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ORIGINAL RESEARCH

Central Corneal Thickness Among Filipino Patients in an Ambulatory Eye Surgery Center Using Anterior Segment Optical Coherence Tomography

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Objective: The purpose of the study was to determine the central corneal thickness (CCT) among Filipino patients that may contribute to different glaucoma diagnosis using the anterior segment optical coherence tomography in an ambulatory eye surgery center.

Methods: A single-center retrospective, cross-sectional study design including 1232 eyes of 641 patients of the Asian Eye Institute, Makati, Philippines from January 2019 to December 2019 who had their CCT measured with Visante anterior segment optical coherence tomography (AS-OCT). CCT was correlated with age, sex, presence of diabetes and/or hypertension, and glaucoma diagnosis.

Results: Among 641 patients who had their CCT measured by Visante AS-OCT, 723 eyes of 369 patients were included. Nearly half of the study population were normal or glaucoma suspects. The mean CCT among Filipino patients was 535.59 ± 34.06 µm. Ocular hypertensive patients had the thickest CCT, while normal tension glaucoma patients had the thinnest CCT. After adjusting for multiple variables, CCT had a direct relationship with the presence of diabetes, IOP level and the diagnosis of ocular hypertension, while inverse relationship with age. Most of the patients presenting with angle closure glaucoma were females aged 60 and above.

Conclusion: Visante AS-OCT is a non-contact and non-aerosol generating instrument allaying the fear of disease transmission from contact or aerosolization of tears. Our study confirms similar relationships of CCT with age, presence of diabetes, IOP level, and diagnosis of ocular hypertension or normal tension glaucoma among Filipino patients with the available literature from other ethnicities.

Keywords: central corneal thickness, Filipino, AS-OCT, Visante, glaucoma diagnosis

Background

Glaucoma comprises a group of optic neuropathies characterized by progressive degeneration and death of retinal ganglion cells associated with gradual and progressive loss of visual field.[1] The biological basis of glaucoma is poorly understood and the factors promoting its progression have not been completely described.[2] Glaucoma is the leading cause of irreversible blindness in the world with 10% being bilaterally blind and is the second leading cause of global blindness after cataract.[3,4]

The identification of risk factors associated with glaucoma is very important. Many risk factors are non-modifiable but still imperative to know to stratify the risk

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profile of each patient. Some of the non-modifiable risk factors include advance age, family history and African-American or Hispanic race. Intraocular pressure (IOP) is at present the most significant and the only treatable risk factor for glaucoma.[5,6] In clinical practice, IOP measurement is essential in the diagnosis, monitoring and treatment of glaucoma; thus, accurate IOP measurement is vital for appropriate management of glaucoma.[7]

The Goldmann applanation tonometry (GAT) is considered as the gold standard for IOP measurement, but it is known to be affected by corneal biometrics issues such as corneal hysteresis (CH) and central corneal thickness (CCT).[8,9] The Ocular Response Analyzer (ORA) accurately determines CH, a superior predictor of glaucoma progression, but it is not widely available to most ophthalmologists.[9] The Ocular Hypertension Study (OHTS) stated that the cornea is not perfectly elastic and a thin CCT is a strong predictor for development of primary open angle glaucoma (POAG) among patients with ocular hypertension (OHT).[10] Studies have shown that CCT varies among different ethnicities and races and among different glaucoma subtypes.[11,12] African Americans have the thinnest CCT compared to other ethnicities.[13] On the other hand, Asians have thinner CCT than Hispanics, Pacific Islanders and Caucasians. Among Asians, Filipinos and Chinese have thinner CCT compared to other Asian ethnicities.[14] Studies have also demonstrated the correlation of thin CCT with POAG and normal tension glaucoma (NTG), and the correlation of thick CCT and OHT.[11,13]

CCT can be measured with different devices. Ultrasound pachymetry (USP) remains the gold standard but is highly operator dependent.[15] The accuracy of its measurement is dependent on the perpendicularity of the probe's application to the cornea and its reproducibility is dependent on the accurate probe placement over the central cornea. It touches the cornea, and may transmit diseases in the process.[16] Many studies have shown good correlation of CCT readings between USP and anterior segment optical coherence tomography (AS-OCT) regardless of the corneal thickness;[17–20] therefore, researchers tend to use noncontact methods.[16] Moreover, the transmissibility of the Coronavirus disease 2019 (COVID-19) from the ocular surface remains indefinite; thus, contact and aerosol-generating procedures are best avoided to prevent transmission, particularly among eyes with high IOP[21] and high tear volume.[22]

Thin CCT underestimates IOP, while thick CCT overestimates IOP. Thin CCT may then delay diagnosis of glaucoma and cause insufficient treatment and rapid progression of glaucoma; thus, CCT measurements should be addressed to properly comprehend the risk for glaucoma in each patient.[23,24] Among Asians, particularly Koreans and Japanese, the prevalence of NTG is highest.[25,26] The knowledge of baseline risk profile based on anatomic discrepancies is important to stratify the risk of Filipinos to this specific subtype of glaucoma.

