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The Age-Related Impact on Applanation vs. Schiotz IOP Discrepancy: Implications for Community Glaucoma Screening

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ABSTRACT:

Glaucoma is a major cause of irreversible blindness, and although it is not defined solely by intraocular pressure (IOP), IOP remains the most important modifiable risk factor, making accurate tonometry critical for community screening in aging populations. This prospective, observational, comparative study assessed age-related agreement between Goldmann applanation tonometry (GAT) and portable Schiøtz indentation tonometry, which is widely used in outreach settings but is more sensitive to biomechanical changes that accompany aging. Adults aged 18–75 years with clear corneas, open angles, and no prior glaucoma were recruited from an eye OPD and community screening programs and stratified into 18–39 years (n=48), 40–59 years (n=314), and 60–75 years (n=14). A single optometrist followed a standardized protocol (GAT first, then Schiøtz; average of two consistent readings), and refractive error was categorized by spherical equivalent to evaluate its influence. Across all age groups, Schiøtz measured higher mean IOP than GAT, with GAT versus Schiøtz values of 14.66±2.38 vs 15.27±2.64 mmHg (18–39), 14.96±2.50 vs 15.63±2.77 mmHg (40–59), and 15.36±3.34 vs 16.12±3.87 mmHg (60–75), indicating a widening discrepancy with age. In older adults, Bland–Altman analysis demonstrated a mean bias of +0.76 mmHg with 95% limits of agreement from −0.47 to +2.00 mmHg, greater scatter at higher mean IOP, and an upper limit approaching the prespecified clinically relevant threshold (>2 mmHg). Discrepancies were largest in myopic eyes—especially among those aged 60–75 years—moderate in hyperopes, and smallest in emmetropes, identifying elderly myopes as the subgroup most prone to clinically meaningful IOP overestimation by indentation tonometry. Overall, Schiøtz tonometry remains a pragmatic low-cost screening tool, but borderline or elevated Schiøtz readings in elderly individuals, particularly those with refractive errors, should be confirmed with applanation-based methods to reduce misclassification and inappropriate referral.

1. Introduction-

1.1 Global Burden of Glaucoma:

Glaucoma remains a formidable public health challenge and is the primary cause of irreversible blindness worldwide. This progressive optic neuropathy is characterised by distinctive structural and functional damage to the ocular system. Although the definition of the disease has evolved beyond simple pressure metrics, elevated intraocular pressure (IOP) remains the most significant and only modifiable risk factor for its development and progression. Given that age is a major

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contributing factor to the condition's prevalence, the increasing longevity of the global population necessitates robust, accurate, and accessible screening protocols to mitigate the burgeoning socioeconomic and clinical burden of vision loss.

1.2 The Gold Standard vs Field Reality:

In clinical practice, Goldmann applanation tonometry (GAT) is universally regarded as the 'gold standard' for measuring intraocular pressure (IOP) and is praised for its accuracy and minimal dependence on scleral rigidity (Lin et al., 2024). However, its requirement for a slit-lamp biomicroscope and upright patient positioning often limits its utility in large-scale community screenings or among bedbound populations. Conversely, the Schiøtz tonometer offers a portable and cost-effective alternative that remains functional without sophisticated infrastructure (Tairi et al., 2022). Despite these practical advantages, the indentation method is highly sensitive to ocular biomechanics, leading to potential discrepancies that may compromise diagnostic reliability in various screening environments.

1.3 Biomechanical Variables:

The accuracy of tonometry is fundamentally tethered to the biomechanical integrity of the eye. As individuals age, the corneoscleral shell undergoes structural stiffening, characterised by increased cross-linking and altered collagen density (Liu & Roberts, 2005). These changes elevate ocular rigidity, quantified by Friedenwald's coefficient, and modify corneal hysteresis and resistance factors (Ávila, 2024). Such age-related "stiffening" disproportionately affects Schiøtz indentation, which displaces a significant volume of intraocular fluid compared to localised Goldmann applanation. This divergence creates a widening "measurement gap" or discrepancy, where the age-induced resistance of the ocular wall may lead to overestimations of the pressure in older cohorts.

