

Intraocular Pressure Measurement Using iCare 200 and Goldmann Applanation Tonometer in Eyes with Normal Central Corneal Thickness

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ABSTRACT

Objective: To compare intraocular pressure measurements by iCare 200 and Goldmann applanation tonometer in patients having central corneal thickness within normal limits.

Study Design: Cross-sectional study.

Place and Duration of Study: Corneal Transplant and Refractive Surgery Department, Armed Forces Institute of Ophthalmology, Rawalpindi, Pakistan, from Nov to Dec 2022.

Methodology: Intraocular pressure measurement by iCare 200 was taken before Goldmann applanation tonometry to avoid artificially lowering the pressure. TOPCON® SP 3000 specular microscope was used to measure central corneal thickness, and a minimum of three readings were documented.

Results: Among 75 patients, 40(53.3%) were males and 35(46.7%) were females. The mean age was 43.02 ± 11.3 years. Mean central corneal thickness was $529 \pm 10.83 \mu\text{m}$. Mean pressure measured by Goldmann applanation tonometry was 15.14 ± 3.03 mmHg, while that measured by iCare 200 was 13.90 ± 3.18 mmHg. iCare 200 readings were relatively lower. The mean difference in intraocular pressure between the two methods was 1.21 ± 0.77 mmHg, with a minimum difference of -2.50 mmHg and maximum difference of 3.50 mmHg ($p < 0.01$). Correlation between central corneal thickness and intraocular pressure measured by both methods was statistically significant ($p < 0.05$).

Conclusion: iCare 200 rebound tonometer provides comparable intraocular pressure readings to Goldmann applanation tonometry in patients with central corneal thickness within the normal range; however, it slightly underestimates intraocular pressure compared with Goldmann applanation tonometry.

Keywords: Goldmann Applanation Tonometry; Intraocular Pressure; Icare 200; Rebound Tonometry

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INTRODUCTION

It was back in the 16th century when Bannister studied a group of patients with eyes that were found to be “firm to the touch” when intraocular pressure (IOP) was initially highlighted as an important part of the diagnostic evaluation of ocular pathologies.¹ In particular, glaucoma, which is an irreversible cause of blindness, has minimal early symptoms, and accurate IOP measurement can prove to be invaluable in diagnosing and early management by lowering the only modifiable risk factor in glaucoma, i.e., IOP.²

The current most widely used method for measuring IOP is the Goldmann applanation tonometer (GAT). It involves utilizing a probe to flatten the cornea of the eye and then measuring the pressure required to do so as a reflection of the IOP.³ Before measurement, a topical anesthetic is often applied to the eye, and measurements using

fluorescein stain are documented to be more accurate.⁴ Even though GAT is the current standard, it is not without its limitations. IOP measurements by GAT are influenced by corneal thickness, corneal surface irregularity or corneal astigmatism, especially irregular astigmatism, and/or disruption of mechanical integrity of corneal tissue. Furthermore, GAT is relatively cumbersome to use both for the Operator and the patient as it involves direct contact of a relatively larger tip and also requires a fair amount of patient cooperation.⁵

As such, to overcome this uncertainty in measurement, several other alternatives have been proposed over the years.⁶ One of these is the iCare 200 tonometer; a handheld tonometer based on the impact-induction principle. Studies have been done comparing the two and have demonstrated comparable results with GAT.⁷ Certain advantages iCare 200 has compared to GAT i.e., minimum and swift contact to patients' cornea that is often unrecognizable by the patient, minimum patient discomfort, less steep learning curve as compared to

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GAT, no need for topical anesthesia before checking the IOP, and minimum disruption of corneal surface as compared to GAT.⁸

Accurate intraocular pressure measurement is essential for the early detection and monitoring of glaucoma, yet readings may vary according to the tonometer used and the central corneal thickness. Because central corneal thickness can influence tonometric readings, restricting the comparison to patients with values within the normal range may reduce this source of measurement variability. Establishing the level of agreement and any systematic difference between these instruments is therefore important before iCare 200 can be used interchangeably with GAT in routine practice. Accordingly, this study compared IOP measurements obtained with iCare 200 and GAT in patients with CCT within normal limits.