In our institution, AS-OCT is routinely done as part of the glaucoma screening procedure in the assessment of narrow angles. To the best of our knowledge, there has not been a prior study on CCT among Filipinos using AS-OCT amongst normal and glaucomatous patients. The research aims to determine the CCT among Filipino patients using the AS-OCT in an ambulatory eye surgery center that may contribute to different glaucoma diagnosis and its correlation with age, sex, presence of diabetes and/or hypertension, and glaucoma diagnosis.

Methods

The study was a single-center retrospective, cross-sectional study design including data from January 2019 to December 2019 at the Asian Eye Institute, Makati, Philippines.

The charts of patients who had CCT taken with the Visante AS-OCT (Carl Zeiss Meditec, Dublin, CA, USA) from January 2019 to December 2019 were reviewed for the study. The charts were included if the subject was aged 18 and above with recorded self-reported ethnicity and had no previous history of eye surgery, including all types of laser surgery. The subjects with a history of eye surgery, uveitis, endophthalmitis, panophthalmitis, choroidal or retinal mass, or any corneal pathology were excluded.

The Visante AS-OCT is a non-contact time-domain optical coherence tomography producing high resolution cross-sectional imaging of the cornea and allowing both central and regional pachymetry as well as sophisticated measurement of anterior chamber parameters. AS-OCT provides 15 mm horizontal scans of 7mm depth of the anterior segment.[17,18] The CCT was measured by the lead investigator with the electronic caliper aligning on the peak reflections at the anterior and posterior boundaries of the central cornea from Visante AS-OCT machine. The clinical data collected from the charts were age, sex, glaucoma diagnosis confirmed by a glaucoma specialist, laterality, presence of co-morbidities (hypertension and/or diabetes), anti-glaucoma medications and IOP measured

with a Tonopen AVIA (TPA, Reichert Inc. NY, USA) or GAT. For bilateral cases, both eyes were included.

The data were extracted by the lead investigator from the patient charts, and all the information were manually entered into an electronic spreadsheet file. The subsequent data processing and analysis were then carried out using the statistical software, Stata 13. The patient identity was not included in the electronic spreadsheet and was replaced by a patient sequence number to ensure privacy and confidentiality. A master list of the patients' names with corresponding sequence number was kept in a separate password-protected electronic spreadsheet.

The investigators adhered to the principles of transparency, legitimate purpose, and proportionality in the collection, retention, and processing of personal information (Data Privacy Act of 2012). The privacy and confidentiality of each subject were upheld. The study was a minimal risk study which will be conducted in full compliance with principles of the 7th iteration of the Declaration of Helsinki, Good Clinical Practice of the WHO, Philippine Health Research Ethics Board and the ethical standards of Asian Eye Institute. The protocol was submitted for ethical evaluation to the St. Cabrini Medical Center-Asian Eye Institute (SCMC-AEI) Review Committee and was conducted upon approval (ERC#2020-016, August 11, 2020).

Statistical Analysis

Descriptive statistics were used such as mean, median, standard deviation, and range for describing the age of participants in years, estimated IOP in mm Hg, and CCT in μm; while frequency and percentage were used for the categorical data variables such as sex, presence of diabetes and/or hypertension, use of glaucoma medications, laterality of the condition, and glaucoma diagnosis (normal-glaucoma suspect, ocular hypertension, open angle glaucoma, angle closure glaucoma, secondary glaucoma).

A series of one-way analysis of variance were also performed to determine differences in the mean age, IOP and CCT across the glaucoma diagnoses. A series of chi-squared tests were used to explore differences between glaucoma diagnosis in terms of sex, presence of diabetes and/or hypertension, and the use of glaucoma medication.

The relationship between IOP and CCT were estimated using the Pearson's correlation coefficient, and presented with its confidence interval.

Multiple linear regression models were used to determine the association between CCT and the glaucoma diagnosis; and another model to explore the association between CCT and known clinically important confounders (age, sex, presence of diabetes and/or hypertension, and use of medications). The adjusted and unadjusted estimates, as well as their confidence intervals, were also calculated to evaluate the clinical importance of these associations. These models were adjusted for significant and clinically important characteristics such as previously mentioned.

