a Nigerian sample[60] (550 µm) and the Ethiopian and South African samples[54,62] (519 µm), respectively. This is interesting considering that the mean age of two of these samples[54,60] differed by only four years yet the difference in mean CCT is 31 µm. Overall, higher mean CCT measurements have been reported in Nigerian populations compared with other African sub-populations (Table 1). Even the minimum CCT measurements (from the ranges reported) are considerably higher in studies involving Nigerian samples[56,57,58,60] compared with the other African samples.[31,54,55,62] One study from Nigeria[35] reported a mean CCT of 535 µm which is slightly different from that reported in other Nigerian studies.[56,57,58,60] The sample used by Mercieca et al.[35] was considerably smaller (n = 29) and older (63.1 ± 11.2 years) than the other Nigerian samples[56,57,58,60] which may explain this discrepancy (Table 1).

Mean CCT measurements (~530 µm) were comparable for the studies conducted in Cameroon, Sudan and Ghana.[31,32,55] In contrast, the studies conducted in South Africa reported lower mean CCT values (~520 µm) despite including relatively young samples.[61,62] This difference may be explained by the use of devices based on Scheimpflug photography to measure CCT in the South African studies.[61,62]

TABLE 1: Summary of studies of central corneal thickness in African populations.

Authors	Country	Sample size (gender allocation)			Mean age in years		CCT technique	Mean CCT (µm)		Mean CCT (µm)	
		n	Male	Female	Mean	Range		Mean	Range	Males	Females
Iyamu et al.[56]	Nigeria	85	49	36	44.65 ± 15.11	20–69	Ultrasound pachymetry	550 ± 36.3	478–662	552.8 ± 38.5	546.3 ± 33.3
Iyamu and Osuobeni[57]	Nigeria	130	77	53	47.8 ± 16.8	20–79	Ultrasound pachymetry	548.97 ± 34.28	478–662	551.00 ± 37.20	546.06 ± 29.62
Iyamu et al.[58]	Nigeria	95	56	39	44.9 ± 15.2	20–69	Ultrasound pachymetry	547.0 ± 29.5	487–618	553.2 ± 33.5	542.6 ± 27.8
Iyamu and Memeh[59]	Nigeria	39	21	18	45.2 ± 15.4	20–75	Ultrasound pachymetry	NR*	NR*	561.8 ± 44.9	541.5 ± 31.1
Iyamu and Eze[60]	Nigeria	95	56	39	47.1 ± 14.1	20–69	Ultrasound pachymetry	550.1 ± 33.1	478–662	552.0 ± 36.4	544.5 ± 28.8
Mercieca et al.[35]	Nigeria	29	17	12	63.1 ± 11.2	17–68	Ultrasound pachymetry	535 ± 38	NR*	541 ± 47	522 ± 22
Eballe et al.[31]	Cameroon	485	163	322	31.4 ± 15.5	5–75	Ultrasound pachymetry	528.74 ± 35.89	440–670	530.27 ± 34.83	527.97 ± 36.41
Gelaw et al.[54]	Ethiopia	300	184	116	42.57 ± 16.71	18–87	Ultrasound pachymetry	518.68 ± 32.92	430–610	517.96 ± 32.74	519.83 ± 33.31
Mohamed et al.[55]	Sudan	94	60	34	NR*	NR*	Ultrasound pachymetry	530.15 ± 58.10	420–610	NR*	NR*
Sardiwalla et al.[61]	South Africa	200	100	100	20.1 ± 1.6	18–25	Scheimpflug photography	519.5 ± 38.6	442–642	516.7 ± 40.1	522.3 ± 37.1
Rampersad et al. (2011)[62]	South Africa	105	29	76	29.27 ± 14.67	18–82	Scheimpflug photography	518.49 ± 33.01	440–606	NR*	NR*
Ntim-Amponsah et al.[32]	Ghana	253	112	141	58 ± 16.1	21–90	Ultrasound pachymetry	530.53 ± 35.64	423–650	NR*	NR*

*NR, not reported; CCT, central corneal thickness.

With the exception of two studies,[54,61] all studies involving African sub-populations reported higher CCT measurements in males (Table 1). However, only Mercieca et al.[35] reported a statistically significant gender difference of 19 µm (541 µm vs. 522 µm, $p = 0.0035$), while the majority of studies reported gender differences which failed to reach statistical significance.[31,54,56,57,59]

Although these studies have provided useful information on CCT measurements in African sub-populations, there are some limitations associated with them which influence the interpretation of their findings and conclusions. Some of these limitations include small sample sizes,[35,59] a wide age range of participants,[31,32,54] use of contact CCT measurement techniques[32,54,59] and unequal distribution of male and female participants.[31,55,60] Moreover, all studies with the exception of Gelaw et al.[54] used convenience sampling to recruit study participants. In the study by Gelaw et al.[54] a power calculation was performed to determine the sample size needed, while none of the other studies included information regarding the sample size estimation. Lastly, some of the studies[35,56,57] reported on clinic-based samples which may not be representative of the general population due to the inherent selection bias associated with such samples.

