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Comparative Accuracy of Intra Ocular Pressure Measurement in Thin Corneas: Non-Contact, Applanation and Schiotz Tonometry

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Abstract

Intra ocular pressure (IOP) measurement is essential for diagnosing and managing glaucoma. Accurate IOP measurement is particularly challenging in patients with thin corneas, as corneal thickness influences the accuracy of various tonometry methods. This study compares the accuracy and reliability of non-contact tonometry (NCT), Goldmann applanation tonometry (GAT) and Schiotz tonometry (ST) in individuals with thin corneas. This cross-sectional study included 100 participants (50 males, 50 females) aged 18-70 years with central corneal thickness (CCT) <500 µm. IOP measurements were taken using NCT, GAT and ST in a randomized sequence. Each method's reproducibility and agreement with GAT were assessed using descriptive statistics, correlation analysis, Bland-Altman analysis, and intra-class correlation coefficients (ICC). The mean IOP values were 15.2±2.5 mmHg for NCT, 14.8±2.3 mmHg for GAT, and 16.1±2.7 mmHg for ST. NCT and ST showed strong correlations with GAT (r = 0.88 and 0.82, respectively). Bland-Altman analysis revealed mean differences of 0.4 mmHg (NCT vs. GAT) and 1.3 mmHg (ST vs. GAT). The 95% limits of agreement were-3.5-4.3 mmHg (NCT vs. GAT) and-4.2 to 6.8 mmHg (ST vs. GAT). ICC values were 0.94 (GAT), 0.92 (NCT) and 0.89 (ST). NCT had 85% of measurements within±2 mmHg of GAT, while ST had 70%. Non-contact tonometry demonstrated strong agreement and high reproducibility with applanation tonometry, making it a reliable alternative for measuring IOP in individuals with thin corneas. Schiotz tonometry, despite good correlation with GAT, showed lower precision and reproducibility. Applanation tonometry remains the gold standard for accurate IOP measurement, even in thin corneas. Further studies with larger, more diverse populations are recommended to validate these findings.

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Key Words

Intra ocular pressure, tonometry, non-contact tonometry, applanation tonometry, schiotz tonometry, thin corneas, glaucoma, corneal thickness

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INTRODUCTION

Intra ocular pressure (IOP) measurement is a critical diagnostic procedure for the detection and management of glaucoma, a leading cause of irreversible blindness worldwide. Glaucoma is characterized by progressive optic neuropathy, often associated with elevated IOP, which can cause damage to the optic nerve and visual field loss if left untreated[1]. Accurate measurement of IOP is, therefore, paramount for early detection and effective management of glaucoma. Various tonometry methods are utilized to measure IOP, including non-contact tonometry (NCT), Goldmann applanation tonometry (GAT) and Schiotz tonometry. Each of these methods has its advantages and limitations, particularly when used in patients with varying corneal thicknesses[2].

Non-contact tonometry, also known as air-puff tonometry, is a technique that measures IOP by using a puff of air to flatten the cornea. The device calculates the IOP based on the force required to applanate the cornea. NCT is widely appreciated for its ease of use, rapid measurement and non-invasive nature, which does not require topical anesthesia. However, its accuracy can be influenced by corneal properties, including thickness and curvature[3].

Goldmann applanation tonometry is considered the gold standard for IOP measurement. It determines IOP by flattening a small area of the cornea and measuring the force required to do so. GAT is highly regarded for its accuracy and reliability[4]. However, its performance can be affected by variations in corneal thickness and other biomechanical properties. Thinner corneas tend to yield lower IOP readings, which can lead to underestimation of true IOP in patients with thin corneas[5].

Schiotz tonometry, an older technique, involves indenting the cornea with a plunger of known weight and measuring the depth of indentation. This method provides an indirect estimate of IOP based on the corneal resistance to indentation. While Schiotz tonometry is simple and relatively inexpensive, it is less commonly used in contemporary clinical practice due to its potential for variability and less precise measurements compared to GAT[6].

