



CORRELATION BETWEEN CENTRAL CORNEAL THICKNESS AND INTRAOCULAR PRESSURE IN PATIENTS SUSPECTED OF GLAUCOMA: A HOSPITAL-BASED CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Accurate assessment of intraocular pressure (IOP) is important in patients suspected of glaucoma. However, IOP measured by Goldmann applanation tonometry may be influenced by central corneal thickness (CCT), potentially affecting interpretation of pressure measurements and glaucoma risk. Regional evidence regarding this relationship remains clinically relevant.

Objectives: To determine the correlation between central corneal thickness and intraocular pressure among patients suspected of glaucoma attending a tertiary care hospital in North India.

Methods: A hospital-based prospective cross-sectional observational study was conducted in the Department of Ophthalmology of a tertiary care hospital in North India from January 2018 to June 2018. A total of 120 consecutive adult patients suspected of glaucoma were included after application of predefined eligibility criteria. Intraocular pressure was measured using Goldmann applanation tonometry, and central corneal thickness was assessed by pachymetry. Demographic and relevant clinical characteristics were recorded using a structured proforma. Continuous variables were summarized using appropriate descriptive statistics. The association between CCT and IOP was assessed using Pearson's correlation coefficient, with linear regression used to further quantify the association. Statistical tests were two-sided, and $p < 0.05$ was considered statistically significant.

Results: The mean age of participants was 55.4 ± 10.9 years; 68 (56.7%) were male and 52 (43.3%) were female. The mean CCT was 532.2 ± 29.5 μm and the mean IOP was 17.6 ± 3.5 mmHg. Participants with CCT < 500 μm had a mean IOP of 14.6 ± 2.2 mmHg, compared with 17.3 ± 3.2 mmHg among those with CCT 500–549 μm and 19.5 ± 3.3 mmHg among those with CCT ≥ 550 μm ($p < 0.001$). CCT demonstrated a significant positive correlation with IOP ($r = 0.474$; 95% CI, 0.322–0.599; $p < 0.001$). Linear regression showed a significant positive association between CCT and measured IOP ($\beta = 0.056$ mmHg per μm ; 95% CI, 0.037–0.074; $p < 0.001$), with an R^2 of 0.225.



Conclusion: Central corneal thickness was significantly and positively associated with Goldmann applanation tonometry-measured IOP among patients suspected of glaucoma. CCT should be considered when interpreting IOP during glaucoma evaluation and should be integrated with other clinical findings for individualized risk assessment.

Keywords: Central corneal thickness; Intraocular pressure; Glaucoma suspect; Goldmann applanation tonometry; Pachymetry; Glaucoma; Ophthalmology

INTRODUCTION

Glaucoma is a major cause of irreversible visual impairment worldwide and represents an important public health problem because visual loss may progress insidiously before patients become aware of functional deterioration. The global burden of glaucoma has increased substantially with population ageing, with an estimated prevalence of approximately 3.5% among individuals aged 40–80 years, and the number of affected individuals projected to rise considerably in coming decades.[1] Early identification of individuals at increased risk is therefore central to glaucoma control, particularly because structural and functional damage that has already occurred cannot generally be restored.

Intraocular pressure (IOP) remains one of the most important measurable parameters in glaucoma evaluation. Although elevated IOP is neither necessary nor sufficient for the diagnosis of glaucoma, it is a major modifiable risk factor and an important component of glaucoma risk assessment and treatment decisions.[2,3] Population-based studies from India have demonstrated that IOP is associated with primary glaucomas and that a substantial proportion of affected individuals may remain undiagnosed until significant damage has developed.[4] Estimates based on available Indian epidemiological data have indicated a considerable national burden of glaucoma, emphasizing the importance of effective detection and accurate assessment of individuals presenting with suspected disease.[5]

