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Original Research Article

A Cross-Sectional Clinical Study to Evaluate the Correlation Between Intraocular Pressure and Central Corneal Thickness in Glaucoma Suspects

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Abstract:

Background: Glaucoma is one of the leading causes of irreversible blindness and is largely affected by intraocular pressure (IOP). Central corneal thickness (CCT) is also used to estimate IOP. Accurate measurement of CCT and its correlation with IOP is important for proper diagnosis and management of glaucoma suspect patients.

Aim: To determine the correlation between IOP and CCT in glaucoma suspects and patients at risk for developing glaucoma.

Methods: Eighty patients older than 40 years who attended the Ophthalmology Department and had IOP measured with Goldmann Applanation Tonometry and CCT recorded by Pachymetry were included in this cross-sectional clinical study. A standardized linear correction factor corrected IOP values and statistical analysis of data utilized Pearson Correlation Coefficient t-test, ANOVA.

Results: There was a statistically significant difference ($p < 0.0001$) between the average IOP and thickness of corneas across the POAG (mean ± SD: 25.28 mmHg ± 6.52, 548.1 µm ± 72.94), PACG (mean ± SD: 23.2 mmHg ± 8.6, 558.9 µm ± 75.25), OHT (mean ± SD: 25.6 mmHg ± 5.42, 566.4 µm ± 74.65), and suspect glaucoma groups (mean ± SD: 20.75 mmHg ± 5.29, 556.2 µm ± 79.03). The highest IOP at 28.15 mmHg is seen in those with thin corneas (< 540 µm) and the lowest at 23.48 mmHg in normal thickness corneas (540–580 mm) and higher at 24.6 mmHg in thick corneas (>580 mm), indicating a statistically significant relationship between CCT and IOP.

Conclusion: In glaucoma suspects, thinner corneas correlate with higher corrected IOP values, while thicker corneas often produce IOP overestimation. Taking CCT into account increases the accuracy of diagnosing glaucoma suspects and is helpful for assigning them risk stratification.

Keywords: Glaucoma, Intraocular Pressure, Central Corneal Thickness, Goldmann Tonometry, Ocular Hypertension.

Introduction

Glaucoma ranks among the most common irreversible blindness causes in the adult population worldwide, and it is still considered a major public health concern because of its asymptomatic beginning, chronicity, and progressive nature. Glaucoma can be described as a chronic, bilateral, and mostly asymmetric optic neuropathy, associated with progressive loss of adult retinal ganglion cells and optic nerve fibers, and typically resulting in characteristic visual field defects. This is a disease that often progresses silently, with symptoms appearing only long after substantial optic nerve damage has taken place. Therefore, due to this insidious natural history, early detection and the identification of individuals at risk are of utmost importance in clinical practice.

Among the many factors implicated in the pathophysiology of glaucoma, intraocular pressure remains the most important and only modifiable risk factor. For a long period, IOP has been identified to be injurious to the structural and functional integrity of the optic nerve head by causing its mechanical compression, disturbance of axoplasmic flow, and ischemic damage to the axons of the retinal ganglion cells [1]. However, this does not preclude the occurrence of glaucomatous optic neuropathy in persons with statistically normal IOPs. At the same time, the contribution of IOP as a principal driver in both the initiation and progression of glaucomatous damage is not minimized. For these reasons, precise measurement and interpretation of IOP are critical components in the screening, diagnosis, and management of glaucoma suspects and confirmed cases.

The epidemiology of glaucoma varies significantly among different populations, depending on demographic, genetic, and environmental factors. POAG, the most common form of glaucoma worldwide, is found most frequently among African populations, while PACG dominates in large parts of Asia. Given that a large section of the global population resides in Asia, this part of the world bears a disproportionately large share of the burden of glaucoma. India is a major contributor to world blindness statistics; according to data from the World Health Organization, the national prevalence of blindness stands at 1% of the total population. Population-based studies within India have provided more detailed information about the burden of glaucoma across various regions and communities [2].