1.4 Problem Statement:

The clinical reliance on tonometry for glaucoma screening in aging populations faces a significant hurdle: age-related escalation of scleral and corneal stiffness. As ocular rigidity increases with age, the displacement of fluid required for Schiøtz indentation results in artificially elevated pressure readings compared to Goldmann applanation tonometry (Nomura et al., 2002). This systematic discrepancy risks a "diagnostic paradox" in community settings, potentially leading to the over-diagnosis of hypertension in the elderly or, conversely, masking pathology if rigidity is unexpectedly low (Han et al., 2016). Without adjusting for these biomechanical shifts, screening programs may suffer from poor predictive value, misallocate healthcare resources, and cause unnecessary patient anxiety.

2. Methods –

2.1 Study Design and Setting:

This prospective, observational, and comparative investigation was designed to evaluate the agreement between applanation and indentation tonometry across different age groups. The study was conducted in a clinical setting with periodic community-based screening involvement to reflect real-world outreach conditions. A prospective design was chosen to ensure standardised data collection and to minimise recall bias. The comparative nature of this study allowed for the direct evaluation of intraocular pressure (IOP) readings obtained using Goldmann applanation tonometry (GAT) and Schiotz indentation tonometry under uniform testing conditions. Ethical approval was obtained from the Institutional Ethics Committee.

2.2 Participants and Age Stratification:

Participants were recruited from patients attending routine eye examinations at the Assam Royal Global University Eye OPD and community screening programs. The inclusion criteria comprised adults aged 18–75 years with clear corneas, open angles on clinical evaluation, and no prior diagnosis of glaucoma. Individuals with corneal pathology, a history of ocular trauma or surgery, active ocular infection, or use of medications known to influence IOP were excluded to reduce the effects on tonometry readings. Eligible participants were stratified into three age groups: Group 1 (18–39 years), Group 2 (40–59 years), and Group 3 (60–75). This grouping was intended to capture age-related biomechanical changes while maintaining clinically meaningful categories. Particular emphasis was placed on Group 3, as this age range represents a high-risk population for glaucoma and is frequently targeted in community screening initiatives. (Weinreb et al., 2014).

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2.3 IOP Measurement Protocol:

IOP was measured using Goldmann applanation tonometry and Schiotz tonometry following a standardised protocol. All measurements were conducted by the same optometrist to minimise inter-observer variability in the measurements. For GAT, topical anaesthesia and fluorescein dye were instilled, and readings were obtained using a slit-lamp-mounted applanation tonometer, following standard clinical guidelines. Schiotz tonometry was performed with the patient in the supine position using calibrated weights, ensuring proper alignment and repeated measurements for accuracy. To reduce order-related bias, the sequence of tonometry was kept consistent across participants, with GAT measurements obtained first, followed by Schiotz readings after a brief interval of time. The average of the two consistent readings was recorded for each instrument.

2.4 Refractive Error Classification:

Using objective and subjective refraction, the refractive status was determined and categorised as myopia, hyperopia, or emmetropia based on spherical equivalent values. Myopia was defined as a spherical equivalent of −0.50 diopters or more, hyperopia as +0.50 diopters or more, and emmetropia as values between −0.50 and +0.50 diopters. As refractive status is known to influence ocular biomechanics, corneal curvature, and scleral rigidity, a subgroup analysis based on refractive error was included. Evaluating refractive error along with age allowed the identification of combinations that may contribute to increased IOP measurement variability in screening settings.

