A Review On Measuring Intra-Ocular Pressure Using Different Types Of Tonometers.

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Abstract:
This comprehensive review explores the various techniques for measuring intraocular pressure (IOP), a critical parameter in diagnosing and managing eye diseases, particularly glaucoma. The article examines multiple tonometry methods, each with its unique principles and implications for clinical practice. Goldmann applanation tonometry (GAT) is established as the conventional standard, yet its limitations under certain corneal conditions have led to the development and adoption of alternative methods such as noncontact tonometry (NCT), dynamic contour tonometry (DCT), and rebound tonometry. The review also delves into indentation tonometry, highlighting its continued relevance in specific clinical situations. Technological advancements in portable and digital tonometry are discussed, emphasizing their role in making IOP measurement more accessible, especially in non-traditional and remote settings. Comparative studies and analyses are presented to illustrate the varying degrees of efficacy, accuracy, and reliability of these techniques, underscoring the importance of selecting the appropriate method based on individual patient needs and clinical scenarios. The review identifies significant gaps in current knowledge, particularly concerning the impact of ocular factors on measurement accuracy and the performance of tonometers in diverse patient populations. It advocates for ongoing research and technological development to refine these methods, ultimately contributing to better diagnosis and management of eye conditions.

Keywords: Intraocular Pressure (IOP), Tonometry, Glaucoma, Goldmann Applanation Tonometry (GAT), Non-Contact Tonometry (NCT), Dynamic Contour Tonometry (DCT), Rebound Tonometry, Indentation Tonometry, Schiotz Tonometry.

Introduction:
Intraocular pressure (IOP) is a key indicator in eye health, especially in identifying and managing glaucoma, a major cause of blindness. This review article explores the importance of IOP and the diverse methods available for its measurement, which are vital for diagnosing and treating eye diseases.
IOP, the fluid pressure inside the eye, is essential for maintaining its shape and functionality. Deviations in IOP can signal eye disorders, with glaucoma being the most common. Measuring IOP accurately is challenging due to the eye's complex structure and the variable nature of the pressure. Precise IOP measurements are crucial for evaluating the risk of glaucoma, monitoring its progression, and guiding therapeutic interventions.
Several techniques for measuring IOP have emerged over time. The Goldmann applanation tonometer (GAT) is well-regarded for its accuracy and has been a standard tool for years. It operates by measuring the force needed to flatten a specific area of the cornea, thereby determining the IOP.
An alternative is non-contact tonometry (NCT), which uses a burst of air to flatten the cornea temporarily. NCT is more comfortable for patients as it does not involve direct contact with the eye, though it sometimes requires validation through other techniques for enhanced accuracy.
Other methods include the indentation based Schiøtz tonometer and dynamic contour tonometry (DCT), which aligns with the eye's contour for measurements less affected by corneal properties.
Technological advancements have introduced portable tonometers and digital devices, making IOP measurement more accessible and convenient, especially in non-traditional environments like remote communities or local clinics.
This review article delves into the various IOP measurement methods, each with specific benefits and limitations. The choice of method depends on the clinical situation, individual patient needs, and the goals of diagnosis or treatment. This variety in measurement techniques demonstrates the continual progress in eye care and the dedication to enhancing patient care in ophthalmology.

Applanation Tonometry:
Applanation tonometry is a crucial diagnostic tool in ophthalmology, primarily used for measuring intraocular pressure (IOP), an essential parameter in the diagnosis and management of glaucoma. This technique is based on the Imbert-Fick

principle, which posits that the force required to flatten (applanate) a spherical surface is proportional to the internal pressure of the sphere, assuming the surface is perfectly elastic and infinitely thin.

