Original Article

Can higher end tonometers be used interchangeably in routine clinical practice?

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Context: Precise intraocular pressure (IOP) measurement is important in glaucoma practise. Various instruments are available today to accurately measure IOP. Thus, the question arises about which instrument to use and whether all of them can be used interchangeably. **Aims:** To assess the agreement between noncontact tonometer (NCT), rebound tonometer (RBT), Goldmann applanation tonometer (GAT), and dynamic contour tonometer (DCT) in measuring IOP. **Subjects and Methods:** 499 eyes of 250 patients were evaluated during a period of 24 months from September 2010 to August 2012 and measurement of IOP by NCT, RBT, GAT, and DCT was done in the given sequence. The agreement was assessed by use of the Bland–Altman plot keeping GAT as a gold standard technique. **Results:** The mean IO*P* value of NCT, RBT, GAT, and DCT was 15.9 ± 5.5, 15.9 ± 5.8, 15.9 ± 4.9, and 16.0 ± 4.7 mm of Hg, respectively. The limits of agreement of GAT with DCT, NCT, and RBT were found to be +5.4 to −5.2, −4.7 to +4.6, and −5.2 to +5.1 mm of Hg, respectively. **Conclusions:** A positive and strong correlation was found between newer tonometers and GAT, but the limit of agreement was clinically unacceptable. The use of a single tonometer should be practised at a glaucoma clinic for a patient at each follow-up.

Key words: Bland–Altman plot, dynamic contour tonometer, Goldmann applanation tonometer, intraocular pressure, noncontact tonometer, rebound tonometer

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In routine clinical practice, intraocular pressure (IOP) measurement along with visual field assessment and optic disc evaluation not only holds a key role in the diagnosis of glaucoma but also for following the progression of this disease and its response to treatment.

At present, in the armamentarium of glaucoma management, achieving "target IOP" is the only available treatment option that reduces retinal ganglion cell loss. Hence, its value as a diagnostic tool hinges on the reliability of measurements taken.

With newer technologies emerging in the field of tonometry and questionable role of Goldmann applanation tonometer (GAT) as a gold standard in corneas with abnormal thickness,[1,2] it is necessary to evaluate the agreement of various tonometers with GAT, i.e., whether these new tonometers can replace the gold standard or can be used as an alternative.

Subjects and Methods

Ethical permission was taken from Human Research and Ethics Committee and written informed consent was taken from the patients participating in the study.

This study is a hospital based study of patients attending the outdoor patient Department of Ophthalmology and those who were admitted in the ophthalmic ward. 499 eyes of 250 patients were examined, and documentation was done.

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Inclusion criteria

1. Patients with age more than 14 years and <75 years
2. Patients with glaucomatous disc changes
3. Ocular hypertensive patients
4. Healthy individuals.

Exclusion criteria

1. Patients with age <14 years and more than 75 years
2. Patients having history of baseline corneal diseases including corneal dystrophy, keratoconus, iridocorneal endothelial syndrome, etc.
3. Patients having history of rigid and soft contact lens use
4. Patients having history of inflammatory eye diseases
5. Patients having history of refractive laser surgery and keratoplasty
6. Patients having history of ocular trauma in last 6 months
7. Patients having history of ocular infection in last 3 months
8. Patients having history of showing noncompliance with respect to dosing schedule, visit schedule, and study procedure
9. Debilitated and bed ridden patients.

Methodology

Complete ocular history including key signs and symptoms at the time of presentation and the duration of the disease

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was noted. Medication history was noted in glaucomatous patients regarding dosage and frequency of instillation of drops.

Complete medical history regarding systemic diseases like hypertension, diabetes mellitus, renal failure, etc., was noted.

All patients were evaluated for best corrected visual acuity by illuminated Snellen's chart for 20 feet distance, near vision was measured with reduced Snellen's near vision chart. Slit lamp biomicroscopy was performed with Appasamy AIA-11 5S. Detailed fundus examination with direct ophthalmoscope (Heine's β 200) and slit lamp biomicroscopy with +78D lens (volk) was performed.