METHODOLOGY

It was a cross-sectional observational study carried out at the Corneal Transplant and Refractive Surgery Department, Armed Forces Institute of Ophthalmology, Rawalpindi, Pakistan, from Nov-Dec 2022. Written informed consent was obtained from all the participants of the study. The hospital ethical review committee approved the study protocol (vide ERC number 326 dated 7 Aug 2023). A sample size of 34 was calculated by using Open Epi Software, keeping the reference prevalence of glaucoma to be 2.2%, confidence level of 95%, and power of test 80%⁹ but we included 75 eyes of 75 patients fulfilling the inclusion and exclusion criteria in our study who reported to our department during the study period.

Inclusion Criteria: Patients of both genders, ranging from age 18 to 70 years with normal anterior and posterior segment ocular examination, and upper IOP reading less than or equal to 21 mmHg, and CCT ranging from 510 μ m to 550 μ m, were included in the study.

Exclusion Criteria: Patients who had a known systemic comorbidity, like Diabetes, hypertension, ischemic heart disease, and a history of use of any systemic beta-blocker drugs, a previous diagnosis of Glaucoma or Glaucoma suspect, having history of any previous ocular surgery or trauma were excluded from the study.

Intraocular pressure measurement by using iCare 200 was taken before the GAT to avoid artificially lowering the IOP after GAT. Two different and senior

Ophthalmologists took the readings separately. The second ophthalmologist was unaware of the readings by iCare 200. As a convention, the reading of the right eye was taken, followed by the left eye. However, data of only the right eye was included for the ease of data analysis and comparison.

A second senior Ophthalmologist took the reading on GAT using a 2% fluorescein strip 1 minute after instillation of topical proparacaine 0.5% eye drops. An average of 6 readings was taken. TOPCON® SP 3000 Specular microscope was used to measure CCT, and a minimum of 3 readings were documented. The data was subsequently input into Statistical Package for Social Sciences version 23 software for analysis. Chi square was applied to compare the Frequency of IOP measured by GAT and IOP measured by iCare 200. A Student's t-test was utilized to compare the IOP means obtained by both methods and CCT. A p-value of less than or equal to 0.05 was considered statistically significant.

RESULTS

Out of a total of 75 patients, 40(53.3%) were males, while 35 were females (46.7%). Age of the studied individuals ranged from 19 to 67 years, and mean age was 43.02 $\pm$ 11.3 years. Mean CCT was 529 $\pm$ 10.83 μ m. Mean IOP measured by GAT was 15.14 $\pm$ 3.03 mmHg, while that measured by iCare 200 RT was 13.90 $\pm$ 3.18 mmHg. Readings by iCare 200 were relatively lower than those measured by GAT. The mean difference (IOP by GAT - IOP by iCare 200) in IOP by the two methods was 1.21 $\pm$ 0.77 mmHg, with a minimum difference being -2.50 mmHg and maximum difference being 3.50 mmHg. *p*-value for the difference in means was statistically significant i.e. *p*<0.01. Correlation between CCT and IOP by iCare 200 and IOP by GAT was statistically significant (*p*<0.05), as shown in Table-I.

Table-I: Association of Central Corneal Thickness with Intraocular Pressure Measured By Icare 200 And Goldmann Applanation Tonometer (n=75)

Central Corneal Thickness (m)	Intraocular Pressure Readings by iCare 200 (mmHg)		p-Value	Intraocular Pressure Readings by Goldmann Applanation Tonometer (mmHg)		p-Value
	3 to 15	16 to 21		3 to 15	16 to 21	
510 to 525	22 (29.34%)	6 (8.00%)	0.02	19 (25.34%)	9 (12.00%)	0.03
526 to 550	25 (33.34%)	22 (29.33%)		20 (26.67%)	27 (36.00%)	

DISCUSSION

In 75 patients with normal central corneal thickness, mean intraocular pressure measured by GAT was 15.14 $\pm$ 3.03 mmHg, compared with 13.90 $\pm$

3.18 mmHg by iCare 200. The mean difference between the two methods was 1.21 ± 0.77 mmHg, with iCare 200 showing consistently lower readings. The difference between the measurements was statistically significant ($p < 0.01$).