Accurate measurement of IOP is consequently essential in patients being evaluated for glaucoma. Goldmann applanation tonometry (GAT) has traditionally served as the clinical reference method for IOP measurement. However, the measurement obtained by applanation tonometry is influenced not only by true intraocular pressure but also by biomechanical properties of the cornea, particularly its thickness.[6,7] A thicker cornea may offer greater resistance to applanation and consequently result in an overestimation of IOP, whereas a thinner cornea may contribute to an underestimation. Experimental and clinical studies have demonstrated a positive relationship between central corneal thickness (CCT) and tonometrically measured IOP, although the magnitude of this relationship varies between individuals and according to the tonometric technique employed.[6-8]

CCT is therefore an important consideration when interpreting IOP in patients suspected of glaucoma or ocular hypertension. The Ocular Hypertension Treatment Study demonstrated that CCT is associated with the assessment of ocular hypertension and glaucoma risk, with thinner corneas being associated with a greater risk of subsequent glaucomatous conversion.[9] Subsequent studies have similarly reported associations between lower CCT and more advanced glaucomatous structural or functional damage.[10] These observations suggest that CCT may have relevance beyond its potential effect on the numerical measurement of IOP and may represent an important component of the overall risk profile of a glaucoma-suspect patient.

The importance of CCT may be particularly relevant in Indian populations because corneal thickness varies across populations and demographic groups. The Chennai Glaucoma Study, involving a large South Indian population, demonstrated substantial variation in CCT according to age, sex and urban-



rural residence and identified a positive association between CCT and IOP.[11] A study from a tertiary-care ophthalmic centre in North India likewise demonstrated relationships among CCT, corneal biomechanical properties and GAT-measured IOP across different categories of glaucoma and glaucoma suspects.[12] However, findings from different populations and studies are not entirely uniform, and the strength of the relationship between CCT and IOP may vary according to the characteristics of the study population, tonometric technique and underlying ocular status.

This variability provides a rationale for evaluating the relationship between CCT and IOP in patients presenting for glaucoma assessment in regional clinical settings. In particular, data from tertiary-care hospitals in North India remain useful for understanding whether variations in CCT are reflected in measured IOP among individuals suspected of glaucoma. Establishing the nature and magnitude of this relationship may assist clinicians in interpreting IOP measurements more appropriately and in avoiding over- or underestimation of glaucoma risk based solely on tonometric readings.

The present study was therefore undertaken to evaluate the correlation between CCT and IOP among patients suspected of glaucoma attending a tertiary-care hospital in North India. By assessing these two parameters in the same clinical population, the study aimed to contribute region-specific evidence regarding their relationship and to reinforce the importance of considering corneal thickness when interpreting IOP during glaucoma evaluation.

METHODOLOGY

Study Design: The present study was designed as a hospital-based prospective cross-sectional observational study to evaluate the relationship between central corneal thickness (CCT) and intraocular pressure (IOP) among patients suspected of glaucoma. Each eligible participant underwent standardized ophthalmic assessment, including measurement of CCT and IOP, during the study period.

Study Setting: The study was conducted in the Department of Ophthalmology of a tertiary care hospital in North India. The department provides comprehensive ophthalmic evaluation and management, including specialized assessment of patients referred for suspected glaucoma. Participants attending the ophthalmology outpatient services and fulfilling the predefined eligibility criteria were evaluated for inclusion in the study.

Study Duration: The study was conducted over a period of six months, from January 2018 to June 2018.

Study Population: The study population comprised consecutive patients attending the ophthalmology department who were clinically suspected of having glaucoma and required evaluation of IOP as part of their ophthalmic assessment. Patients were considered glaucoma suspects on the basis of clinical findings warranting glaucoma evaluation, such as raised or suspicious IOP, suspicious optic disc appearance, abnormal or suspicious visual-field findings, or other ophthalmic findings considered suggestive of possible glaucomatous disease by the examining ophthalmologist.

Inclusion Criteria

Participants were eligible for inclusion if they fulfilled the following criteria:

1. Patients clinically suspected of glaucoma and referred for glaucoma evaluation.
2. Age ≥ 18 years.
3. Ability to undergo reliable ophthalmic examination and tonometric assessment.
4. Ability to undergo pachymetric assessment of central corneal thickness.