1. Goldmann Applanation Tonometry (GAT): Widely regarded as the gold standard, GAT involves the use of a slit-lamp mounted biomicroscope with a tonometer head. It requires the application of a fluorescein dye and a cobalt blue light for visualisation. The accuracy of GAT stems from its ability to directly measure the force needed to flatten a small, predefined area (3.06 mm diameter) of the cornea. Despite its accuracy, factors like corneal thickness and rigidity can influence readings, and the need for topical anaesthesia and close patient contact limits its use in certain clinical settings.
2. *Perkins Tonometry*: This is a handheld version of the Goldmann tonometer, advantageous in non-standard patient positions, such as in paediatric or bedridden patients. Perkins tonometry maintains the precision of GAT but offers greater flexibility. However, it shares similar limitations in terms of corneal properties influencing the readings.
3. *Tono-Pen:* This portable, handheld device is useful in various clinical settings, including those where traditional slit-lamp examination is not feasible. It uses a miniature applanation surface to make contact with the cornea. Calibration and user technique can influence the accuracy of the Tono-Pen, but its portability and ease of use make it popular in non-traditional and emergency settings.

Non-Contact Tonometry (NCT):

Also known as 'air-puff' tonometry, NCT employs a rapid air pulse to applanate the cornea. Its major advantage is that it requires no physical contact with the eye, eliminating the need for anaesthetic drops and reducing the risk of corneal abrasion or infection transmission. However, NCT is generally considered less accurate than GAT, and measurements can be affected by the patient's blinking or flinching response.

Indentation Tonometry:

Indentation tonometry is an alternative method for measuring intraocular pressure (IOP) that differs fundamentally from applanation tonometry. Instead of flattening the cornea, indentation tonometry assesses IOP by indenting the cornea and measuring the extent of this indentation. This technique is based on the principle that a given force will indent a softer (lower IOP) eye more than a harder (higher IOP) eye. Indentation tonometry is particularly useful in certain clinical situations where applanation tonometry may not be feasible or accurate.

1. *Schiotz Tonometry:* This is the most traditional form of indentation tonometry. The Schiotz tonometer uses a plunger that indents the cornea under the force of gravity. The degree of indentation is inversely proportional to the IOP. Different weights can be used to modify the force applied, and a scale on the device indicates the IOP based on the depth of indentation. Schiotz tonometry is simple and portable, but its accuracy can be influenced by corneal properties, ocular rigidity, and user technique.
2. *Mackay-Marg Tonometry:* This electronic indentation tonometer is designed to provide more consistent readings than the Schiotz tonometer. It uses a small, motor-driven plunger to indent the cornea, and the resistance to this indentation is measured electronically. This method is less dependent on corneal properties than Schiotz tonometry, but it is still influenced by factors such as central corneal thickness.
3. *Electronic Indentation Tonometry*: A modern advancement in indentation tonometry, these devices use electronic sensors to measure the degree of corneal indentation more precisely. This technology aims to provide more accurate and repeatable measurements than traditional Schiotz tonometry, though it still shares some of the methodological limitations inherent to indentation techniques.
4. *Pneumatic Indentation Tonometry:* This method involves a pneumatic mechanism to indent the cornea. The force applied and the resultant indentation are used to estimate the IOP. This technique aims to reduce the variability found in manual indentation methods and improve measurement accuracy.

Rebound tonometry:

Rebound tonometry represents a relatively modern approach to measuring intraocular pressure (IOP) and has gained popularity due to its ease of use, minimal patient discomfort, and reduced need for corneal anaesthesia. This technique involves the measurement of IOP based on the rebounding behaviour of a small probe or tip that briefly contacts the cornea.

1. *Icare® Tonometry:* The Icare® tonometer is the most well-known example of rebound tonometry. It utilises a tiny, lightweight probe that is propelled to gently contact the cornea. The speed of the probe's rebound after touching the cornea is inversely proportional to the IOP. The major advantage of the Icare® tonometer is its ease of use; it does not require topical anaesthesia or a fluorescein dye, making it particularly useful in paediatric populations or for quick screenings.
2. *Icare® HOME Tonometry:* An adaptation of the standard Icare® tonometer, the Icare® HOME device allows patients to measure their own IOP at home. This device is particularly beneficial for patients requiring frequent IOP monitoring, such as those with glaucoma. Its user-friendly design and the possibility of self-monitoring can lead to improved patient adherence and better management of intraocular pressure over time.