The Vellore Eye Survey reported the prevalence of POAG as 0.41% in the age group 30–60 years, whereas the Andhra Pradesh Eye Diseases Study estimated a significantly higher prevalence of 2.56% among urban dwellers aged 40 years and above. Likewise, results from the Aravind Comprehensive Eye Survey established the prevalence of POAG as 1.2% [3]. These epidemiological studies put together emphasize that POAG is an important public health problem in India, and the disease often goes undetected until it has reached an advanced stage. Early detection of glaucoma suspects and those at risk therefore is an important preventive strategy to reduce the national burden of irreversible blindness.

While elevated IOP represents an established major risk factor for POAG [4], there is growing awareness that accuracy in the measurement of IOP may itself be liable to be affected by a range of ocular biometric parameters; of these, CCT has emerged as a figure of particular significance. The gold standard for IOP measurement, Goldmann applanation tonometry, is based on its original calibration against an average thickness for the cornea of about 520 µm. Deviations from this value may carry significant inaccuracies: IOP tends to be underestimated in eyes with thinner corneas and overestimated in those where the cornea is thicker. Such errors have significant resonance in clinical decision-making and epidemiological evaluations, respectively, since misclassification of IOP may result in under-recognition of subjects at risk for glaucomatous optic neuropathy [5].

Recent studies have pointed out that CCT itself may be associated with the susceptibility of the optic nerve to damage and thus the need to consider CCT when interpreting IOP values in glaucoma suspects. For example, thinner corneas have been related not only to IOP underestimation but also to inherently higher risk of developing glaucomatous damage independent of IOP measurement errors. On the other hand, thicker corneas may mask high IOP readings and delay needed interventions. In this respect, understanding the relationship between IOP and CCT is important to ensure appropriate clinical assessment, correct risk stratification, and timely management of patients [6].

Given these clinical implications, analysis of the relationship between intraocular pressure and central corneal thickness becomes particularly pertinent in glaucoma suspects, a group often identified based on borderline or asymmetrically elevated IOP, suspicious optic disc appearance, or visual field abnormalities. Accurate assessment in such cases is extremely important in deciding whether such individuals should be monitored, treated, or reassessed using alternative diagnostic modalities.

The present cross-sectional clinical study, therefore, determines the correlation between IOP and CCT among glaucoma suspects. In evaluating these parameters and their relationship in a clinical population, this work aims to contribute toward further refinement of diagnostic precision, enhanced risk stratification, and an increasingly individualized approach to clinical decision-making in the care of glaucoma patients. Further exploration of the CCT-IOP relationship will not only improve the assessment of glaucoma suspects but may also contribute to the prevention of avoidable blindness by enabling the earliest possible and most accurate diagnosis of the glaucomatous disease.

Materials and Methods

Study Design: This study was designed as a cross-sectional clinical study aimed at evaluating the correlation between intraocular pressure (IOP) and central corneal thickness (CCT) among glaucoma suspects and patients with glaucoma risk features.

Study Area: The study was conducted in the Department of Ophthalmology, Bhagwan Mahaveer Institute of Medical Sciences (BMIMS), Pawapuri, Nalanda, Bihar, India.

Study Duration: The study was carried out over a period of nine months from August 2023 to April 2024.

Sample Size: A total of 80 participants were included in the study.

Study Population: The study population consisted of patients attending the Ophthalmology outpatient department during the study period who were diagnosed with glaucoma cases or glaucoma suspects based on ocular examination findings.

Inclusion Criteria

- Patients aged **more** than 40 years.
- Patients diagnosed as glaucoma or glaucoma suspects, based on:

  - Elevated intraocular pressure,
  - Optic nerve head appearance suggestive of glaucoma,
  - Visual field defects are indicative of glaucoma.

- Patients with open angles and narrow/closed angles as classified by gonioscopy.

Exclusion Criteria

- Patients aged below 40 years.
- Patients with secondary glaucoma, including:
  - Traumatic glaucoma,
  - Neovascular glaucoma,
  - Uveitic glaucoma,
  - Lens-induced glaucoma.
- Patients with a history of ocular trauma or prior ocular surgery affecting corneal biomechanics.
- Patients with corneal pathologies (scarring, edema, keratoconus) that could alter CCT measurements.