5. Willingness to participate in the study and provide informed consent.

Exclusion Criteria

Patients were excluded if they had any of the following:

1. Previous ocular surgery, including corneal, cataract, or glaucoma surgery, likely to influence CCT or IOP measurements.
2. Active corneal disease, corneal oedema, corneal scarring, or other corneal pathology affecting pachymetric or tonometric measurements.
3. Active ocular inflammation or significant ocular trauma.
4. Secondary glaucoma with an identifiable ocular cause likely to substantially influence IOP.
5. Use of topical or systemic medication expected to substantially alter IOP or corneal thickness where reliable pre-treatment measurements were unavailable.
6. Conditions preventing reliable measurement of IOP or CCT.
7. Inability or unwillingness to provide informed consent.

Sample Size: The sample size was determined for assessment of the correlation between CCT and IOP. The calculation was based on an anticipated correlation coefficient of approximately $r = 0.26$, representing a small-to-moderate positive association considered clinically relevant for the planned analysis. A two-sided significance level (α) of 0.05 and statistical power of 80% were used. For estimation of the sample size required to detect a Pearson correlation coefficient, Fisher's z transformation was used, and a final sample size of 120 participants was selected for the study.

Sampling Technique: Eligible participants were recruited using consecutive sampling. Patients attending the ophthalmology department during the study period were screened against the predefined inclusion and exclusion criteria, and eligible individuals were enrolled consecutively until the required sample size of 120 participants was achieved. No random allocation or intervention-based grouping was performed.

Data Collection Tools & Procedure: After obtaining informed consent, demographic and relevant clinical information was recorded using a structured data collection proforma. A comprehensive ophthalmic examination was performed, including visual acuity assessment, slit-lamp examination, optic disc evaluation and measurement of IOP. IOP was measured using Goldmann applanation tonometry after instillation of topical anaesthetic and fluorescein, with the tonometer appropriately calibrated according to standard clinical practice. Central corneal thickness was subsequently measured using ultrasound pachymetry after topical corneal anaesthesia. The pachymeter probe was positioned perpendicularly over the central cornea with minimal pressure, and repeated measurements were obtained according to the instrument's standard operating procedure; a consistent central reading was recorded for analysis. Measurements were performed under standardized examination conditions, and the recorded values were entered into a structured study proforma for subsequent statistical analysis. Where both eyes were eligible for assessment, the eye designated according to the predefined study protocol was used for the primary participant-level analysis to avoid inappropriate statistical duplication of observations.

Study Variables: The principal independent variable was central corneal thickness, measured in micrometres (μm). The principal dependent variable was intraocular pressure, measured in millimetres of mercury (mmHg) using Goldmann applanation tonometry. Demographic variables included age and sex. Relevant clinical and ophthalmic variables recorded during evaluation included visual acuity, clinical indication for glaucoma suspicion and other examination findings considered relevant to glaucoma assessment. The primary outcome was the correlation between CCT and



measured IOP. Secondary analyses included assessment of the relationship between CCT and IOP across relevant demographic and clinical characteristics.

Statistical Analysis: Data were entered into a computerized database and analyzed using IBM SPSS Statistics. Continuous variables were summarized using mean and standard deviation when approximately normally distributed and median with interquartile range when distributions were substantially skewed. Categorical variables were summarized as frequencies and percentages. The distribution of continuous variables was assessed using graphical methods and an appropriate test of normality. The association between CCT and IOP was assessed using Pearson's correlation coefficient when both variables satisfied the assumptions for parametric correlation; Spearman's rank correlation coefficient was used when the assumptions of Pearson correlation were not met. The magnitude and direction of the correlation coefficient were reported with the corresponding two-sided *P* value. For comparisons of continuous variables between two independent groups, the independent-samples *t* test was used for normally distributed data and the Mann–Whitney *U* test for non-normally distributed data. For comparisons involving more than two groups, one-way analysis of variance or the Kruskal–Wallis test was used as appropriate. Categorical variables were compared using the chi-square test or Fisher's exact test where the expected cell frequencies were small. Where appropriate, linear regression analysis was used to further examine the association between CCT and IOP while considering relevant covariates. Effect estimates were reported with 95% confidence intervals where applicable. All statistical tests were two-sided, and a *P* value <0.05 was considered statistically significant.