Table-II: Association of means for intraocular pressure measured by iCare and Goldmann applanation tonometer (n=75)

Intraocular Pressure Readings by Goldmann Applanation Tonometer (mmHg)	Intraocular Pressure Readings by iCare 200		p-value
	3 to 15 (mmHg)	16 to 21 (mmHg)	
3 to 15 (mmHg)	39 (52.00%)	Nil	<0.01
16 to 21 (mmHg)	8 (10.67%)	28 (37.34%)	

Overall, iCare 200 provided comparable readings to GAT but showed a slight tendency to underestimate intraocular pressure. Accurate IOP measurements are invaluable in screening and monitoring patients with Glaucoma. IOP remains the only modifiable risk factor in the management of Glaucoma.¹⁰ Thus, a reliable measurement of IOP has pivotal role in the diagnosis and treatment of Glaucoma.¹¹ Measurement of IOP by cannulation of the anterior chamber remains the gold standard for IOP measurement. However, it still has a limited role in clinical management due to its limited availability, large disease burden, and invasive nature of the test.¹² To date, GAT has the privilege of being the global standard method for accurate and reliable measurement of IOP and is also considered a standard for comparison of IOP measurements by other clinically available methods.¹³ GAT works on the Imbert-Fick principle and measures the intraocular pressure by application of force required to applanate the central 3.06 mm² of the cornea.¹⁴ iCare, a newer portable IOP measuring device based on the principle of rebound tonometer, has shown comparable IOP measurements as compared to GAT, especially in animal models. Gao F *et al.*, studied iCare and GAT readings in patients with normal corneas and documented the results of both tonometers having a statistically significant correlation ($r=0.806$, $P=0.001$). The iCare measurements were a little lower than those obtained with GAT (-0.22 ± 3.07 mmHg), similar to the results of our study.¹⁵

Salvetat *et al.*, also compared iCare with GAT and found iCare significantly underestimated IOP in all groups compared with GAT (GAT minus iCare of 3.5 ± 3.5 mmHg, $P < 0.001$). The results were somewhat similar to our study, where the mean difference in IOP

between the measurements of two tonometers was $1.21 (\pm 0.77)$ mmHg.¹⁶ Sachdeva *et al.*, compared GAT with iCare Pro and iCare 200 and found a reasonable agreement between readings of the above three tonometers. However, both iCare tonometers underestimated IOP by approximately 2 mmHg compared with the GAT, and the results were quite similar to our mean difference between GAT and iCare.¹⁷ Subramaniam *et al.*, in their study on 1000 eyes, reported that mean IOP was significantly lower when measured by iCare than by GAT (12.1 vs. 16.2 mmHg, $p < 0.0001$) as reported in our study i.e. IOP measured by GAT was $15.14 (\pm 3.03)$ mmHg while that measured by iCare RT was $13.90 (\pm 3.18)$ mmHg.¹⁸ A local study by Mirza *et al.*, also compared iCare with GAT and found underestimation of IOP by iCare. Furthermore, they documented that the difference between the mean iCare vs Goldmann applanation tonometer readings was statistically insignificant (p -value = 0.867).¹⁹

LIMITATION OF STUDY

The sample size was small in our case. Moreover, only individuals with normal IOP and anterior and posterior segment examination were included in the study. Furthermore, patients with only normal CCT were included in the study. The results of the study can be extrapolated to individuals with normal IOP and CCT and not to patients with glaucoma or patients having any other ocular pathology.

CONCLUSION

The iCare 200 rebound tonometer demonstrated intraocular pressure readings that were generally comparable to those obtained with Goldmann applanation tonometry in patients whose central corneal thickness was within the normal range. Nevertheless, iCare 200 produced slightly lower measurements than GAT, indicating a small but consistent tendency to underestimate intraocular pressure. Its portability, ease of use, rapid measurement, and lack of requirement for topical anesthesia make it a practical option for routine screening and clinical assessment. However, the observed difference between the two instruments should be considered when interpreting readings, particularly near diagnostic or treatment thresholds. Therefore, GAT should remain the reference method when precise intraocular pressure assessment is clinically important.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

TAK & TA: Data acquisition, data analysis, critical review, approval of the final version to be published.

AK & AQ: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

SHB & OI: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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