Measurement of IOP by NCT (Topcon CT-80), rebound tonometer (RBT) (iCare), GAT (Haag-Streit), and dynamic contour tonometer (DCT) (Pascal's) was done in the given sequence.[3-5] An interval of 10 min was kept between each procedure, and an average of three readings was documented.[6]

Statistical analysis was done with the help of SPSS-16.0 (SPSS Inc., Chicago, IL, USA) and SigmaPlot 12.1 (Systat Software, San Jose, CA, USA). Association between variables was assessed by using Pearson's correlation coefficient. Bland–Altman plots were constructed for assessing agreement between different tonometers keeping GAT as a gold standard. The systematic mean difference was termed "bias." Ninety-five percentage confidence interval (CI) or limits of agreement (LoA) was calculated as a mean difference ±1.96 standard deviation, which provided interval within which 95% of difference between measurements by two devices were expected to lie.

Results

In the study group, the mean age was 50.08 ± 14.98 years. And the maximum number of patients was from the age group of 41 to 60 years (43.6%). A male preponderance with 61.2% males as compared to 38.8% female patients was found in the current study group. Three hundred and ninety-three eyes (197 patients) of normal patients, 78 eyes (39 patients) of glaucoma patients, and 28 eyes (14 patients) of patients with ocular hypertension were examined.

The mean IO*P* value of noncontact tonometer (NCT), RBT, GAT, and DCT was 15.9 ± 5.5, 15.9 ± 5.8, 15.9 ± 4.9, and 16.0 ± 4.7 mm of Hg, respectively.

An excellent correlation was found between DCT and GAT by Pearson's correlation coefficient (*r* - 0.84). It was observed from the Bland–Altman plot that the mean difference between GAT and DCT was good (bias - 0.14) which was close to the zero line but the LoA between the two instruments was wide (+5.4 to −5.2) [Fig. 1]. A positive bias shows that there is a mild overestimation of measurements by DCT as compared to GAT. Moreover, the plot shows that there is a good agreement between the two instruments as the average of the two measurements increase.

An excellent correlation was found between NCT and GAT by Pearson's correlation coefficient (*r* - 0.9). It was observed from Bland–Altman plot that the mean difference between GAT IOP and NCT IO*P* values was good (bias - −0.006) showing a good concordance between GAT and NCT measurements but the LoA was wide (−4.7 to +4.6) [Fig. 2].

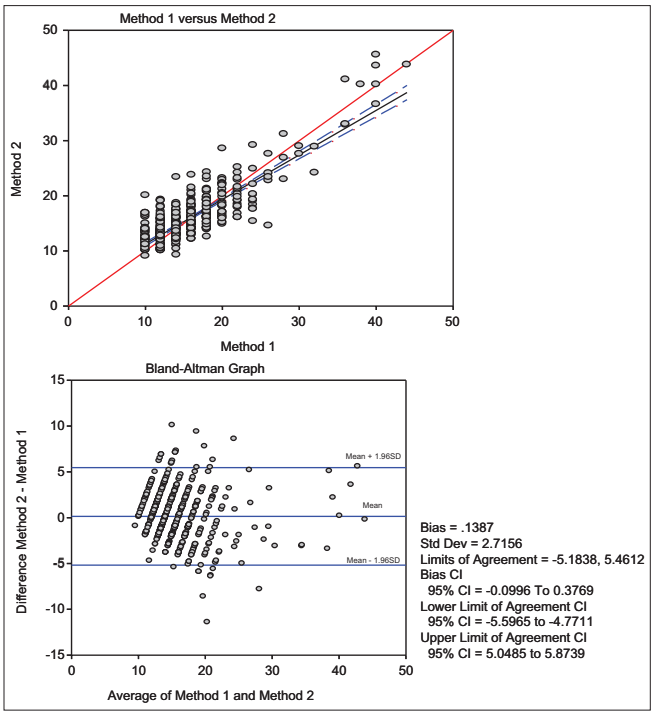

Figure 1: Comparison of Goldmann applanation tonometer (method 1) with dynamic contour tonometer (method 2)

The scatter plot between GAT and RBT showed a good correlation between the two by Pearson's correlation coefficient (*r* - 0.89). It was observed from Bland–Altman plot that the mean difference between GAT IOP and RBT IO*P* values was good (bias - −0.016) which shows a good concordance between the two but the LoA being −5.2 to +5.1 is not clinically acceptable [Fig. 3]. It was observed from the plot that the deviation of the scatter around the bias line is low till average IO*P* values of about 20. Hence, RBT can play a good role in glaucoma screening programs.