Ethical Considerations: The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and applicable institutional and regulatory requirements. Written informed consent was obtained from eligible participants before study-related assessment. Participants were informed about the purpose and procedures of the study, and participation was voluntary. Confidentiality of participant information was maintained throughout data collection, analysis and reporting. Identifying information was not included in the analytical dataset or study reports, and participants retained the right to decline participation or withdraw from the study without affecting their clinical care.

RESULTS

A total of 120 patients suspected of glaucoma were included in the analysis. The mean age of the study participants was 55.4 ±10.9 years, with 68 (56.7%) males and 52 (43.3%) females. The distribution of patients according to the principal clinical basis for glaucoma suspicion is presented in Table 1.

Table 1. Demographic and clinical characteristics of the study participants (N=120)

Characteristic	Number (%) / Mean ± SD
Age (years), mean ± SD	55.4 ± 10.9
Sex	
Male	68 (56.7)
Female	52 (43.3)
Clinical basis for glaucoma suspicion	
Suspicious optic disc appearance	58 (48.3)
Ocular hypertension	34 (28.3)



Elevated IOP with disc suspicion	28 (23.3)
Relevant clinical characteristics	
Family history of glaucoma	29 (24.2)
Diabetes mellitus	24 (20.0)
Hypertension	41 (34.2)

The overall mean CCT was $532.2 \pm 29.5 \mu\text{m}$, while the mean IOP was $17.6 \pm 3.5 \text{ mmHg}$. The observed values demonstrated variability across participants, permitting assessment of the relationship between corneal thickness and measured IOP (Table 2).

Table 2. Central corneal thickness and intraocular pressure in the study population

Parameter	Mean $\pm$ SD	Median (IQR)	Range
Central corneal thickness (μm)	532.2 ± 29.5	532.0 (512.1–551.7)	463–609
Intraocular pressure (mmHg)	17.6 ± 3.5	17.5 (15.2–19.8)	9.9–25.6

When participants were categorized according to CCT, 15 (12.5%) had a CCT $<500 \mu\text{m}$, 72 (60.0%) had a CCT of $500\text{--}549 \mu\text{m}$, and 33 (27.5%) had a CCT $\geq 550 \mu\text{m}$. Mean IOP increased progressively across these CCT categories. The mean IOP was $14.6 \pm 2.2 \text{ mmHg}$ among participants with CCT $<500 \mu\text{m}$, compared with $17.3 \pm 3.2 \text{ mmHg}$ among those with CCT of $500\text{--}549 \mu\text{m}$ and $19.5 \pm 3.3 \text{ mmHg}$ among those with CCT $\geq 550 \mu\text{m}$. The difference in mean IOP across the three CCT categories was statistically significant (one-way ANOVA, $F=13.42$; $p<0.001$) (Table 3).

Table 3. Intraocular pressure according to central corneal thickness category

CCT category	n (%)	Mean CCT (μm)	Mean IOP (mmHg)	SD of IOP
$<500 \mu\text{m}$	15 (12.5)	479.4	14.6	2.2
$500\text{--}549 \mu\text{m}$	72 (60.0)	528.0	17.3	3.2
$\geq 550 \mu\text{m}$	33 (27.5)	565.2	19.5	3.3
Overall	120 (100)	532.2	17.6	3.5

The relationship between CCT and IOP was further evaluated using Pearson's correlation coefficient. A statistically significant positive correlation was observed between CCT and IOP ($r=0.474$, $p<0.001$), indicating that participants with greater central corneal thickness tended to have higher measured IOP. The coefficient of determination (R^2) was 0.225, indicating that approximately 22.5% of the variability in measured IOP was explained by its linear relationship with CCT (Table 4).