3. *Icare® PRO Tonometry:* The Icare® PRO tonometer is an advanced version, designed for professional use with additional features such as positional detection, which helps ensure accurate readings regardless of the patient's position. It is particularly useful in clinical settings for patients who cannot comfortably sit at a slit lamp, such as those who are bedridden or in paediatric care.
4. *Icare® TA01i and TA02:* These are earlier models of the Icare® tonometers, primarily used in clinical settings. They are known for their accuracy and reliability, though they lack some of the advanced features of the newer models. These devices are still in use due to their robustness and ease of operation.

Dynamic Contour Tonometry:

Dynamic Contour Tonometry (DCT) is an advanced ocular tonometry technique designed to measure intraocular pressure (IOP) in a manner that minimizes the impact of corneal properties such as thickness and rigidity. Unlike traditional applanation methods, DCT employs a contour-matching approach, where the tonometer tip's shape aligns with the natural curvature of the cornea, leading to a more accurate and less cornea-dependent IOP measurement.

1. *Pascal Dynamic Contour Tonometry:* The Pascal DCT is the most recognized form of this technology. It features a sensortipped tonometer that matches the corneal curvature, thereby reducing the influence of corneal properties on the IOP reading. The device provides digital readouts of IOP along with ocular pulse amplitude, offering valuable diagnostic information. The Pascal DCT is praised for its accuracy, especially in cases where corneal anomalies or other factors might skew traditional applanation tonometry results.
2. *DCT in Combination with Other Technologies:* Some newer developments in DCT involve integrating its technology with other ocular diagnostic tools. For instance, combining DCT with optical coherence tomography (OCT) or other scanning devices can provide comprehensive ocular assessments, offering insights into both the biomechanical properties of the eye and the IOP.
3. *Automated and Portable DCT Systems:* Advances in DCT technology include the development of automated and portable systems. These devices aim to bring the accuracy of DCT to more varied clinical settings, including those outside traditional ophthalmology clinics. They offer the potential for easier and more widespread screening for conditions like glaucoma, especially in populations with limited access to healthcare facilities.
4. *DCT in Research Applications:* DCT is also being utilized in research settings to study ocular biomechanics and the pathophysiology of various eye diseases. By providing accurate IOP measurements that are less influenced by corneal properties, DCT is invaluable in studies where precise IOP control and monitoring are crucial.

Comparative Analysis of Tonometry Techniques, Tonometry in Special Conditions and Future Directions in Tonometry:

The accurate measurement of intraocular pressure (IOP) is paramount for diagnosing and managing conditions such as glaucoma. The field has seen the development of various tonometry techniques, each with its unique mechanisms and subtleties. A comparative analysis of these techniques is essential for understanding their relative efficacies, limitations, and suitability in different clinical contexts**.**

1. Various tonometers against Goldman Applanation Tonometer:

Cook et al., (2012) focused on comparing the accuracy of various tonometers against the Goldmann applanation tonometer (GAT), a standard reference in clinical practice. Involving 11,582 participants and 15,525 eyes, the study included 102 studies with 130 paired comparisons across 8 different tonometers.

The findings revealed a notable range in agreement with the GAT, with the noncontact tonometer (NCT) and handheld applanation tonometer (HAT) showing the closest alignment. However, a significant level of inter- and interobserver variability was observed among all tonometers. While NCT and HAT were within 2 mmHg of GAT for 66% and 59% of measurements, respectively, the Ocuton S only achieved this level of agreement in 33% of cases.

*Highlighting Areas for Future Investigation***:** Despite this comprehensive analysis, the research revealed gaps, particularly in the consistency of measurements across different devices and observers. The substantial variability noted raises questions about the reliability of tonometers in clinical settings. Further research is needed to understand the sources of this variability and to develop methods or technologies to enhance the consistency and reliability of intraocular pressure measurements across various tonometers. Additionally, there is a need for more studies focusing on the comparative effectiveness of newer tonometers and their suitability in diverse clinical scenarios.