A series of independent *t*-tests for unequal variances were performed to determine the difference between the values of IOP and CCT from the current sample population, and the values of the Filipino sub-population from the study of Badr.[14] One-way analyses of variance were also performed to compare the results of the current study and the measurements of Badr[14] and Soriano.[27]

The level of significance for all sets of analysis was set at a p-value less than 0.05 using two-tailed comparisons. The significance levels were adjusted for multiple comparisons procedure using the Fisher-Hayter standardized method, as evidenced by the results of the analyses of variance.

The sample size was computed based on a two-tailed 95% level of confidence, a power arbitrarily set at 80%; based on the estimated population of patients who underwent AS-OCT for the past year, and a small effect size (between 0.10 to 0.20) based on the studies by Badr[14] and Soriano.[27] Post-hoc power analyses were performed using the same parameters and the effect size was set to 0.20 resulting to an accrued power of 0.80, which is relatively acceptable.

Results

Demographic Characteristics

The study was composed of 1232 eyes of 641 patients from January 2019 to December 2019 who received Visante AS-OCT measurement. There were 723 eyes of 369 patients included in the study, while 509 eyes met one or more of the exclusion criteria, among which: 290 had previous eye surgery; 111 had previous laser surgery; 24 had corneal pathology; 4 had uveitis; 37 had missing information; 8 were less than 18 years old; and 35 were not Filipinos.

The age of the patients included ranged from 19 to 90 years old with a mean age of 54 years old. Table 1 summarizes the demographic characteristics of the study population. Two-thirds of the study population were females and most of the patients had bilateral affectation.

Table 1 Baseline Characteristics of the Study Population (N: 369)

Characteristics	Summary Measures
Age in years	54.09 ± 15.99
Sex of the patient	
Male	146 (29.57%)
Female	223 (60.43%)
Degree of affectation	
Unilateral	31 (8.40%)
Bilateral	338 (91.60%)
Presence of diabetes	
Yes	77 (20.92%)
No	291 (79.08%)
Presence of hypertension	
Yes	91 (24.73%)
No	277 (75.27%)

Table 2 Clinical Characteristics of Each Eye Measurement (N: 723)

Characteristics	Summary Measures
Degree of affectation	
Left eye	358 (49.52%)
Right eye	365 (50.48%)
Glaucoma medications	
No	622 (86.03%)
Yes	101 (13.97%)
Number of medications	0 (0 to 5)
Topical	
Beta-blockers	54 (7.47%)
Carbonic anhydrase inhibitors	24 (3.32%)
Prostaglandins	71 (9.82%)
Alpha-adrenergic agonists	41 (5.67%)
Miotics	6 (0.83%)
Oral	
Acetazolamide	9 (1.24%)
Central corneal thickness (CCT)	535.59 ± 34.06
Intraocular pressure (IOP)	17.42 ± 5.02
Glaucoma diagnosis	
Normal - Glaucoma Suspect (GS)	320 (44.26%)
Ocular Hypertension (OHT)	78 (10.79%)
Open Angle Glaucoma (OAG)	77 (10.65%)
Normal Tension Glaucoma (NTG)	19 (2.63%)
Primary Open Angle Glaucoma (POAG)	58 (8.02%)
Angle Closure Glaucoma (ACG)	239 (33.06%)
Primary Angle Closure Suspect (PACS)	176 (24.34%)
Primary Angle Closure (PAC)	26 (3.60%)
Primary Angle Closure Glaucoma (PACG)	37 (5.12%)
Secondary Glaucoma (SG)	9 (1.24%)

Table 2 shows the clinical characteristics of each eye measurement. Right and left eyes were similarly affected. Nearly 15% of the patients were on medications. The most common medications used were prostaglandins and beta-blockers. The mean CCT across all diagnosis was between 535 to 536 µm. The minimum CCT measured was 430 µm and the maximum at 650 µm.

The glaucoma diagnosis was divided into normal-glaucoma suspect (GS) group, ocular hypertension (OHT), open angle glaucoma (OAG) group, angle closure glaucoma (ACG) group and secondary glaucoma (SG) group. Almost half of the study population comprised the normal-glaucoma suspect group. The normal–glaucoma suspect group included patients with no glaucoma or glaucoma suspect patients with open angles and a suspicious glaucomatous disc damage or glaucomatous visual field defect on automated visual field in the absence of elevated IOP. The OHT group included patients with elevated IOP greater than 21 mm Hg without any optic nerve damage or visual field loss. The OAG group included patients with NTG or POAG, while ACG group included patients with PACS, PAC or PACG.