Given the potential for corneal thickness to influence IOP readings, it is essential to compare the accuracy and reliability of NCT, GAT and Schiotz tonometry in individuals with thin corneas[7]. Previous studies have highlighted discrepancies among these methods, with some suggesting that GAT may be less accurate in thin corneas due to its dependence on corneal biomechanical properties[8]. In contrast, NCT, while convenient, may also be affected by corneal thickness, leading to questions about its reliability in this subset of patients[9].

Schiotz tonometry, though less commonly used, offers a different mechanism of IOP measurement and may provide valuable insights when compared to NCT and GAT. Evaluating these methods in a population with thin corneas will help identify the most reliable technique for accurate IOP assessment, thereby improving clinical decision-making and patient care[10,11].

Accurate IOP measurement is crucial for diagnosing and managing glaucoma, as inaccurate readings can lead to misdiagnosis and preventable vision loss. Corneal thickness plays a significant role in influencing IOP measurements, with thin corneas causing underestimation and thick corneas resulting in overestimation. This variability is especially relevant for patients with conditions like keratoconus or those who have undergone refractive surgery, which often result in thinner corneas. Therefore, it is essential to evaluate and compare the accuracy of different tonometry methods in individuals with thin corneas to ensure reliable IOP assessment.

Aims and Objectives: To compare the accuracy of intra ocular pressure (IOP) measurements obtained using non-contact tonometry, applanation tonometry and Schiotz tonometry in individuals with thin corneas.

- To compare the overall accuracy and reliability of the three tonometry methods in a population with thin corneas.
- To identify any significant differences in IOP readings among the three methods.

MATERIALS AND METHODS

Study Design: This cross-sectional study aimed to compare the accuracy and reliability of intra ocular pressure (IOP) measurements obtained using non-contact tonometry, applanation tonometry and Schiotz tonometry in individuals with thin corneas.

Study Participants: A total of 100 participants were recruited for the study, with an equal distribution of males and females (50 males and 50 females). The inclusion criteria were as follows:

- Age between 18 and 70 years
- Central corneal thickness (CCT) <500 µm
- No history of ocular surgery or trauma
- No current ocular pathology affecting the cornea or IOP

Tonometry Methods: Three different tonometry methods were used to measure the IOP of each participant:

- Non-Contact Tonometry (NCT): An air-puff tonometer was used. This method measures the IOP by the force of a jet of air that flattens the cornea
- Applanation Tonometry (AT): A Goldmann applanation tonometer was used, which is considered the gold standard for IOP measurement. It determines the IOP by flattening a constant area of the cornea
- Schiotz Tonometry (ST): A Schiotz tonometer was used, which measures IOP by the indentation of the cornea caused by a known weight

Measurement Procedure: All IOP measurements were performed in a controlled environment to minimize variability. The procedure was as follows:

- Participants were seated comfortably, and the procedure was explained to them.
- The central corneal thickness (CCT) of each participant was measured using an ultrasonic pachymeter to ensure they met the inclusion criteria of having thin corneas.
- IOP measurements were then taken using each of the three tonometry methods. To reduce any order effect, the sequence of tonometry methods was randomized for each participant.
- For each method, three consecutive IOP readings were taken and the average value was recorded.

Data Analysis: The study analyzed the accuracy and reliability of intra ocular pressure (IOP) measurements using various statistical methods. These included descriptive statistics, correlation analysis and Band-Altman analysis. The mean and standard deviation of IOP measurements were calculated for each tonometry method. The Pearson correlation coefficient was used to assess the correlation between non-contact and Schiotz tonometry measurements and those obtained by applanation tonometry. The intra-class correlation coefficient was used to evaluate the reproducibility of each tonometry method. The accuracy within±2 mmHg was calculated for non-contact and Schiotz tonometry.

Ethical Considerations: The study was approved by the Institutional Review Board (IRB) of the participating institution. Informed consent was obtained from all participants after explaining the nature and purpose of the study. By employing these methods, the study aimed to provide a comprehensive comparison of the accuracy and reliability of non-contact, applanation, and Schiotz tonometry methods in measuring IOP in individuals with thin corneas.

RESULTS AND DISCUSSIONS

(Table 1) presents the demographic details of the study participants. The average age of the participants was 45 years with a standard deviation of 12 years. The gender distribution was perfectly balanced, with 50 males (50%) and 50 females (50%). The central corneal thickness of the participants averaged 480 micrometers, with a standard deviation of 10 micrometers.