2.5 Statistical Analysis:

Statistical analyses were performed using standard statistical software. The mean IOP values obtained from GAT and Schiotz tonometry were compared across the age and refractive error groups using appropriate tests after confirming data normality. Agreement between the two tonometry methods was assessed using Bland–Altman analysis, which provided mean differences and limits of agreement (LoA). A clinically relevant cutoff of greater than 2 mmHg difference between instruments was used to identify potentially significant discrepancies. This threshold was selected to reflect the differences that may influence referral decisions in community glaucoma screening programs.

3. Results –

3.1 Demographic and Clinical Profile:

A total of 376 participants aged 18–75 years were included in the final analysis. Based on predefined criteria, participants were 729ategorized into three age groups: 18–39 (n = 48), 40–59 (n = 314), and 60–75 (n = 14) years. The middle-aged group constituted the largest proportion of the study population, reflecting the routine clinical attendance patterns. No significant sex imbalance influenced the intraocular pressure (IOP) measurements.

The refractive error distribution showed some age-related variations. Myopia was more prevalent in the younger and middle-aged groups, whereas emmetropia and mild hyperopia were more frequently observed in the older group. In each age group, all refractive error categories were represented, allowing a comparative analysis of the tonometry readings across both age and refractive status.

3.2 Age-Stratified IOP Comparison:

Mean IOP values were measured using Goldmann applanation tonometry (GAT) and Schiotz tonometry, which demonstrated a progressive increase with age (Table 1). In the 18–39 years group, the mean IOP was 14.66 ± 2.38 mmHg with GAT and 15.27 ± 2.64 mmHg with Schiotz tonometry. A similar pattern was observed in the 40–59 years group, where the mean GAT IOP was 14.96 ± 2.50 mmHg, while Schiotz readings averaged 15.63 ± 2.77 mmHg.

The difference between the two methods was more pronounced in the 60–75 years age group. In this group, the mean GAT-measured IOP was 15.36 ± 3.34 mmHg, whereas Schiotz tonometry recorded a higher mean IOP of 16.12 ± 3.87 mmHg. Although Schiotz tonometry consistently gives higher IOP values across all age groups, the magnitude of the discrepancy was greatest in older adults.

Figure 1 presents a comparative bar graph illustrating the age-wise mean IOP values measured by both instruments, highlighting the increasing gap between the methods in the senior age group.

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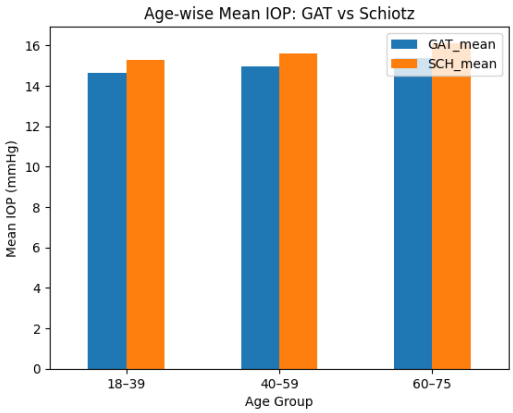

3.3 Analysis in Older Adults:

The difference between GAT and Schiotz tonometry in the 60–75 years age group was further assessed using Bland–Altman analysis (Figure 2). The mean difference between the two tonometers, Schiotz and GAT, was 0.76 mmHg. This indicates a systematic tendency for Schiotz tonometry to overestimate IOP relative to GAT. The limits of agreement ranged from −0.47 mmHg to +2.00 mmHg is 95%.

While the mean bias remained within clinically acceptable limits for screening purposes, the upper limit of agreement approached the predefined clinical threshold of 2 mmHg. This suggests increased measurement variability in older eyes. A greater scatter was observed at higher mean IOP values. This indicates that the variability between the two methods increased with age and IOP. These findings suggest that although Schiotz tonometry remains reasonably aligned with GAT in elderly patients, caution is advised when interpreting borderline or higher values in this age group.

Figure 2 illustrates the Bland–Altman plot for participants aged 60–75 years, emphasising the clinical relevance of the observed limits of agreement (LoA).