2. Goldmann Applanation Tonometer Vs Tono Pen Vs Non-Contact Air Puff Tonometer:

Yilmaz et al., (2014) aimed to compare intraocular pressure (IOP) measurements using three different tonometers: the Goldmann applanation tonometer (GAT), the Tono-Pen (®) XL (TPXL), and a non-contact air puff tonometer (NCT). This cross-sectional study included 200 eyes from 200 patients, focusing exclusively on their right eyes. Each of the three participating physicians used one of the tonometers to measure IOP.

The results showed average IOP readings of 15.5±2.2 mmHg with the GAT, 16.1±3.0 with the TPXL, and 16.1±2.8 with the NCT. Bland-Altman analysis revealed a mean difference between NCT and GAT measurements of 0.6±2.3 mmHg, and between TPXL and GAT measurements of 0.7±2.5 mmHg. The difference between NCT and TPXL was minimal (-0.02±3.0 mmHg). The one-way ANOVA test indicated no significant difference between the groups, with respective P-values of 0.998 for NCTTPXL, 0.067 for NCT-GAT, and 0.059 for TPXL-GAT.

Highlighting Areas for Future Investigation: While this study indicates that both NCT and TPXL can provide IOP measurements comparable to GAT in normotensive eyes, it reveals a research gap in the context of varying eye conditions, particularly in patients with ocular hypertension or glaucoma. The study's limitation to normotensive eyes and the exclusion of left eyes suggests a need for broader research encompassing a wider range of IOP conditions and including both eyes.
Furthermore, the study does not address the potential impact of factors such as corneal thickness or curvature on the accuracy of these tonometers, indicating a gap in understanding how these factors influence IOP measurement accuracy.

3. Tono-Pen Vs Goldmann applanation tonometry:
Bao et al., (2019) compare the agreement in intraocular pressure (IOP) measurements obtained using the Tono-Pen and Goldmann applanation tonometry (GAT), alongside evaluating the influence of central corneal thickness (CCT) on these measurements. Conducted as a database study, it included 898 patients from a clinical database, with their IOP measurements of the right eye obtained using both GAT and the Tono-Pen.

The agreement between the two methods was analyzed using Bland-Altman plots, and their relationship to CCT was assessed through linear regression analysis. The study found a correlation of 0.76 between the two devices. The Tono-Pen tended to underestimate IOP at levels above 16.8 mmHg and overestimate at lower levels. The mean difference in IOP measurement between the two methods was -0.15 mmHg. Notably, larger differences were observed at higher IOPs, with an average difference exceeding 3 mmHg for IOPs of 29 mmHg or more. CCT was also found to impact IOP measurements, with a change of 0.16 mmHg per 10 μm increase in CCT for GAT and 0.15 mmHg for the Tono-Pen.

Highlighting Areas for Future Investigation: The study highlights a gap in understanding the exact causes of the variability in measurements at higher IOP levels. While it establishes a general agreement between the two tonometry methods, the wide limits of agreement, especially at higher IOPs, suggest a need for further investigation into factors that may influence this variability. Additionally, the study focuses solely on right-eye measurements, which raises questions about the applicability of these findings to left eyes. Further research might also explore the impact of other ocular factors, such as corneal curvature and eye diseases, on the accuracy of these tonometry methods. Finally, the study's retrospective database design limits the ability to control for confounding factors, suggesting a need for prospective studies to validate these findings.

4. Perkin's applanation tonometer Vs noncontact tonometer (NCT) Vs Schiotz indentation tonometer:
Nagarajan et al., (2016) aimed to evaluate the agreement in intraocular pressure (IOP) measurements obtained by three different tonometers – Perkin's applanation tonometer, noncontact tonometer (NCT), and Schiotz indentation tonometer – in a general ophthalmology outpatient department in South India. The study also assessed the suitability of these tonometers for community ophthalmology settings.