The measurements of each variable were tested across normal-glaucoma suspect (Normal-GS), open angle glaucoma (OAG), angle closure glaucoma (ACG) and secondary glaucoma (SG) for differences as shown in Table 3. More males were observed among the OAG group and more females among the ACG group. Among SG group, most of them have diabetes and hypertension. Significant differences were noted with age and IOP. Fisher-Hayter standardized method showed that the mean age and IOP

Table 3 Measurements of Each Variable Across Glaucoma Diagnosis

Characteristics	Normal-GS	OAG	ACG	SG	p-val
Number (Percentage)	320 (44.26%)	77 (10.65%)	239 (33.06%)	9 (1.24%)	
Age in years	48.93 ± 17.10	57.16 ± 15.14	61.73 ± 10.39	55.22 ± 20.64	<0.01
Sex of the patient					
Female	198 (61.88%)	24 (31.17%)	71 (71.55%)	6 (66.67%)	<0.01
Male	122 (38.13%)	53 (68.83%)	68 (28.45%)	3 (33.33%)	
Degree of affectation					
Unilateral	10 (3.13%)	5 (6.49%)	32 (13.39%)	3 (33.33%)	<0.01
Bilateral	310 (96.88%)	72 (93.51%)	207 (86.61%)	6 (66.67%)	
Presence of diabetes	56 (17.50%)	17 (22.08%)	57 (23.85%)	6 (66.67%)	<0.01
Presence of hypertension	48 (15%)	33 (42.86%)	77 (32.22%)	5 (55.56%)	<0.01
Glaucoma medications					
No	320 (100%)	35 (45.45%)	201 (84.10%)	3 (33.33%)	<0.01
Yes	–	42 (54.54%)	38 (15.90%)	6 (66.67%)	
Topical					
Beta-blockers	–	27 (35.06%)	18 (7.53%)	2 (22.22%)	<0.01
CA inhibitors	–	9 (11.69%)	11 (4.60%)	2 (22.22%)	<0.01
Prostaglandins	–	31 (40.26%)	27 (11.30%)	2 (22.22%)	<0.01
Alpha agonists	–	14 (18.18%)	21 (8.79%)	3 (33.33%)	<0.01
Miotics	–	–	6 (2.51%)	–	–
Oral (Acetazolamide)	–	–	7 (2.93%)	2 (22.22%)	<0.01
Central corneal thickness	532.26 ± 34.86	535.87 ± 34.45	531.72 ± 30.13	532.78 ± 35.64	0.81
Median (Range)	533 (430–644)	534 (456–650)	530 (460–610)	526 (500–620)	
Intraocular pressure	15.34 ± 2.91	20.62 ± 5.53	17.27 ± 4.87	23 ± 9.08	<0.01
Median (Range)	15 (8–21)	19 (13–48)	16 (10–41)	23 (14–37)	

Abbreviations: GS, glaucoma suspect; OAG, open angle glaucoma; ACG, angle closure glaucoma; SG, secondary glaucoma; CA, carbonic anhydrase.

were notably lower among Normal-GS group as compared to the three other disease groups. ACG group was also significantly older as compared to the OAG group; and SG group appeared to have higher average IOP than ACG and OAG groups. No significant difference was observed on CCT amongst the groups.

The measurements of each variable were tested across open angle glaucoma subgroups, ocular hypertension group and normal-glaucoma suspect (Normal-GS) group as shown in Table 4. Significantly more males were observed among POAG group. Among NTG and POAG groups, nearly half of them appeared to have hypertension. Significant differences were noted with age, IOP and CCT. Fisher-Hayter standardized method showed that Normal-GS and OHT groups were significantly younger compared to NTG and POAG groups. The NTG group had the thinnest CCT, and the OHT groups had the thickest CCT. The IOP of Normal-GS and NTG groups was significantly lower than the PAOG and OHT groups as expected.

The measurements of each variable were tested across angle closure glaucoma subgroups and normal-glaucoma suspect (Normal-GS) groups as shown in Table 5.

Table 4 Measurements of Each Variable Across Open Angle Glaucoma Subgroups, Ocular Hypertension Group and Normal-Glaucoma Suspect Group