3.4 Influence of Refractive Errors:

Based on the refractive status analysis, the IOP discrepancies between GAT and Schiotz tonometry were not uniform across the refractive groups. Myopic eyes, particularly within the 60–75 years age group, demonstrated the largest mean differences between the two measurement techniques. Hyperopic eyes showed moderate discrepancies, whereas emmetropic eyes showed the closest agreement between GAT and Schiotz readings.

The combination of advanced age and myopia was the highest-risk profile for increased IOP measurement variability. This interaction suggests that the limitations of indentation tonometry amplify age-related ocular rigidity combined with refractive-error-associated biomechanical differences. These findings highlight the need for cautious interpretation of Schiotz-derived IOP values in elderly patients with refractive errors during community screenings for glaucoma.

Table 1. Age-wise comparison of mean intraocular pressure measured by GAT and Schiotz tonometry

Age Group (years)	n	GAT Mean IOP (mmHg) Mean ± SD	Schiotz Mean IOP (mmHg) Mean ± SD
18–39	48	14.66 ± 2.38	15.27 ± 2.64
40–59	314	14.96 ± 2.50	15.63 ± 2.77
60–75	14	15.36 ± 3.34	16.12 ± 3.87

Figure Legends

Figure 1. Comparative bar graph showing age-wise mean intraocular pressure values measured using Goldmann applanation tonometry and Schiotz indentation tonometry.

Figure 2. Bland–Altman plot demonstrating agreement between Schiotz and Goldmann applanation tonometry in participants aged 60–75 years. The central line represents the mean difference, and the upper and lower lines indicate the 95% limits of agreement.

4. Discussion –

4.1 Principal Findings:

The present study demonstrated a clear age-related divergence between intraocular pressure (IOP) measurements obtained using Goldmann applanation

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tonometry (GAT) and Schiotz indentation tonometry. Higher mean IOP values were consistently recorded in Schiotz tonometry compared to GAT across all age groups. The magnitude of this discrepancy increased with age and was most pronounced in individuals aged 60–75 years. Bland–Altman analysis in the senior group revealed a positive bias in the Schiotz measurements, with upper limits of agreement approaching the clinically relevant threshold of 2 mmHg.

The key research question directly addressed these findings by indicating that the reliability of Schiotz tonometry declines in older patients, particularly when age-related variability is considered. Although the mean differences remained modest, the increased scatter and wider limits of agreement in the elderly suggest reduced precision. This effect was further elevated in participants with refractive errors, particularly myopia. Collectively, these results suggest that although Schiotz tonometry remains useful for screening, its reliability is context-dependent and diminished in older, high-risk populations.

4.2 Comparison with Previous Studies:

The tendency of Schiotz tonometry to overestimate IOP relative to GAT is consistent with earlier comparative studies that reported a systematic positive bias associated with indentation methods (Kotecha, 2007). Prior research has shown acceptable agreement between Schiotz and applanation tonometry in younger populations, supporting their continued use in basic screening environments (Sood et al., 2018). However, many of these studies did not stratify the results by age or explore the agreement specifically in older adults.

Our findings extend the existing literature by providing age-stratified evidence that the agreement between the two methods deteriorates in older adults. Unlike studies reporting uniform agreement across age ranges, the present analysis highlights that the limits of agreement widen significantly in the 60–75 years group, even when the mean differences remain small. This refinement is clinically important because the prevalence of glaucoma increases with age, and screening accuracy becomes more critical rather than less.

Furthermore, the identification of refractive error, especially myopia, as a modifier of measurement discrepancy adds a layer of clinical insight that has not been consistently addressed in earlier studies. By integrating refractive status and age, this study contributes to a more detailed understanding of when Schiotz tonometry aligns with or deviates from GAT in real-world screening contexts.