Discussion

Since the introduction of GAT in 1957, it is enjoying the privilege of being the gold standard instrument for measuring IOP and is awaited by a tonometer to take its place. It relies on the principle of Imbert-Ficks law and its major limitation is nonreliability in patients with abnormal corneal thickness.

In 1970s, NCT came into use as paramedical staff could not instill eye drops in patients in the USA. It also works on the principle of applanation and a jet of air is used to applanate the cornea.

Around the year 2000, there was an emergence of rebound tonometry after being used for some time in animal research and the commercial iCare tonometer being available since 2003. It electromechanically measures the deceleration of probe after bouncing back from the cornea and provides IOP. Rebound tonometry (RT) has been used with ease in pediatric patients because of its innate qualities like portability, use in reclining position, good tolerability, and use without anesthesia.[7]

In 2002, Pascal's DCT was introduced to eliminate or reduce systematic errors inherent to all previous tonometers such

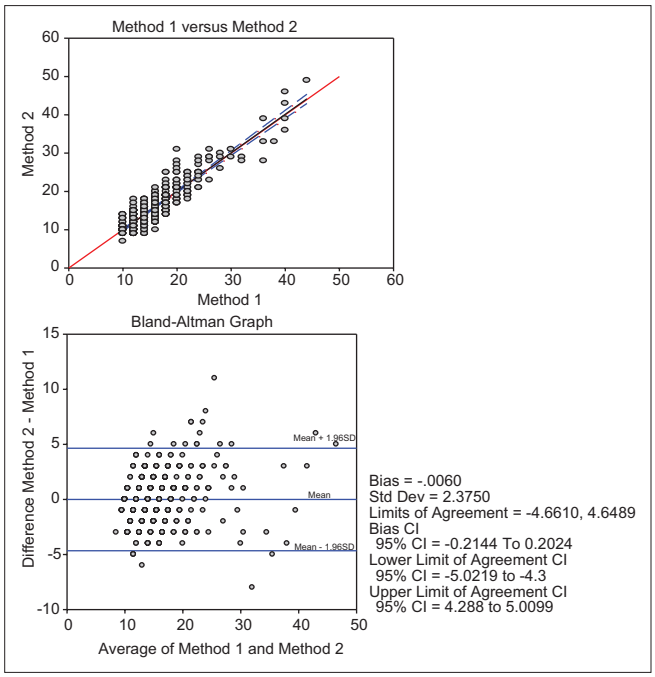

Figure 2: Comparison of Goldmann applanation tonometer (method 1) with noncontact tonometer (method 2)

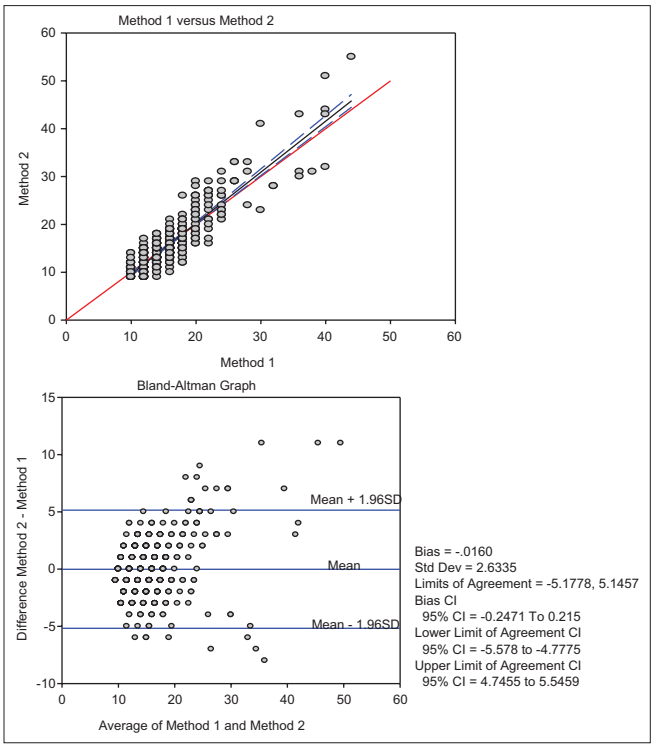

Figure 3: Comparison of Goldmann applanation tonometer (method 1) with rebound tonometer (method 2)