Data Collection: Data collection was carried out among patients attending the Ophthalmology outpatient department during the study period. After obtaining relevant history regarding any previous ocular trauma, ocular surgery, or family history of glaucoma, each participant underwent a complete ophthalmic evaluation. Slit-lamp bio-microscopy was performed to assess the conjunctiva, cornea, sclera, iris, pupil, anterior chamber, and lens. Intraocular pressure was measured using the Goldmann Applanation Tonometer, and the mean of three readings was considered for analysis. Gonioscopy was performed using a four-mirror contact goniolens to evaluate the anterior chamber angle status, followed by posterior segment evaluation with a 90D lens to assess the optic nerve head for glaucomatous changes. Central corneal thickness was measured using Quantel Compact pachymetry, and three consecutive readings were averaged. Based on IOP levels, optic nerve findings, gonioscopy results, and visual field assessment, the subjects were categorized as primary open-angle glaucoma, primary angle-closure glaucoma, ocular hypertensives, or glaucoma suspects.

IOP Correction Based on CCT: A linear correction formula proposed by Shih CY, Graff Zivin JS et al. [7] was applied, wherein 2.5 mmHg was added or subtracted for every 50 μm deviation from the reference CCT value of 545 μm.

$$\text{Corrected IOP} = \text{Measured IOP} - \left(\frac{\text{CCT} - 545}{50} \times 2.5\right) \text{mmHg}$$

Explanation:

- For every 50 μm difference from 545 μm, adjust IOP by 2.5 mmHg.
- If the cornea is thicker than 545 μm, subtract the adjustment (because measured IOP is overestimated).
- If the cornea is thinner than 545 μm, add the adjustment (because measured IOP is underestimated).

Example Table:

Corneal Thickness (μm)	Measured IOP (mmHg)	Corrected IOP (mmHg)
495 (Thin)	24	26.5
545 (Normal)	24	24
595 (Thick)	24	21.5

Procedure: After enrollment, each participant underwent a standardized sequence of examinations beginning with history-taking, followed by a thorough slit-lamp evaluation of the anterior segment. Intraocular pressure was measured using the Goldmann Applanation Tonometer under standard conditions. Gonioscopic evaluation was performed to classify the angle configuration, and posterior segment evaluation was carried out using a 90D lens to identify glaucomatous optic nerve changes. Central corneal thickness was recorded using Quantel Compact pachymetry. The corrected IOP was calculated using the Shih CY, Graff Zivin JS et al. linear correction formula, which adjusts measured IOP based on deviations of CCT from the reference value of 545 μm. All collected measurements and clinical findings were documented systematically for statistical analysis.

Statistical Analysis: The collected data were compiled and analyzed using appropriate statistical software such as SPSS (version 27). Descriptive statistics, including mean, standard deviation, and frequency distributions, were used to summarize demographic characteristics and clinical parameters of the study population. The correlation between intraocular pressure (both measured and corrected) and central corneal thickness was assessed using the Pearson correlation coefficient. Comparative analysis among diagnostic groups such as POAG, PACG, OHT, and glaucoma suspects was conducted using independent t-tests for two-group comparisons and one-way ANOVA for multiple groups. A p-value of less than 0.05 was considered statistically significant for all statistical tests."

Result

Table 1 compares intraocular pressure (IOP) and central corneal thickness (CCT) across four study groups (N = 80). The POAG group (n = 38) showed a mean IOP of 25.28 mmHg and mean CCT of 548.1 µm, while the PACG group (n = 10) had a slightly lower mean IOP of 23.2 mmHg and a higher CCT of 558.9 µm. The OHT group (n = 20) demonstrated the highest CCT (566.4 µm) along with a mean IOP of 25.6 mmHg. In comparison, the GS group (n = 12) had the lowest mean IOP at 20.75 mmHg but maintained a relatively high CCT of 556.2 µm. Across all groups, the T test values were high, with p < 0.0001, indicating statistically significant differences between measured parameters.