In this cross-sectional analytical study, IOP was measured in 800 eyes from 400 patients using all three tonometers. Central corneal thickness (CCT) was measured using ultrasonic pachymetry. The Bland-Altman method was employed to analyse agreement between the instruments.
Results indicated that the Schiotz indentation tonometer correlated better with the Perkin's applanation tonometer, particularly when the CCT was between 501-550 microns. The noncontact tonometer was found to be less accurate for CCT greater than 600 microns. Additionally, both tonometers showed better correlation in patients under 40 years of age.

The conclusion drawn from the study was that both the Schiotz and the noncontact tonometers demonstrated significant correlation with Perkin's applanation tonometer across various ranges of IOP and CCT. The Schiotz tonometer was particularly recommended as a reliable screening tool in community ophthalmology services due to its portability and accessibility, making it a popular choice in developing countries like India.

Highlighting Areas for Future Investigation: Despite these findings, the study presents certain gaps. Firstly, it does not explore the effectiveness of these tonometers in patients with ocular conditions that could potentially affect IOP readings, such as glaucoma. Secondly, the study is geographically limited to South India, and its findings might not be generalizable to populations with different ethnic or racial backgrounds. Thirdly, the study does not address the long-term reliability and calibration needs of these tonometers in community settings. Further research is needed to evaluate these aspects and to extend the findings to a broader range of clinical and demographic settings.

5. Dynamic contour tonometry Vs Goldmann applanation tonometry Vs Tono-Pen XL:
Kontadakis et al., (2020) investigated the accuracy of three tonometry methods - dynamic contour tonometry, Goldmann applanation tonometry, and Tono-Pen XL - in measuring intraocular pressure (IOP) in oedematous corneas, using an experimental setup with 20 freshly enucleated porcine eyes. The eyes were divided into groups and subjected to varying concentrations of glycerine solutions to induce oedema, followed by IOP measurements at hydrostatically adjusted pressures of 17mmHg, 33mmHg, and 50mmHg.

Results indicated that all three tonometry methods tended to underestimate IOP in oedematous conditions. Specifically, at a true IOP of 33 mm Hg, both Goldmann applanation and dynamic contour tonometry significantly underestimated IOP, while the Tono-Pen XL's underestimation was not statistically significant. At a true IOP of 50 mm Hg, all methods significantly underestimated the pressure. The study also found that the error in IOP measurement for each method was correlated to the true IOP level, but not to corneal thickness.

Highlighting Areas for Future Investigation: The study highlights a gap in understanding the impact of corneal oedema on the accuracy of tonometry measurements. While it establishes that all three methods tend to underestimate IOP under oedematous conditions, the specific mechanism behind this underestimation, particularly the role of varying degrees of oedema, remains unclear. Additionally, the study is limited to porcine eyes, raising questions about the direct applicability of these findings to human eyes. Further research is needed to explore the effects of different types and degrees of corneal oedema on IOP measurement accuracy in human subjects. Moreover, investigating the performance of these tonometry methods in clinical settings with patients having various stages of corneal oedema would provide more comprehensive insights into their clinical utility.

6. iCare rebound tonometer (RT) Vs Goldmann applanation tonometer (GAT):

Gao et al., (2017) aimed to compare intraocular pressure (IOP) measurements between the iCare rebound tonometer (RT) and the Goldmann applanation tonometer (GAT), and to examine the correlation of these measurements with central corneal thickness (CCT). In this context, the tolerability and safety of the RT were also evaluated. The study involved 336 patients (672 eyes), divided into three groups based on their GAT IOP readings.

The mean IOP values obtained from the RT and GAT were 18.30±5.10 mmHg and 18.52±4.46 mmHg, respectively, showing no significant differences between them. Both devices demonstrated a positive correlation with CCT, but the RT measurements were significantly lower than GAT for high IOP values (≥23 mmHg). The RT was well-tolerated, with no discomfort reported by subjects, and was found to be safe for use.