Table 4. Correlation between central corneal thickness and intraocular pressure

Analysis	Result
Pearson correlation coefficient (r)	0.474
95% CI for r	0.322–0.599
R^2	0.225
p-value	<0.001



Direction of association	Positive
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Simple linear regression demonstrated a significant positive association between CCT and measured IOP. The regression coefficient for CCT was 0.056 mmHg per μm (95% CI, 0.037–0.074; $p < 0.001$). Thus, within this study population, higher CCT was associated with higher measured IOP (Table 5).

Table 5. Linear regression analysis of the association between central corneal thickness and intraocular pressure

Variable	Regression coefficient (β)	95% CI	p-value
CCT (per 1 μm increase)	0.056 mmHg	0.037–0.074	<0.001
Constant	-11.95	-21.97 to -1.94	0.019
Model R^2	0.225	—	<0.001

Overall, the study demonstrated a statistically significant positive association between central corneal thickness and Goldmann applanation tonometry-measured intraocular pressure. The relationship remained evident when participants were examined according to predefined CCT categories, with progressively higher mean IOP observed across increasing CCT categories.

DISCUSSION

The present study evaluated the relationship between central corneal thickness (CCT) and intraocular pressure (IOP) among 120 patients suspected of glaucoma. The principal finding was a statistically significant positive correlation between CCT and Goldmann applanation tonometry (GAT)-measured IOP ($r=0.474$, $p < 0.001$). Participants with thicker corneas had higher measured IOP, with mean IOP increasing from 14.6 mmHg among those with CCT $< 500 \mu\text{m}$ to 19.5 mmHg among those with CCT $\geq 550 \mu\text{m}$. Linear regression similarly demonstrated a positive association between CCT and measured IOP. These findings support the clinical importance of considering corneal thickness when interpreting tonometric measurements in patients undergoing glaucoma evaluation.

The observed positive association is consistent with the established influence of corneal properties on applanation tonometry. Goldmann applanation tonometry is based on assumptions concerning corneal thickness and biomechanical behavior, and deviations from these assumptions can influence the measured IOP.[6,7] A thicker cornea generally offers greater resistance to applanation and may therefore result in a higher measured pressure, whereas a thinner cornea may contribute to lower measured IOP. Importantly, this does not imply that CCT directly causes an increase in true intraocular pressure; rather, part of the observed association may reflect the influence of corneal characteristics on the tonometric measurement itself.

The magnitude of the association observed in the present study is broadly compatible with findings from Indian populations. In the Chennai Glaucoma Study, Vijaya et al. evaluated more than 6,700 phakic South Indian participants and found a positive association between CCT and IOP. Their analysis indicated that a 100- μm increase in CCT was associated with an approximately 2-mmHg increase in IOP in rural participants and approximately 2.5 mmHg in urban participants.[11] The direction of association therefore agrees closely with the present findings. However, the present study involved a substantially smaller, hospital-based population specifically comprising glaucoma suspects, whereas the Chennai study was population-based and included a broader spectrum of



individuals. Differences in population characteristics, referral patterns and distribution of IOP and CCT may consequently account for differences in the magnitude of the observed relationship.

The findings are also relevant to evidence from tertiary-care ophthalmic practice in North India. Kaushik et al. examined CCT and corneal biomechanical parameters across the glaucoma spectrum, including a substantial group of glaucoma suspects, and evaluated their relationship with GAT-measured IOP.[12] Their findings emphasized that corneal biomechanical properties, particularly corneal resistance factor, may influence GAT measurements and may provide information beyond simple geometric CCT. Thus, while the significant CCT–IOP association observed in the present study is clinically relevant, CCT should not be regarded as a complete surrogate for the biomechanical behavior of the cornea. The present findings are therefore best interpreted as evidence that CCT is an important factor to consider when evaluating a measured IOP rather than as evidence that CCT alone determines the patient's true IOP.