Characteristics	Normal-GS	NTG	POAG	OHT	p-val
Number (Percentage)	320 (44.26%)	19 (4%)	58 (12.21%)	78 (16.42%)	
Age in years	48.93 ± 17.10	61.37 ± 14.38	55.78 ± 15.90	47.32 ± 14.46	<0.01
Sex of the patient					
Female	198 (61.88%)	10 (52.63%)	14 (24.14%)	39 (50%)	<0.01
Male	122 (38.13%)	9 (47.37%)	44 (75.86%)	39 (50%)	
Degree of affectation					
Unilateral	10 (3.13%)	1 (5.26%)	4 (6.90%)	4 (5.13%)	0.52
Bilateral	310 (96.88%)	18 (94.74%)	54 (93.10%)	74 (94.87%)	
Presence of diabetes	56 (17.50%)	2 (10.53%)	15 (25.86%)	12 (15.38%)	0.31
Presence of hypertension	48 (15%)	8 (42.11%)	25 (43.10%)	11 (14.10%)	<0.01
Glaucoma medications					
No	320 (100%)	13 (68.42%)	22 (37.93%)	63 (80.77%)	<0.01
Yes	–	6 (31.58%)	36 (62.07%)	15 (19.23%)	
Topical					
Beta-blockers	–	4 (21.05%)	23 (39.66%)	7 (8.97%)	<0.01
CA inhibitors	–	2 (10.53%)	7 (12.07%)	2 (2.56%)	<0.01
Prostaglandins	–	4 (21.05%)	27 (46.55%)	11 (14.10%)	<0.01
Alpha agonists	–	2 (10.53%)	12 (20.69%)	3 (3.85%)	<0.01
Central corneal thickness	532.26 ± 34.86	521.58 ± 27.49	540.55 ± 35.41	561.15 ± 31.27	<0.01
Median (Range)	533 (430–644)	515 (468–574)	540 (456–650)	558 (511–643)	
Intraocular pressure	15.34 ± 2.91	15.53 ± 1.90	22.29 ± 7.64	22.67 ± 2.54	<0.01
Median (Range)	15 (8–21)	15 (13–20)	20 (13–48)	23 (16–28)	

Abbreviations: GS, glaucoma suspect; NTG, normal tension glaucoma; POAG, primary open angle glaucoma; OHT, ocular hypertension; CA, carbonic anhydrase.

Significantly more females and bilateral affectation were observed among PACS group. Significant differences were noted with age and IOP. Fisher-Hayter standardized method showed that Normal-GS group was significantly younger compared to the other disease groups. Also, it was noted that Normal-GS and PACS groups have significantly lower IOP than the PAC and PACG groups. No significant difference was observed on CCT amongst the groups.

Based on a series of correlations performed as shown in Tables 6–8, there was a relatively weak but significant direct relationship between CCT and IOP among Normal-GS group and overall group (Table 6). A moderate to strong correlation between these two measurements was present among PAC and PACG groups (Table 8); however, no significant correlation was noted for CCT and IOP among other disease groups and subgroups (Tables 6–8).

Based on the univariable linear regression presented in Table 9, CCT decreases significantly with age, but appeared to increase along with increases in the intraocular pressure. Ocular hypertension appeared to have thicker CCT than patients who are classified as Normal-Glaucoma Suspect. There was no noted association in the univariable analysis between CCT and other variables.

Table 5 Measurements of Each Variable Across Angle Closure Glaucoma Subgroups and Normal-Glaucoma Suspect Group

Characteristics	Normal-GS	PACS	PAC	PACG	p-val
Number (Percentage)	320 (44.26%)	176 (31.48%)	26 (4.65%)	37 (6.62%)	
Age in years	48.93 ± 17.10	60.40 ± 10.53	64.58 ± 9.84	66.08 ± 8.58	<0.01
Sex of the patient					
Female	198 (61.88%)	133 (75.57%)	16 (61.54%)	22 (59.46%)	0.01
Male	122 (38.13%)	43 (24.43%)	10 (38.46%)	15 (40.54%)	
Degree of affectation					
Unilateral	10 (3.13%)	13 (7.39%)	6 (23.08%)	13 (35.14%)	<0.01
Bilateral	310 (96.88%)	163 (92.61%)	20 (76.92%)	24 (64.86%)	
Presence of diabetes	56 (17.50%)	45 (25.27%)	7 (26.92%)	5 (13.51%)	0.10
Presence of hypertension	48 (15%)	55 (31.25%)	12 (46.15%)	10 (27.03%)	<0.01
Glaucoma medications					
No	320 (100%)	176 (100%)	19 (73.08%)	6 (16.22%)	<0.01
Yes	–	–	7 (26.92%)	31 (83.78%)	
Topical					
Beta-blockers	–	–	2 (7.69%)	16 (43.24%)	<0.01
CA inhibitors	–	–	–	11 (29.73%)	–
Prostaglandins	–	–	5 (19.23%)	22 (59.46%)	<0.01
Alpha agonists	–	–	2 (7.69%)	19 (51.35%)	<0.01
Miotics	–	–	1 (3.85%)	5 (13.51%)	<0.01
Oral (Acetazolamide)	–	–	–	7 (18.92%)	–
Central corneal thickness	532.26 ± 34.86	531.27 ± 30.71	542.58 ± 27.96	526.22 ± 27.48	0.27
Median (Range)	533 (430–644)	530 (460–610)	540 (500–604)	530 (469–608)	
Intra-ocular pressure	15.34 ± 2.91	15.73 ± 2.67	20.35 ± 5.26	22.41 ± 7.59	<0.01
Median (Range)	15 (8–21)	16 (10–24)	20 (12–32)	22 (11–41)	

Abbreviations: GS, glaucoma suspect; PACS, primary angle closure suspect; PAC, primary angle closure; PACG, primary angle closure glaucoma; CA, carbonic anhydrase.

