Central Corneal Thickness in a Korean Population: The Namil Study

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PURPOSE. We investigated the distribution of central corneal thickness (CCT), and its association with age, sex, intraocular pressure (IOP), anterior chamber depth (ACD), axial length (AL), and the presence of systemic hypertension and diabetes in a Korean population.

METHODS. Our study is a population-based glaucoma prevalence study of residents aged ≥40 years in Namil-meon area, located in central South Korea. All subjects underwent a complete ophthalmic examination that included CCT measurement with an ultrasonic pachymeter, ACD and AL measurements by optical biometry, and Goldmann applanation tonometry. The right eye of all subjects was analyzed.

RESULTS. The mean (SD) CCT of the 1259 right eyes was 530.9 (31.5) μm. In univariate analysis, a thicker CCT was associated with a higher IOP (P < 0.001), a longer AL (P = 0.003), and a younger age (P < 0.001). ACD was not correlated significantly with CCT (P = 0.087). Men had a 5.7 μm higher CCT than women (age adjusted, P = 0.001). Subjects with hypertension had a 4.1 μm lower CCT than those without hypertension (age, sex-adjusted, P = 0.027), and the presence of diabetes was not associated significantly with CCT (age, sex-adjusted, P = 0.558). In multivariate analysis, a higher CCT was associated with a higher IOP (P < 0.001), younger age (P = 0.001), male sex (P = 0.005), and the absence of hypertension (P = 0.018).

CONCLUSIONS. The mean CCT of a Korean population was 530.9 μm. CCT was associated with IOP, age, sex, and hypertension. (Invest Ophthalmol Vis Sci. 2012;53:6851–6855) DOI: 10.1167/iovs.12-10175

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Subjects were in the sitting position while fixating on a distant target. The average of 3 measurements was recorded. The intra-observer variability as presented by intraclass correlation coefficient was 0.997, which suggests good measurement repeatability. Glaucoma specialists performed slit-lamp biomicroscopy examinations, including van Herick measurements of the ACD, gonioscopy using a Goldmann-type contact lens, and measurement of the IOP with a Goldmann applanation tonometer under topical anesthesia. Binocular optic disc evaluation was performed with a 90-diopter lens on the slit-lamp, and fundus photography was performed with a retinal camera (TRC-NW200; Topcon). The screening visual field test was performed by frequency doubling technology (FDT; N30-1 screening; Humphrey Matrix; Carl Zeiss Meditec, Inc., Dublin, CA). All subjects completed a questionnaire regarding their medical history, including past systemic illnesses, ocular disease, and medication history (i.e., systemic hypertension and diabetes).

Subjects were suspected of having glaucoma if the FDT screening examination indicated abnormal findings or low test reliability, the Goldmann applanation tonometry revealed an IOP \(>20\) mm Hg, and/or optic disc abnormalities were detected (including a vertical cup-to-disc ratio \(>0.6\) or a difference in the cup-to-disc ratio between the 2 eyes of \(>0.2\)) and were referred for a definitive examination to confirm the diagnosis of glaucoma. This analysis consisted of visual field tests with the Humphrey Field Analyzer SITA Standard 30-2 program (HFA II 720; Carl Zeiss Meditec, Inc.), retinal nerve fiber layer analysis with optical coherence tomography (Stratus OCT; Carl Zeiss Meditec, Inc.), and scanning laser polarimetry (GDx VCC; Carl Zeiss Meditec, Inc.).

Subjects were diagnosed with primary open angle glaucoma if a glaucomatous visual field defect occurred together with 1 or more of the following in the same baseline phase: a vertical cup-to-disc ratio \(>0.6\), a difference in the cup-to-disc ratio \(>0.2\) between both eyes, and an IOP \(>21\) mm Hg. In addition, the subject also was required to have open and normal anterior chamber angles without any other abnormalities that could explain the visual field defect. A subject was diagnosed with ocular hypertension if the IOP exceeded 21 mm Hg, there were no glaucomatous visual field defects, and the cup-to-disc ratio was \(>0.5\). A patient with angle-closure was classified into 1 of 3 clinical subtypes, including primary angle-closure suspect, primary angle-closure, and primary angle-closure glaucoma using the definitions reported by the International Society of Geographical and Epidemiological Ophthalmology as described in a previous study. 

### Table 1. Age- and Sex-Specific CCT, \(\mu m\)

<table>
<thead>
<tr>
<th>Age Groups, y</th>
<th>Male No. Mean (SD)</th>
<th>Female No. Mean (SD)</th>
<th>Entire Study No. Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 to 49</td>
<td>98 537.8 (28.1)</td>
<td>108 542.1 (31.9)</td>
<td>206 540.0 (30.2)</td>
</tr>
<tr>
<td>50 to 59</td>
<td>146 537.8 (29.6)</td>
<td>150 530.2 (31.2)</td>
<td>296 534.0 (30.6)</td>
</tr>
<tr>
<td>60 to 69</td>
<td>152 531.9 (31.4)</td>
<td>218 527.2 (30.8)</td>
<td>370 529.1 (31.1)</td>
</tr>
<tr>
<td>(\geq70)</td>
<td>160 530.8 (32.3)</td>
<td>227 521.5 (31.1)</td>
<td>387 525.3 (31.9)</td>
</tr>
<tr>
<td>All age groups</td>
<td>556 534.1 (30.7)</td>
<td>703 528.3 (31.8)</td>
<td>1259 530.9 (31.5)</td>
</tr>
</tbody>
</table>

Subjects were diagnosed with secondary glaucoma or suspected to have glaucoma if they had a history of significant ocular trauma, iridocyclitis, and the presence of new vessels in the iris or chamber angle, or showed other ocular findings that could cause a glaucomatous optic disc or visual field changes.