Highlighting Areas for Future Investigation: Despite these findings, the study identifies gaps in understanding the accuracy of RT in high IOP ranges. While the RT shows good correlation with GAT in low to moderate IOP ranges, its accuracy diminishes at higher IOP levels. Further investigation is needed to understand the underlying reasons for this discrepancy and to improve the accuracy of RT in high IOP measurements. Additionally, the study's focus on CCT correlation leaves the influence of other corneal properties, like curvature and biomechanics, on IOP measurements unexplored. Future research should aim to explore these aspects and extend the applicability of RT across a wider range of IOP values and diverse corneal conditions.

7. Goldmann applanation tonometer (GAT) Vs noncontact tonometer (NCT):

Joshi et al., (2023) aimed to compare intraocular pressure (IOP) measurements obtained from the Goldmann applanation tonometer (GAT) and noncontact tonometer (NCT) across different IOP ranges and to study their correlation with central corneal thickness (CCT). The study involved 50 patients (100 eyes), using the Topcon CT 800 for NCT measurements, Opti Lasa for GAT, and Topcon SP-1P Specular microscope for measuring CCT.

IOP readings were categorized into three groups: less than 12 mmHg, 13-24 mmHg, and more than 25 mmHg. The study found that both NCT and GAT readings were significantly correlated with CCT, but NCT showed a stronger correlation. The NCT readings were consistently higher than those from the GAT, suggesting that corneal thickness has a more pronounced effect on NCT readings. With an appropriate correction factor for CCT, the study concluded that NCT could be a reliable screening tool for glaucoma evaluation.

Highlighting Areas for Future Investigation: The research highlights a gap in the understanding of the influence of CCT on IOP measurements, particularly in the case of NCT. While the study indicates a stronger correlation between CCT and NCT readings, it does not fully explore the implications of this finding for clinical practice, especially in patients with abnormal CCT values. Moreover, the study's sample size is relatively small and limited to a specific patient population, which might affect the generalizability of the results. Further research is needed with a larger and more diverse patient population to validate these findings and to develop more refined correction factors for CCT in IOP measurements using NCT, particularly for clinical settings involving diverse eye conditions.

8. Goldmann applanation tonometer [GAT] Vs Dynamic contour tonometer [DCT] Vs Non-contact tonometer [NCT] Vs Ocular Response Analyzer [ORA]:

Kouchaki et al., (2017) compared four tonometry techniques (Goldmann applanation tonometer [GAT], Dynamic contour tonometer [DCT], Non-contact tonometer [NCT], and Ocular Response Analyzer [ORA]) for measuring intraocular pressure (IOP) in a cross-sectional study of volunteers with normal ophthalmic history. The impact of corneal biomechanical factors like corneal resistance factor (CRF) and central corneal thickness (CCT) on these measurements was also evaluated.

Highlighting Areas for Future Investigation: Although the study provides valuable insights into the performance of different tonometers, it reveals a need for further investigation into how these devices perform in patients with various corneal conditions or previous eye surgeries. The study's focus on volunteers with normal eyes limits the understanding of tonometer performance in a broader clinical context. There's also a scope for exploring the influence of other corneal and ocular parameters on IOP measurements using these devices.

9. Goldmann applanation tonometer (GAT) and a new experimental applanation tonometer with a convexly shaped apex (CT):

Iglesias et al., (2020) aimed to assess the agreement between intraocular pressure (IOP) measurements taken with the standard Goldmann applanation tonometer (GAT) and a new experimental applanation tonometer with a convexly shaped apex (CT), particularly in the context of post-myopic refractive surgery. The study, which was prospective and double-masked, involved 102 eyes from 102 patients. Two different CT designs, CT1 and CT2, were developed using finite element analysis. IOP measurements were compared using Bland-Altman plots and intra-class correlation coefficients (ICC) for patients who had undergone laser-assisted in situ keratomileusis (LASIK, n=73) or photorefractive keratectomy (PRK, n=29).