A multivariable linear regression model was created which accounted for 12.39% of the variability in the estimation of CCT from the study population ($p<0.01$). After considering all the other variables, a year increase in age is associated with reduction in CCT by 0.37 (up to 0.55) µm. On the other hand, an increase in IOP by 1 mm Hg was accompanied by an increased CCT by around 0.14 to 1.29 µm. The patients with diabetes appeared to have CCT that were approximately 9 µm higher compared to those without diabetes. This association was not present in the univariable analysis but appeared to have an effect in the multivariable analysis. The patients diagnosed with ocular hypertension had significantly higher CCT between 15 to 33 µm compared to the Normal-GS group. The use of anti-glaucoma medications including prostaglandins appeared to have no effect on CCT on both univariable and multivariable analyses.

The results of our study did not differ in terms of mean overall CCT and IOP from the published results of the Filipino subpopulation of Badr[14] as shown in Table 10. The mean IOP from our study did not differ with Soriano[27] when comparing primary open angle glaucoma, ocular

Table 6 Correlation Between Intraocular Pressure and Central Corneal Thickness Among Glaucoma Diagnosis

Estimates	Overall	Normal-GS	OAG	ACG	SG
Correlation coefficient (ρ)	0.195	0.158	0.103	0.124	0.299
95% CI	0.12 to 0.26	0.05 to 0.26	−0.06 to 0.26	−0.03 to 0.25	−0.46 to 0.80
p-value	<0.01	0.01	0.20	0.16	0.44

Abbreviations: GS, glaucoma suspect; OAG, open angle glaucoma; ACG, angle closure glaucoma; SG, secondary glaucoma.

hypertension and primary angle closure glaucoma, but the mean IOP of our normal tension glaucoma subgroup was significantly higher compared with normal tension glaucoma group of the said study. In terms of CCT, the primary open angle glaucoma group of Soriano[27] had significantly lower values than the two other studies; and for those with ocular hypertension, the values from Badr[14] were significantly lower than those measured by the two other studies. Badr[14] used LenStar ocular low-coherence reflectometer in measuring CCT, while Soriano[27] used an ultrasound pachymeter.

Discussion

In Asia, the pooled overall glaucoma prevalence was 3.54% with POAG at 2.34% predominating over PACG at 0.73%. Normal tension glaucoma diagnosis is on the rise particularly in neighboring countries like China, Japan and Korea.[28] Currently, the published data about the relationship of CCT and glaucoma diagnosis in our country is not enough because of the lack of national statistics. Our study showed no significant difference on the CCT amongst patients with normal-glaucoma suspect, open angle glaucoma, angle closure glaucoma and secondary glaucoma.

Ventura reported that patients with ocular hypertension tend to be younger than other glaucoma diagnosis.[29] The OHTS reported that a greater mean CCT was found in younger patients who have glaucoma.[7] These findings are consistent with our results wherein an inverse relationship between age and CCT was found. Our study also reported that patients with normal tension glaucoma are generally older, have thinner CCT and have associated non-IOP cardiovascular dysregulation such as hypertension, supporting current literature.[30] Our study also showed that patients with ocular hypertension have the thickest cornea while normal tension glaucoma patients have the thinnest cornea, similar to published data in the literature.[12] The prevalence of normal tension glaucoma in our study population however was quite low as compared to our neighboring Asian countries.[14]

PACG is higher in Asians than Caucasians and Africans, with over 80% if PACG worldwide in Asia.[31] Angle closure glaucoma is more common among females who have more crowded angles and smaller anterior chamber parameters. This type of glaucoma is also more common among elderly individuals, which highlights the non-pupillary block mechanisms that may be involved in angle closure.[32] These findings are consistent with our results that showed angle closure glaucoma are typically more prevalent among female patients older than 60 years old.