The association between primary open angle glaucoma, ocular hypertension, angle-closure, and CCT in our study population has been described previously. Therefore, eyes with glaucoma or ocular hypertension were excluded from our study. In addition, to minimize the effect of intraocular surgery on CCT, eyes with a history of intraocular surgery or corneal refractive surgery also were excluded. Because CCT in the right and left eyes was highly correlated (correlation coefficient = 0.946, \(P < 0.001\)), only the right eyes were used for the analysis.

### Statistical Analysis

Linear regression analysis was performed to assess the effect of continuous variables (age, IOP, ACD, and AL) on CCT, using CCT as the dependent variable. Refractive error and AL were correlated significantly (correlation coefficient = \(-0.600, P < 0.001\)); therefore, only AL was considered as an independent variable in our study. To identify the effect of binary variables on CCT, differences in CCT between sex and the presence of systemic disease (hypertension and diabetes) were evaluated using the \(t\)-test. Analysis of covariance was performed additionally for the adjustment of age and sex. Multivariate analysis was performed for variables that were associated significantly with CCT in univariate analysis. A \(P\) value < 0.05 was considered significant. All statistical analyses were performed using SPSS software version 12.0 (SPSS Inc., Chicago, IL).

### Results

Among the 1928 subjects \(\geq 40\) years of age in the Namil-meon area who participated in the Namil study, both eyes of 1532 subjects were examined. Of the 1532 right eyes examined, CCT measurements were available for 1504 eyes. In addition, eyes with glaucoma or ocular hypertension and/or history of intraocular surgery or corneal refractive surgery were excluded. Therefore, the remaining 1259 non-glaucomatous right eyes were included in our analysis. The mean (SD) age, refractive error, and IOP of the 1259 subjects was 62.4 (11.4) years (range 40–99), 0.22 (2.00) diopters (range –22.38–7.13), and 13.5 (2.7) mm Hg (range 5–21), respectively.

The distribution of the CCT values is shown in Figure 1. The mean (SD), median, skewness, and kurtosis of CCT distribution was 530.9 (31.5) \(\mu m\) (range 380–627), 529.0 \(\mu m\), 0.08, and 0.32, respectively, which suggest a normal distribution. The distributions of CCT for age categories are presented in Table 1. In univariate analysis, a thicker CCT was correlated significantly with a younger age (\(P < 0.001\)), higher IOP (\(P < 0.001\)), and longer AL (\(P = 0.003\)); however, CCT was not associated significantly with ACD (\(P = 0.087\), Table 2).

According to the regression line, CCT decreased by 4.0 \(\mu m\) for every decade of life (95% confidence intervals [CI] 2.4–5.5
Table 2. Univariate and Multivariate Linear Regression Analysis with CCT as a Dependent Variable and Other Ocular and Systemic Factors as Independent Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Univariate</th>
<th>Final Model*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>P</td>
</tr>
<tr>
<td>Age</td>
<td>−0.40</td>
<td>0.001</td>
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<tr>
<td>Sex</td>
<td>5.89</td>
<td>0.001</td>
</tr>
<tr>
<td>IOP</td>
<td>2.73</td>
<td>0.001</td>
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<tr>
<td>ACD</td>
<td>4.37</td>
<td>0.087</td>
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<tr>
<td>AL</td>
<td>2.84</td>
<td>0.003</td>
</tr>
<tr>
<td>Hypertension</td>
<td>−5.57</td>
<td>0.007</td>
</tr>
<tr>
<td>Diabetes</td>
<td>2.17</td>
<td>0.493</td>
</tr>
</tbody>
</table>

* Adjusted R² = 0.072, P < 0.001.

μm), increased by 2.73 μm for every 1 mm Hg increase in the IOP (95% CI 2.10–3.36 mm Hg), and increased by 2.84 μm for every mm increase in the AL (95% CI 0.98–4.71 μm). When CCTs of male and female subjects were compared, the average CCT in men was 5.8 μm more than that in women (P = 0.001, Table 3). The average CCT in subjects with hypertension was 5.5 μm less than that in those without hypertension (P = 0.007), whereas the presence of diabetes was not associated significantly with CCT (P = 0.493, Table 3). When age and sex were adjusted using the analysis of covariance, the average CCT in men was 5.7 μm more than that in women (age-adjusted, P = 0.001), the average CCT in subjects with hypertension was 4.1 μm less than that in those without hypertension (age and sex-adjusted, P = 0.027), and the presence of diabetes was not associated significantly with CCT (age- and sex-adjusted, P = 0.892, Table 3).