as the influence of corneal thickness, rigidity, curvature, or elastic properties and became a very reliable instrument in post-LASIK patients.[8] Dynamic (continuous pulsatile IOP) contour (matching contour of the cornea) tonometry works on the concept of contour matching, a concept differing from the already existing tonometers of indentation and applanation method. As with GAT, its major limitation is nonreliability in patients with corneal pathologies.

Since 1898, it has been known that there occurs normal diurnal variation in IOP which increases in glaucoma patients.[9] Most of the times IOP is measured in ophthalmologist's clinic during office hours, and this important aspect is missed which can have clinical implications in screening and management of glaucoma. Both NCT and RT are used for home tonometry as they do not require anesthetic eye drops, have good reproducibility, and no risk of infection as used with disposable tips (RT) or air (NCT). RT seems to be an appropriate instrument for self-tonometry[10] and is under clinical trials for Food and Drug Administration approval for being used as a self-tonometer.

As newer tonometers had distinct advantages over GAT, studies were conducted to evaluate the efficacy and accuracy of these tonometers and their ability to replace GAT in routine practice.

Study conducted by Barleon *et al*. found disagreement between DCT and GAT and suggested that both cannot be used interchangeably in clinical practice. They observed that at smaller IO*P* values DCT measured higher than GAT, whereas for higher IO*P* values DCT measured lower than GAT.[11] Heras-Mulero *et al*. also found that it was impossible to measure IOP in 7.3% of the patients.[12] Similarly, studies conducted by Salvetat *et al*. (LoA 0.1–6.8 mmHg)[13] and Carbonaro *et al*. (LoA - 0.49–6.2 mmHg)[14] have found the agreement clinically unacceptable and DCT measuring higher IOP than GAT.

Tonnu *et al*.[15] concluded that there was a moderate agreement between GAT and NCT (Cannon TX-10) and that NCT overestimated IOP at higher values and underestimated at lower values, a finding observed in other studies like those of Salim *et al*. (portable PT100)[16] and Ahmad *et al*. (Keeler PT100).[17]

Munkwitz *et al*. observed that there was a moderate agreement between RT and GAT in normal to moderate elevated IOP, and a poor agreement in the higher IOP range (95% CI -

8.7–10.2 mm Hg in 62.7%).[18] Similarly, Sahin *et al*. (95% CI - 4.4–5.3 mmHg),[19] Fernandes *et al*., (95% CI - 2.6–5.3),[20] and Martinez-le-da-casa *et al*. (95% CI - 3.7–7.3 mm Hg)[21] concluded that RT can be used as an alternative to GAT in low to moderately elevated IOP but not in higher IOPs and that it is a good screening tool.

Cook *et al*. conducted a meta-analytical study comparing 8 tonometers and concluded that GAT continues to be the gold standard. It was observed that NCT was having least disagreement with GAT (NCT - 3.8–4.3, RT - 4.3–6.1, and DCT - 2.9–6.5 mm Hg), a finding similar to our study.[22]

In our study, it was observed that in spite of good correlation between GAT and other newer tonometers, the LoA was found to be clinically unacceptable proving the role of Bland–Altman plot in comparison of newer devices with the gold standard technique. Moreover, the role of a single tonometer in glaucoma practise at each follow-up examination is emphasized. RBT being a simple, portable device can be incorporated as a tool in

glaucoma screening programs. The role of various parameters like ocular pulse amplitude, corneal curvature, refractive error, axial length, corneal hysteresis, and ocular rigidity as a confounder needs to be assessed by measuring the agreement between various tonometers.

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Conflicts of interest

There are no conflicts of interest.

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