In our study, after adjusting the CCT for age, sex, use of medications, presence of hypertension and/or diabetes, the ocular hypertension subgroup showed a statistically thicker CCT. These findings were consistent with the

Table 7 Correlation Between Intraocular Pressure and Central Corneal Thickness Among Open Angle Glaucoma Subgroups, Ocular Hypertension Group and Normal-Glaucoma Suspect Group

Estimates	Normal-GS	NTG	POAG	OHT
Correlation coefficient (ρ)	0.158	0.407	−0.026	−0.119
95% CI	0.05 to 0.26	−0.06 to 0.73	−0.28 to 0.23	−0.33 to 0.11
p-value	0.01	0.08	0.85	0.30

Abbreviations: GS, glaucoma suspect; NTG, normal tension glaucoma; POAG, primary open angle glaucoma; OHT, ocular hypertension.

Table 8 Correlation Between Intraocular Pressure and Central Corneal Thickness Among Angle Closure Glaucoma Subgroups and Normal-Glaucoma Suspect Group

Estimates	Normal-GS	PACS	PAC	PACG
Correlation coefficient (ρ)	0.158	−0.114	0.555	0.530
95% CI	0.05 to 0.26	−0.26 to 0.04	0.21 to 0.78	0.25 to 0.73
p-value	0.01	0.13	0.01	<0.01

Abbreviations: GS, glaucoma suspect; PACS, primary angle closure suspect; PAC, primary angle closure; PACG, primary angle closure glaucoma.

Table 9 Linear Regression Models for the Different Glaucoma Diagnoses

Predictors	Univariable		Multivariable	
	β (95% CI)	p-value	β (95% CI)	p-value
Age in years	−0.36 (−0.21 to −0.52)	<0.01	−0.37 (−0.20 to −0.55)	<0.01
Sex of the patient				
Female	Reference		Reference	
Male	2.76 (−2.33 to 7.85)	0.29	1.34 (−3.80 to 6.49)	0.61
Use of glaucoma medications				
Beta-blockers	2.21 (−7.26 to 11.67)	0.65	−0.09 (−12.16 to 11.98)	0.99
Carbonic anhydrase inhibitors	−6.13 (−20.01 to 7.76)	0.39	−6.01 (−22.86 to 10.84)	0.48
Prostaglandins	−3.00 (−11.36 to 5.36)	0.48	−7.58 (−18.10 to 2.94)	0.16
Alpha agonists	4.39 (−6.36 to 15.15)	0.42	11.79 (−2.44 to 26.02)	0.19
Miotics	−4.96 (−32.39 to 22.47)	0.72	−4.34 (−34.66 to 25.97)	0.78
Acetazolamide	1.20 (−21.24 to 23.65)	0.92	7.60 (−17.85 to 33.05)	0.56
Presence of diabetes	1.92 (−4.25 to 8.08)	0.54	8.97 (2.37 to 15.58)	0.01
Presence of hypertension	−5.11 (−10.91 to 0.70)	0.09	−2.88 (−9.32 to 3.57)	0.38
Intraocular pressure (mm Hg)	1.32 (0.84 to 1.81)	<0.01	0.71 (0.14 to 1.29)	0.02
Diagnosis				
Normal Glaucoma Suspect	Reference		Reference	
Ocular Hypertension	28.89 (20.75 to 37.04)	<0.01	24.16 (14.99 to 33.32)	<0.01
Normal Tension Glaucoma	−10.68 (−25.91 to 4.55)	0.17	−3.92 (−19.40 to 11.55)	0.62
Primary Open Angle Glaucoma	8.29 (−0.91 to 17.50)	0.08	7.25 (−4.62 to 19.11)	0.23
Primary Angle Closure Suspect	−0.99 (−7.03 to 5.06)	0.75	2.94 (−3.38 to 9.26)	0.36
Primary Angle Closure	10.32 (−2.82 to 23.46)	0.12	13.32 (−0.49 to 27.13)	0.10
Primary Angle Closure Glaucoma	−6.04 (−17.23 to 5.14)	0.85	−4.68 (−19.91 to 10.56)	0.55
Secondary Glaucoma	0.52 (−21.29 to 22.32)	0.96	−8.29 (−31.47 to 14.90)	0.48

study of Soriano[27] which was similarly done in our country; however, our study showed poor correlation between IOP and CCT amongst patients with ocular hypertension. Badr found out that the presence of diabetes was associated with 10.57 ± 2.5 μm thicker CCT compared to the patients with no diabetes. This finding was similarly seen in our study that patients with diabetes appeared to have 9 μm thicker CCT compared to those without diabetes. Our study also noted that the level of IOP had a direct relationship with CCT.