In multivariate analysis, when age, IOP, AL, sex, and the presence of hypertension were considered as independent variables and CCT was considered as a dependent variable, a higher CCT was associated with a higher IOP (β = 0.001, 2.56 μm increase in CCT for every 1 mm Hg increase in the IOP [95% CI 1.92–3.20 μm]), younger age (β = 0.001, 2.6-μm decrease in the CCT for every decade of life [95% CI 1.0–4.1 μm]), male sex (β = 0.005), and the absence of hypertension (P = 0.018, Table 2).

When the effect of CCT on IOP was analyzed separately, IOP increased by 2.0 mm Hg for every 100-μm increase in the CCT (P < 0.001, 95% CI 1.5–2.5 mm Hg, Fig. 2). When a multivariate analysis was performed additionally to identify the effect of CCT on IOP after adjustment for age, sex, and the presence of hypertension,24 IOP increased by 1.9 mm Hg for every 100-μm increase in the CCT (P < 0.001, 95% CI 1.4–2.3 mm Hg).

**DISCUSSION**

In our study, the mean CCT measured by ultrasound pachymetry in a Korean population was 530.9 μm, and the skewness and kurtosis of CCT distribution was 0.08 and 0.32, respectively, which suggest a normal distribution. According to previous population-based studies, the mean CCT of an Asian population ranged from 485.7 to 561.4 μm, as summarized in Table 4.7–21 When only studies using ultrasound pachymetry were considered, the mean CCT was 539.1 μm for Nepalese,6 521.9 μm for Burmese,5 541.2 μm for Singaporean Malay,11 541.5 μm for Singaporean,12 527.6 μm for southern Chinese,14 511.4 μm for southern Indian,18 and 514 μm for central Indian19 populations. Although the comparison of CCTs among studies is confounded by the variation in the characteristics of each study population and frequency of the ultrasound pachymetry, these results suggest that Nepalese, Singaporean Malay, Singaporean, and southern Chinese populations may have, on an average, thicker central corneas than Koreans, whereas Burmese, northern Chinese, and Indians may have, on an average, thinner central corneas than Koreans. Differences in ocular and systemic factors among various studies may account for the variations in reported CCT among the studies.

Goldmann applanation tonometry, which is the current gold standard IOP measurement technique, estimates IOP by measuring the force required to flatten an area of the cornea. Therefore, corneal characteristics, including its thickness1–3 or System 2.89, can affect IOP measurement. With regard to the correlation between IOP and CCT, all previous studies reported a higher IOP with a greater CCT,7–14,16–18,20,21 which confirms the importance of CCT for the proper assessment of IOP (Table 4). In previous studies in Asian populations, the IOP increase ranged from 1.0–3.6 mm Hg for each 100-μm CCT increase,7–10,12–14,17,18,20,21 which is in agreement with the results of our study (1.9 mm Hg IOP change per 100 μm CCT increase).
Our findings between hypertension and thinner central corneas were consistent after age and sex adjustment, which suggests that hypertension per se or blood pressure-lowering medication may affect CCT. In a previous study with the same study population used in the present report, the presence of hypertension was associated significantly with a higher IOP. A thinner CCT and a higher IOP in subjects with hypertension may suggest a possible role of hypertension as a real risk factor rather than a confounder for ocular hypertension or glaucoma.

In previous studies, the presence of abnormal glaucoma metabolism and/or diabetes was associated with a thinner central cornea (Table 4). This may be due to an osmotic gradient drawing fluid into the corneal stroma or a tendency among diabetics for corneal collagen to develop disulphide cross-linking. In our study, no significant difference was found in CCT between subjects with and without diabetes. Difference in distribution and severity of diabetes among study populations may account for this discrepancy.

It has been reported that a thicker central cornea is associated with a greater radius of corneal curvature, which in turn is correlated with a greater AL. Therefore, an eye with a greater AL may have a thicker central cornea. In our study, a greater AL was associated significantly with a thicker central cornea in a univariate analysis, whereas the association was no longer significant in a multivariate analysis; this is in agreement with previous study results. Corneal curvature was not investigated in our study; therefore, the cause of this discrepancy remains unclear.

There are some limitations of our study, including its cross-sectional study design, identifying systemic disease based on the information provided by the subjects without measuring blood pressure and blood glucose level, and the lack of analysis of other confounding factors, such as corneal curvature, body height, and weight. In our study, although age, sex, IOP, hypertension, and CCT were correlated significantly, the associations were not strong, which is in agreement with previous study results. Therefore, it remains unclear how these associations will affect glaucoma evaluation in a clinical setting.

In conclusion, the mean CCT of a Korean population was 530.9 μm, and was associated with IOP, age, sex, and hypertension. These findings would be helpful for the evaluation of glaucoma in this population.
References


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APPENDIX

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