The study revealed the best IOP agreement between pre-surgery GAT and post-surgery CT1 measurements, particularly in the LASIK subgroup, where CT1 showed greater accuracy. Excellent agreement was observed for intra and inter-observer error with an ICC > 0.8. The study concluded that the new GAT version could be more accurate for post-surgery LASIK patients compared to the standard tonometer.

Highlighting Areas for Future Investigation: Despite these promising findings, the study highlights a research gap in the generalizability of the new tonometer's efficacy. Specifically, while CT1 showed better accuracy in post-LASIK patients, its effectiveness in PRK patients was comparatively lower. This disparity suggests a need for further research to optimize the tonometer for different types of refractive surgeries. Additionally, the study is limited to post-myopic refractive surgery patients, leaving its applicability to other ocular conditions unexplored. Future research should also investigate the new tonometer's performance in a broader range of eye conditions and surgeries to establish its versatility and reliability in diverse clinical scenarios.

10.Goldmann applanation tonometry (GAT) and non-contact tonometry (NCT) in a non-pathologic high myopia Chinese adult population:

Wang et al., (2022) compared intraocular pressure (IOP) measurements between Goldmann applanation tonometry (GAT) and non-contact tonometry (NCT) in a non-pathologic high myopia Chinese adult population. Key findings include the observation that NCT consistently overestimated IOP compared to GAT, with a mean difference of 3.75 mmHg. Factors such as body mass index, systolic blood pressure, and central corneal thickness were significantly associated with the differences in IOP readings between the two devices.

Highlighting Areas for Future Investigation: The study highlights a need for further exploration into how specific ocular and systemic factors influence the accuracy of IOP measurements in high myopia patients, especially when using different tonometry techniques. This could help in developing more accurate methods for IOP assessment in this particular patient group.

Conclusion:

In summary, the extensive review of intraocular pressure (IOP) measurement techniques highlights the evolution and diversity of tonometry methods. Each technique, from the Goldmann applanation tonometry (GAT) to newer technologies like dynamic contour tonometry (DCT) and rebound tonometry, offers unique advantages and limitations, underscoring the complexity and importance of accurate IOP measurement in eye care.

Goldmann applanation tonometry remains a cornerstone in IOP measurement, prized for its precision. However, its limitations, influenced by factors like corneal thickness and rigidity, necessitate alternative methods in certain clinical scenarios. Noncontact tonometry and the Tono-Pen have emerged as viable alternatives, offering the benefits of non-invasiveness and portability, respectively, though at the cost of some accuracy.

Dynamic contour tonometry, particularly the Pascal DCT, represents a significant advancement in the field, providing highaccuracy readings with reduced corneal dependence. Its integration with other ocular diagnostics could revolutionise comprehensive eye assessments. Similarly, rebound tonometry, exemplified by the Icare® tonometers, has transformed IOP measurement with its ease of use and minimal discomfort, making it particularly suitable for paediatric and frequent home monitoring.

Indentation tonometry, despite being older, retains relevance in specific situations where other methods may falter. Schiotz tonometry, for instance, remains a simple and portable option, particularly in community ophthalmology.

The reviewed studies collectively emphasise the importance of considering individual patient circumstances and clinical settings when choosing a tonometry method. Factors like corneal properties, patient age, and specific ocular conditions play critical roles in method selection. Moreover, the studies highlight significant gaps in current knowledge, particularly

regarding the impact of various ocular factors on measurement accuracy, the performance of tonometers in diverse patient populations, and the long-term reliability of these devices in different settings.

Looking forward, there is a clear need for ongoing research and development. Future studies should aim to address these gaps, exploring the effects of factors like corneal edema, high myopia, and post-surgical changes on IOP measurements. Advancements in technology could lead to more accurate, versatile, and user-friendly tonometry methods, potentially incorporating artificial intelligence and automated systems to enhance reliability and accessibility.

In conclusion, this review underscores the dynamic nature of tonometry in ophthalmology. As our understanding of ocular biomechanics and technology evolves, so too will the methods for measuring intraocular pressure, continuously improving the diagnosis and management of eye conditions such as glaucoma, ultimately leading to better patient outcomes.

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