Table 1: Comparison of CCT and IOP in Various Study Groups (N = 80)

Group	N	IOP (mmHg) Mean	SD	CCT (µm) Mean	SD	T test	P value
POAG	38	25.28	4.1	548.1	20.85	15.4	<0.0001
PACG	10	23.2	3.7	558.9	19.4	9.8	<0.0001
OHT	20	25.6	4.9	566.4	24.95	10.5	<0.0001
GS	12	20.75	2.58	556.2	14.3	11.3	<0.0001

Table 2 presents the comparison of central corneal thickness (CCT) and corrected intraocular pressure (corrected IOP) among the four study groups (N = 80). The POAG group (n = 38) showed a corrected IOP of 25.12 mmHg with a mean CCT of 548.1 µm, while the PACG group (n = 10) demonstrated a slightly lower corrected IOP of 22.5 mmHg and a higher CCT of 558.9 µm. The OHT group (n = 20) had the highest CCT (566.4 µm) with a corrected IOP of 24.53 mmHg, and the GS group (n = 12) recorded the lowest corrected IOP at 20.19 mmHg with a CCT of 556.2 µm. In all groups, the T test values were high, with p < 0.0001, indicating statistically significant differences between the measured parameters.

Table 2: Comparison of CCT and Corrected IOP in Various Study Groups (N = 80)

Group	N	Corrected IOP (mmHg) Mean	SD (estimated*)	CCT (µm) Mean	SD	T test	P value
POAG	38	**25.12**	4.10*	548.1	20.85	14.9	<0.0001
PACG	10	**22.5**	3.70*	558.9	19.4	9.5	<0.0001
OHT	20	**24.53**	4.90*	566.4	24.95	10.1	<0.0001
GS	12	**20.19**	2.58*	556.2	14.3	11.1	<0.0001

Table 3 describes the relationship between central corneal thickness (CCT) categories and corrected intraocular pressure (IOP) among 80 participants. Patients with thin corneas (<540 µm; n = 18) had the highest mean corrected IOP at 28.15 mmHg, with values ranging from 17.2 to 37.1 mmHg. Those with normal corneal thickness (540–580 µm; n = 50) showed a lower mean corrected IOP of 23.48 mmHg (range: 16.4–32.5 mmHg). In contrast, individuals with thick corneas (>580 µm; n = 12) had a mean corrected IOP of 24.6 mmHg, with values between 16.8 and 31 mmHg. Overall, thinner corneas were associated with higher corrected IOP values, while normal and thicker corneas showed comparatively lower pressures.

Table 3: Relationship Between Different CCT Groups and Corrected IOP (N = 80)

CCT Group	N	Corrected IOP (mmHg) Mean	SD	Min	Max
<540 µm (Thin)	18	28.15	5.62	17.2	37.1
540–580 µm (Normal)	50	23.48	3.7	16.4	32.5
>580 µm (Thick)	12	24.6	3.88	16.8	31

Discussion

The current cross-sectional study also demonstrated a significant association of CCT with IOP among glaucoma suspects and patients with established glaucoma. The mean IOP in the POAG and OHT groups was the highest, at 25.44±4.20 mmHg and 25.52±5.03 mmHg, respectively. In contrast, the mean IOP in the PACG patients was slightly lower, at 23.08±3.84 mmHg, while that of the GS patients was the lowest, at 20.8±2.62 mmHg. This agrees with an earlier report by Copt et al. (1999) [8], wherein POAG and OHT patients showed high IOP, with normal-tension glaucoma and suspects having low pressures. In our series, the mean CCT values were 547.75±21.23 µm in POAG, 559.38±19.91 µm in PACG, 567.12±25.49 µm in OHT, and 556.80±14.63 µm in GS. The relatively thicker corneas noticed in OHT in comparison to the other groups agree with Wu et al. (2000) and Emara et al. (1999), who noted that ocular hypertensive eyes had thicker corneas and drew attention to the importance of CCT as a factor influencing the measurement of IOP [9,10]. This brings into focus the fact that CCT should always be considered when interpreting tonometric readings, as thick corneas can artificially raise the measured IOP."

When IOP was corrected for CCT using the linear regression formula (2.5 mmHg per 50 µm deviation from 545 µm), the trends remained largely consistent. Corrected IOP in POAG and PACG remained elevated, suggesting that the higher pressures observed were not solely an artifact of corneal thickness but reflect genuinely elevated physiologic IOP. In OHT, corrected IOP decreased more markedly, reflecting the contribution of thicker corneas to the apparent elevation in uncorrected readings. However, the corrected values still remained elevated above normal ranges, supporting the clinical diagnosis of ocular hypertension. Similarly, Wei et al. (2014) demonstrated that while correction for corneal thickness reduces IOP in juvenile populations, those with inherently high pressures continue to exhibit elevated IOP even after adjustment [11]. In contrast, GS demonstrated minimal differences between measured and corrected IOP, indicating limited influence of CCT on IOP in eyes without glaucomatous damage. The findings agree with the observation that the effect of CCT is most pronounced in pathological or borderline cases and not much in the normal eye [12].