Discussion

The interest in this review lies in better understanding the reported CCT measurements in normal African sub-populations. Due to the potential of CCT measurements in influencing IOP and subsequently glaucoma diagnosis and management,[33,47,48] this corneal parameter has received much attention in recent literature. Particularly in Africa, interest in understanding CCT measurements may also be related to the call for Africanisation of knowledge. As a process, Africanisation involves placing renewed emphasis on problems experienced in Africa by generating knowledge about these problems and striving to create African solutions for them.[63] It can then be proposed that by researching CCT in African populations, one may be able to better understand the role of CCT measurements in non-glaucomatous and glaucomatous individuals within an African context.

According to a meta-analysis which included 300 studies conducted over a period of 31 years, Doughty and Zaman[64] reported an expected CCT measurement of 535 µm. Moreover, when an ultrasound device is used, the expected mean CCT is higher averaging 544 µm.[64] When compared to the mean CCT measurements reported in African studies included in this review, only studies involving the Nigerian samples[56,57,58,60] are comparable to the suggested normal value (544 µm). All studies involving the other African sub-populations reported considerably lower mean CCT measurements.[31,32,54,55,61,62] This implies that there are variations in mean CCT measurements in the different normal African sub-populations. This trend has also been observed in different Asian sub-populations (Chinese, Japanese, Filipino and Malay) where a wide range of CCT measurements have been reported by researchers.[65,66,67,68] It is possible that environmental and climatic factors are responsible for these African and Asian sub-population CCT differences.[69]

Studies that have compared CCT measurements among Caucasians, Hispanics, Asians and African-Americans have reported significantly thinner measurements in the latter group.[65,66,70,71] Two other studies[69,72] compared CCT measurements between North African individuals and those from Europe including France and Russia. Both studies[69,72] concluded that the North African participants had significantly thinner mean CCT measurements when compared to their European counterparts. Dimasi et al.[53] suggested that differences in the thickness and composition of the stromal layer may account for the varied CCT measurements obtained in the different race groups.

The mean CCT measurement in African-Americans, when using ultrasound pachymetry, ranges between 525 µm and 535 µm.[65,66,70] This implies that the mean CCT measurements in African sub-populations (Table 1) may not necessarily be similar to those values reported for African-Americans. The precise reason for this difference is not known. The mean CCT in Caucasians[65,66,70] and Asians (predominantly Chinese),[65,67] when using ultrasound pachymetry, ranges between 553 µm and 563 µm, and 566 µm and 570 µm, respectively. This suggests that, on average, normal African sub-populations have thinner mean CCT measurements than Caucasians and Asians but thicker than the average CCT reported in African-Americans. However, this comparison should be interpreted with caution since other factors such as age, anthropometric measurements, gender distributions and refractive error influence CCT measurements.[23,57,64,73]

The distribution of CCT measurements follows a Gaussian curve in the general population.[53] Studies involving non-African populations have reported that CCT measurements are normally distributed.[4,6,68] However, only one African study,[61] from those included in this review, described the distribution of CCT measurements which was shown to be normally distributed. In addition, previous studies have suggested that CCT and gender are related with thicker mean CCT measurements in males than females.[9,19,35,66] This trend was also observed in majority of the African studies[56,57,58,59,60] included in the review. Furthermore in most of the African studies, the gender difference in CCT measurements was not statistically significant as has been reported in other studies.[8,23,65,74]

Conclusion

The broad distribution of mean CCT measurements reported in the studies reviewed suggests that variations exist among the different African sub-populations. These results have important implications for the assessment and interpretation of CCT and IOP measurements in African sub-populations. This review is limited to studies conducted on normal healthy African samples and excludes those that have included individuals with systemic conditions[75] (diabetes mellitus and

hypertension) and glaucoma disorders[76,77], as these factors can influence CCT measurements.[1,48,64,78] In conclusion, this review draws attention to the assumption that CCT measurements in one African population cannot necessarily be extrapolated to other African populations. This implies that there may be other factors, even within the same race group, that contribute to differences in CCT measurements.

Acknowledgements

Competing interests

The authors declare that they have no financial or personal relationships which may have inappropriately influenced them in writing this article.

Authors' contributions

N.R. wrote the manuscript and R.H. provided feedback on the structure and content of the manuscript.

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