4.3 Mechanistic Explanation:

The age-related increase in the discrepancy between Schiotz and GAT measurements can be explained by changes in ocular biomechanics. Aging is associated with increased scleral rigidity due to collagen crosslinking and reduced tissue compliance. Because Schiotz tonometry relies on the indentation of the ocular coats, increased scleral stiffness may result in reduced indentation depth, leading to artificially elevated IOP readings (Liu & Roberts, 2005).

In addition to scleral changes, the corneal biomechanical properties evolve with age. Reduced corneal elasticity and alterations in corneal hysteresis can influence both applanation and indentation measurements; however, the effect is more pronounced for indentation-based methods. These biomechanical shifts may explain the greater variability and wider limits of agreement observed in the older participants.

The refractive status further modifies these effects. Myopic eyes, which often exhibit altered scleral architecture and biomechanical behaviour, demonstrated the greatest discrepancies in this study. The combination of refractive error-associated structural differences and age-related rigidity reduces the reliability of Schiotz tonometry in elderly myopic individuals.

4.4 Clinical Implications for Community Screening:

These findings support the continuous use of Schiotz tonometry in community and outreach screening programs, particularly among younger and middle-aged adults, where agreement with GAT remains acceptable. In these groups, Schiotz provides a rapid, cost-effective, and logistically feasible method for identifying individuals who may require further evaluation of their IOP.

However, caution should be exercised when interpreting IOP values in patients aged 60–75 years using Schiotz tonometry, particularly in those with refractive errors.

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In this population, borderline or elevated IOP readings obtained by Schiotz tonometry should be confirmed by timely assessment using applanation methods whenever feasible. Overreliance on Schiotz measurements in elderly patients may increase false-positive referrals or misclassification of glaucoma risk.

For outreach camps, a practical approach is recommended: Schiotz tonometry may serve as an initial screening tool, but age and refractive status should inform the referral criteria. Incorporating simple age-based decision rules can enhance screening accuracy while preserving the operational advantages of Schiotz tonometry in resource-limited settings.

5. Conclusion –

This study demonstrated that the agreement between Schiotz and Goldmann applanation tonometry is influenced by age, with measurement reliability declining progressively in older individuals. While Schiotz tonometry consistently produced slightly higher intraocular pressure values across all age groups, supporting its continued use in routine screening settings, it remained clinically acceptable in younger and middle-aged adults.

The agreement between the two methods showed increased variability, with wider limits of agreement approaching clinically significant thresholds in participants aged 60–75 years. This finding indicates that Schiotz tonometry is less reliable as a standalone measurement tool in this age group, particularly in the presence of refractive errors. Elderly myopic individuals were the highest-risk subgroup for clinically meaningful IOP overestimation.

These findings provide practical guidance for screening optometrists. Schiotz tonometry remains a low-cost, valuable, and accessible tool for community and outreach screening; however, age and refractive status should be considered during evaluation. In elderly patients, especially those with borderline or elevated IOP readings, confirmation with applanation-based methods is strongly recommended before referral or a final prescription.

Overall, Schiotz tonometry should not be viewed as outdated but as a useful, context-dependent screening instrument that is effective when applied judiciously and interpreted within an age-sensitive clinical framework.

6. Limitations and Future Directions –

The sample size in the older age group (60–75 years) was relatively small compared to younger groups, which may limit the strength of the subgroup analysis in this high-risk population. Although this distribution reflects typical community screening attendance, larger elderly samples would improve the reliability and population applicability of the age-specific findings.

The absence of central corneal thickness and corneal biomechanical assessments is another limitation. As corneal properties influence intraocular pressure measurements, the lack of such adjustments may have contributed to the variability between the tonometry methods. However, this aligns with real-world outreach settings, where pachymetry is often unavailable.

Future research should include larger elderly populations and incorporate corneal thickness and other biomechanical parameters. Longitudinal studies examining age-related biomechanical changes over time will further clarify the clinical reliability of Schiotz tonometry in community glaucoma screening.

7. Acknowledgments –

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8. Conflict of Interest –

The authors declare no conflicts of interest related to this study.

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