There has been a growing number of evidence that prostaglandin analogues can cause corneal thinning. Schlote demonstrated on his case series that using travoprost within a year was linked to reduction in CCT which might affect IOP measurements with GAT.[33] Another study demonstrated corneal thinning associated with bimatoprost usage.[34] However, these findings were not evident in our study. The duration of prostaglandin use was likewise not investigated in our study. The proposed mechanism of corneal thinning with prostaglandin analogues is the

Table 10 Comparison of IOP and CCT Values with Previous Studies

Measurements	Badr (2019)[14]	Soriano (2007)[27]	Sosuan (2021)	p-value
Intraocular Pressure	16.61 ± 3.50	–	17.42 ± 5.02	0.14
Ocular Hypertension	–	23 ± 4	22.67 ± 2.54	0.77
Normal Tension Glaucoma	–	13 ± 4	15.53 ± 1.90	0.01
Primary Open Angle Glaucoma	–	23 ± 7	22.29 ± 7.64	0.70
Primary Angle Closure Glaucoma	–	28 ± 15	22.41 ± 7.59	0.20
Central Corneal Thickness	535.44 ± 39.70	–	535.59 ± 34.06	0.97
Normal-Glaucoma Suspect	534.10 ± 37.40	–	532.26 ± 34.86	0.72
Ocular Hypertension	503.62 ± 44.50	588 ± 28	561.15 ± 31.27	<0.01
Normal Tension Glaucoma	525.50 ± 6.40	526 ± 40	521.58 ± 27.49	0.92
Primary Open Angle Glaucoma	548 ± 56.70	538 ± 33	540.55 ± 35.41	0.01
Primary Angle Closure Glaucoma	535.71 ± 43.80	531 ± 32	526.22 ± 27.48	0.63
Secondary Glaucoma	539.27 ± 25	–	532.78 ± 35.64	0.62

regulation of matrix metalloproteinase activity and the remodeling of the extracellular matrix within the cornea.[35]

The advantages of the current study include the use of Visante AS-OCT to measure CCT which is a non-contact and non-aerosol generating instrument. With the advancements in anterior segment imaging, there have been different modalities used in the acquisition of anterior chamber parameters among which AS-OCT (Visante, ANTERION) gained importance in our clinical practice, as it can measure objectively anterior segment parameters with precision and no risk of disease transmission from contact or aerosolization of tears.

The limitation of this study include that the study was conducted in an ambulatory eye surgery center, thus, the results of the study might not be completely generalizable to the patient population in the community settings. The sample population used in the study was limited to those patients who underwent glaucoma screening procedure and/or assessment of narrow angles, which may be similar to a selection bias. In addition, we relied on the self-reported ethnicity of the patient which can cause some variability. Another limitation is the small number of subjects in the normal tension glaucoma subgroup. Lastly, Visante AS-OCT is less commonly available in the country as compared to ultrasound pachymeter (USP). Although many studies have shown good correlation of CCT readings between the two instruments, the reading of Visante AS-OCT might not be entirely equivalent to that of the USP.

Conclusion

The researchers found that the mean CCT using the Visante AS-OCT was 535.59 ± 34.06 μm among Filipino patients. The patients with ocular hypertension had the thickest CCT, while patients with normal tension glaucoma had the thinnest CCT. After adjusting for multiple variables, CCT had a direct relationship with the presence of diabetes, IOP level and the diagnosis of ocular hypertension, while it had an inverse relationship with age. The patients presenting with angle closure glaucoma were females aged 60 and above. Further prospective epidemiologic studies, with a larger number of subjects, may be needed to confirm these findings.

Abbreviations

ACG, angle closure glaucoma; AS-OCT, anterior segment optical coherence tomography; CCT, central corneal thickness; CH, corneal hysteresis; COVID-19, Coronavirus disease 2019; GAT, Goldmann applanation tonometry; GS, glaucoma suspect; IOP, intraocular pressure; NTG, normal tension glaucoma; OAG, open angle glaucoma; OHT, ocular hypertension; OHTS, Ocular Hypertension Study; ORA, Ocular Response Analyzer; SCMC-AEI, St. Cabrini Medical Center-Asian Eye Institute; PAC,

primary angle closure; PACS, primary angle closure suspect; PACG, primary angle closure glaucoma; POAG, primary open angle glaucoma; SG, secondary glaucoma; USP, ultrasound pachymetry.

Data Sharing Statement

The datasets used and analyzed in the current study are available from the corresponding author on reasonable request.

Ethics Approval and Consent to Participate

Approval and adherence to the tenets of the Declaration of Helsinki was assessed by the St. Cabrini Medical Center-Asian Eye Institute (SCMC-AEI) Review Committee and was conducted upon approval (ERC#2020-016, August 11, 2020). Since all data collected were retrospective, the requirement of the informed consent is waived by the review committee. The patient anonymity and confidentiality were and are protected and preserved with identifiable data omitted.

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Disclosure

The authors reported no conflicts of interest for this work.

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