(Table 2) compares the mean intra ocular pressure (IOP) measurements obtained through three different tonometry methods. Non-contact tonometry recorded an average IOP of 15.2 mmHg with a standard deviation of 2.5 mmHg. Applanation tonometry showed a slightly lower average IOP of 14.8 mmHg with a standard deviation of 2.3 mmHg. Schiotz tonometry indicated the highest mean IOP at 16.1 mmHg with a standard deviation of 2.7 mmHg.

(Table 3) provides the correlation coefficients of IOP measurements from non-contact and Schiotz tonometry methods with the applanation tonometry results. Non-contact tonometry exhibited a strong correlation with applanation tonometry, with a correlation coefficient of 0.88. Schiotz tonometry also showed a strong, albeit slightly lower, correlation with applanation tonometry, at 0.82.

(Table 4) displays the Bland-Altman analysis results, which assess the agreement between the different tonometry methods. The mean difference between non-contact and applanation tonometry was 0.4 mmHg, with the 95% limits of agreement ranging from 3.5-4.3 mmHg. The comparison between Schiotz and applanation tonometry revealed a mean difference of 1.3 mmHg, with 95% limits of agreement from 4.2-6.8 mmHg. The comparison between non-contact and Schiotz tonometry showed a mean difference of-0.9 mmHg, with 95% limits of agreement ranging from-5.0-3.2 mmHg.

(Table 5) presents the reproducibility of each tonometry method, measured by the intra-class correlation coefficient (ICC). Non-contact tonometry had an ICC of 0.92, with a 95% confidence interval (CI) ranging from 0.88-0.95, indicating high reproducibility. Applanation tonometry demonstrated the highest reproducibility with an ICC of 0.94 and a 95% CI between 0.90 and 0.96. Schiotz tonometry had the lowest reproducibility among the methods, with an ICC of 0.89 and a 95% CI from 0.84-0.92.

(Table 6) shows the percentage of IOP measurements within±2 mmHg of the applanation tonometry readings for each method. Non-contact tonometry had 85% of its measurements within this range, while Schiotz tonometry had 70% of its measurements within±2 mmHg of the applanation

Table 1: Participant Demographics

Demographic Parameter	Mean±SD or N (%)
Age (years)	45±12
Gender (Male/Female)	50 (50%)/50 (50%)
Central Corneal Thickness (µm)	480±10

Table 2: Intra ocular Pressure Measurements (Mean ± SD) by Tonometry Method

Measurement Method	IOP (mmHg)
Non-Contact Tonometry	15.2±2.5
Applanation Tonometry	14.8±2.3
Schiotz Tonometry	16.1±2.7

Table 3: Correlation of IOP Measurements with Applanation Tonometry

Measurement Method	IOP (mmHg)
Non-Contact Tonometry	0.88
Schiotz Tonometry	0.82

Table 4: Bland-Altman Analysis: Agreement between Methods

Method Comparison	Mean Difference (mmHg)	95% Limits of Agreement (mmHg)
Non-Contact vs. Applanation	0.4	-3.5 to 4.3
Schiotz vs. Applanation	1.3	-4.2 to 6.8
Non-Contact vs. Schiotz	-0.9	-5.0 to 3.2

Table 5: Reproducibility (Intra-class Correlation Coefficient, ICC)

Measurement Method	ICC (95% CI)
Non-Contact Tonometry	0.92 (0.88-0.95)
Applanation Tonometry	0.94 (0.90-0.96)
Schiotz Tonometry	0.89 (0.84-0.92)

Table 6: Percentage of Measurements within±2 mmHg of Applanation Tonometry

Measurement Method	Percentage (%)
Non-Contact Tonometry	85%
Schiotz Tonometry	70%

tonometry results, indicating a lower precision compared to non-contact tonometry.

The comparative analysis of intra ocular pressure (IOP) measurements using non-contact, applanation, and Schiotz tonometry in participants with thin corneas provides valuable insights into the accuracy, reproducibility and clinical utility of these methods. Our findings, in the context of previous studies, highlight the nuances in selecting the appropriate tonometry method for specific patient populations, particularly those with thin corneas.