The mean CCT in the present study was $532.2 \pm 29.5 \mu\text{m}$, while the mean IOP was $17.6 \pm 3.5 \text{ mmHg}$. The CCT distribution also demonstrated clinically meaningful variability, with 12.5% of participants having CCT below $500 \mu\text{m}$ and 27.5% having CCT $\geq 550 \mu\text{m}$. This variability is important because patients at the thinner and thicker extremes may be affected differently by interpretation of GAT-derived IOP. The Ocular Hypertension Treatment Study demonstrated that CCT has significance not only because of its potential influence on IOP measurement but also because thinner CCT was independently associated with an increased risk of developing primary open-angle glaucoma among individuals with ocular hypertension.[9,10] Consequently, CCT measurement can provide additional risk information during glaucoma assessment, particularly when IOP values are interpreted alongside optic nerve and visual-field findings.

The clinical relevance of the present findings is therefore greater than simply identifying a statistical correlation. An apparently elevated IOP in a patient with a relatively thick cornea may partly reflect the effect of corneal thickness on applanation measurement, whereas a seemingly normal IOP in a patient with a thin cornea should not automatically be considered reassuring. Such observations are particularly important in glaucoma-suspect patients, in whom clinical decisions are based on the integration of IOP, optic disc morphology, visual-field findings and other risk factors rather than on IOP alone. The present findings consequently support incorporation of CCT assessment into comprehensive glaucoma evaluation.

The study has several strengths. The participants were recruited consecutively from a tertiary-care ophthalmology service, reducing the likelihood of selective enrolment based solely on the investigator's preference. CCT and IOP were assessed using established clinical techniques, and the same participant population was used for correlation and regression analyses. The study also focused specifically on glaucoma suspects, a clinically relevant population in which accurate interpretation of IOP is particularly important.

Several limitations should nevertheless be considered. First, the cross-sectional design permits assessment of association but cannot establish causality or determine whether differences in CCT predict subsequent development or progression of glaucoma. Second, the study was conducted at a single tertiary-care centre and included patients referred for suspected glaucoma; therefore, the findings may not be directly generalizable to the general population. Third, GAT-derived IOP was used as the principal pressure measurement, and the study did not incorporate more comprehensive measures of corneal biomechanics such as corneal hysteresis or corneal resistance factor. The observed association may consequently reflect both the influence of CCT on tonometry and other



unmeasured corneal characteristics. Finally, the sample size was modest compared with large population-based studies, limiting the precision of subgroup analyses.

Future studies involving larger, multicentre populations could evaluate the relationship between CCT, IOP and other corneal biomechanical parameters in greater detail. Longitudinal studies would also be valuable to determine whether CCT contributes independently to the subsequent development or progression of glaucoma after accounting for established risk factors. Such research could help refine individualized interpretation of IOP and improve risk stratification among glaucoma suspects.

CONCLUSION

This study demonstrated a significant positive correlation between central corneal thickness and Goldmann applanation tonometry-measured intraocular pressure among patients suspected of glaucoma. Participants with thicker corneas had higher measured IOP, and the association remained statistically significant across CCT categories and on linear regression analysis. These findings emphasize the importance of considering CCT when interpreting IOP in patients undergoing glaucoma evaluation, particularly because variations in corneal thickness may influence the tonometric measurement and may also contribute to overall glaucoma risk assessment. CCT should therefore be interpreted together with IOP, optic nerve findings, visual-field assessment and other relevant clinical risk factors rather than being used as an isolated determinant of diagnosis or treatment. Further multicentre and longitudinal studies incorporating additional measures of corneal biomechanics are warranted to clarify the independent contribution of CCT to glaucoma risk and to improve individualized interpretation of IOP measurements.

DECLARATIONS

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Conflict of Interest: NIL

Consent: Informed consent was specified as part of the study methodology; however, documentation details were not provided.

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