Stratification of the eyes according to CCT into thin (<540 µm), normal (540-580 µm), and thick (>580 µm) revealed a clear pattern. The eyes with thin corneas had the highest corrected IOP, with averages in the upper 20s, while normal-thickness eyes had corrected pressures lower in the low- to mid-20s. Notably, thick corneas, despite the presence of an elevated measured IOP, showed corrected pressures that were intermediate, lower than in thin but above normal ranges in OHT patients. This pattern would be consistent with studies by Gazzard et al. (2003), which underlined the independent risk represented by the thin cornea to progression of glaucoma after adjusting for corneal biomechanics [13] Our data thus reinforces the concept that thin CCT can be a marker for high true IOP and heightened susceptibility to glaucomatous optic neuropathy, while thick corneas mainly influence the tonometric reading without being fully able to explain high IOP in hypertensive eyes.

Comparisons with previous epidemiological studies reveal consistency and some regional variations. The prevalence of POAG as the most common glaucoma subtype in our cohort agrees with reports from Indian populations by Jacob et al. (1998) and Vijaya et al. (2005), reflecting the generalizability of our findings [2,3]. As for CCT, our values are within the range reported by Copt et al. (1999) [8] and Wu et al. (2000) [9]; minor discrepancies may reflect demographic and ethnic differences. For their part, Emara et al. (1999) [10] reported similarly thicker corneas in OHT compared to POAG, corroborating the relationship between CCT and apparent IOP. Furthermore, our finding that thin corneas translate into higher corrected IOP agrees with Shih et al. (2004) [12], who concluded that CCT is not just a measurement artifact but a predictive risk factor in glaucoma.

Our study also points to the clinical importance of CCT in the management of glaucoma. By showing that corrected IOP is still high in POAG and OHT despite allowance for corneal thickness, we reinforce the use of corrected values for risk stratification and treatment indications. McMonnies 2008 [6] said that CCT has been ignored due to misclassification of risk, which could lead to the undertreatment of patients with thin corneas and overtreatment of patients with thick corneas. This is very important in PACG, in which our mean CCT was 559.38±19.91 µm, slightly higher than in POAG; however, corrected IOP was also elevated, thereby indicating a real physiologic pressure rise rather than a corneal artifact. This finding is consistent with a report by Gazzard et al. 2003 [13].

Taken together, our findings confirm the strong influence of CCT on IOP measurements and clinical interpretation of the glaucoma risk. Thin corneas are invariably associated with higher corrected IOP, reinforcing the fact that a thin cornea could be an independent risk factor for the progression of glaucoma. Thick corneas, though increasing the measured IOP, fail to explain the cause of high pressures in OHT patients, raising the need for individual evaluation. Overall, the correlations of CCT and IOP in our cohort agreed well with previous reports, reinforcing the concept that correct evaluation of glaucoma needs consideration of corneal thickness in addition to tonometry and clinical findings.

Conclusion

This research indicates that there is a consistent and direct link between Central Corneal Thickness (CCT) and Intraocular Pressure (IOP) readings for all of the suspect groups for Glaucoma. There is an increased pressure adjustment for those individuals who have a thinner cornea while there is lower pressure adjustment for those individuals who have a thicker cornea. For all types of glaucoma, Primary Open Angle Glaucoma (POAG), Primary Angle Closure Glaucoma (PACG), Ocular Hypertensive (OH) and Glaucoma Suspects (GS) in addition to uncorrected and corrected IOP readings a Direct relationship or systematic variation can be noted between pressure readings and CCT; this suggests that biomechanical properties of the cornea influence tonometric readings. The Overall trends noted in the distribution of the corrected IOP readings for thin, normal and thick corneas highlighted the tendency for underestimating the true IOP in patients with thinner corneas and overestimating the IOP in thicker corneas. The overall findings highlight the importance of including CCT when interpreting IOP to improve the accuracy of the diagnosis and risk classification for those individuals evaluated for glaucoma.

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