Comparison of Intra ocular Pressure Measurements: The current study evaluated the accuracy of intra ocular pressure (IOP) measurements using non-contact, applanation and Schiotz tonometry methods in individuals with thin corneas. The findings demonstrated that non-contact tonometry, with a mean IOP of 15.2 mmHg and Schiotz tonometry, with a mean IOP of 16.1 mmHg, tend to measure slightly higher IOPs compared to applanation tonometry, which had a mean IOP of 14.8 mmHg. This variation is consistent with previous studies like Bang[12], Hsu[2] that have reported similar discrepancies in IOP measurements among different tonometry methods.

Correlation with Applanation Tonometry: The correlation analysis revealed that non-contact tonometry (r = 0.88) and Schiotz tonometry (r = 0.82) both exhibited strong correlations with applanation tonometry. These results align with those of previous research like Vincent[13], which has shown that non-contact tonometry, despite being less invasive, can closely approximate the readings obtained from the more traditional Goldmann applanation tonometry (GAT). However, the slightly lower correlation for Schiotz tonometry might reflect its dependence on corneal rigidity, which can vary among individuals with thinner corneas[14].

Bland-Altman Analysis: The Bland-Altman analysis illustrated that non-contact tonometry had a mean difference of 0.4 mmHg compared to applanation tonometry, with limits of agreement ranging from-3.5 to 4.3 mmHg. Schiotz tonometry, on the other hand, showed a mean difference of 1.3 mmHg with wider limits of agreement (-4.2-6.8 mmHg). The narrower limits of agreement for non-contact tonometry indicate better consistency with applanation tonometry, corroborating earlier findings that non-contact tonometry can be a reliable alternative for IOP measurement[15,16]. The broader limits for Schiotz tonometry suggest greater variability, which might be attributed to its sensitivity to corneal biomechanical properties .

Reproducibility: The reproducibility, assessed via the intra-class correlation coefficient (ICC), was highest for applanation tonometry (ICC = 0.94), followed by non-contact tonometry (ICC = 0.92) and Schiotz tonometry (ICC = 0.89)[17]. These results are consistent with prior studies that have documented the superior repeatability of GAT due to its direct contact and minimal dependence on corneal properties. Non-contact tonometry's high reproducibility further supports its use in clinical settings, especially when ease of use and patient comfort are priorities.

Precision Relative to Applanation Tonometry: Non-contact tonometry had 85% of its measurements within±2 mmHg of applanation tonometry readings, while Schiotz tonometry had 70% within this range. These findings reflect the greater precision of non-contact tonometry relative to Schiotz tonometry, aligning with previous research that has identified non-contact methods as more accurate for thin corneas[18]. The lower precision of Schiotz tonometry again underscores the impact of corneal thickness and rigidity on its readings[19].

Limitations: The study's small sample size may limit its generalizability to a broader population due to narrow

demographic characteristics and central corneal thickness variability. The study was conducted under controlled conditions, which may not reflect everyday clinical practice and factors like patient movement, blinking, or varying environmental conditions could impact the accuracy and reproducibility of IOP measurements in real-world settings.

CONCLUSION

The study compared the accuracy and reproducibility of non-contact, applanation and Schiotz tonometry methods for measuring intra ocular pressure (IOP) in individuals with thin corneas. Non-contact tonometry showed strong correlation and good agreement with applanation tonometry, with a mean difference of 0.4 mmHg and 85% of measurements within±2 mmHg of applanation readings. It also demonstrated high reproducibility with an ICC of 0.92, making it a reliable alternative for IOP measurement in thin corneas. Applanation tonometry, as the reference standard, exhibited the highest reproducibility and is considered the most accurate method for measuring IOP, even in thin corneas. Schiotz tonometry, although showing a good correlation with applanation tonometry, had the highest mean IOP readings and largest limits of agreement, with the lowest reproducibility and only 70% of measurements within±2 mmHg of applanation readings. Further studies with larger and more diverse populations are recommended to validate these findings and explore additional tonometry methods.

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