Comparison of iCare rebound tonometer, non-contact tonometer and Goldmann applanation tonometer in intraocular pressure measurement

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ABSTRACT

Objective: To compare intraocular pressure (IOP) measurements provided by the iCare rebound tonometer (RBT), non-contact tonometer (NCT) and Goldmann applanation tonometer (GAT) in healthy people and to analyze the correlation between central corneal thickness (CCT) and IOP measurements.

Materials and Methods: This retrospective study included 318 eyes of 161 patients, having a mean age of 42.8±14.8 years (range 12 to 84 years). All eyes were healthy without any anterior or posterior segment abnormalities. IOP was measured with the RBT and NCT before they received topical anesthetic, and with the GAT after instillation of topical proparacaine, with a 5-minute interval between readings, respectively. CCT was measured using an ultrasonic pachymeter after all IOP measurements had been made under topical anesthesia.

Results: The mean IOP values of NCT, RBT, and GAT were 17.94±5.19 mmHg, 17.66±4.04 mmHg, and 15.69±3.89 mmHg, respectively. The average CCT was 530.7±40.84 µm. There was no significant difference between the IOP measured by the NCT and RBT ($p=0.822$). There was a significant difference between the IOP measured by the RBT-GAT and NCT-GAT ($p<0.001$ and $p<0.001$, respectively). A significant positive correlation was found between IOP results (with all IOP measuring devices) and CCT.

Conclusion: In routine outpatient screening, tonometers such as RBT can be considered as an alternative to GAT because of their advantages such as ease of measurement and low infection risk. In particular, using RBT for screening and confirming the diagnosis with GAT when necessary seems to be an appropriate approach.

Keywords: Intraocular pressure, iCare rebound tonometer, non-contact tonometer, Goldmann applanation tonometer.

INTRODUCTION

Intraocular pressure (IOP) measurements are widely used in ophthalmology clinics and are of great importance in terms of glaucoma diagnosis. In routine clinical practice, Goldmann applanation tonometer (GAT) remains the worldwide accepted for IOP measurement and is currently one of the most popular tonometers available.[1,2]

However high astigmatism may increase the error rate of GAT, in addition, some limitations such as the necessity of topical anesthesia and fluorescein instillation, difficulty in using it in childhood, and measurement difficulties in disabled, bedridden patients, led clinicians to seek alternatives to GAT. Therefore, various alternatives have been developed. Non-contact tonometer (NCT) and the rebound tonometer (RBT) are the most widely used ones.[3]

NCT uses a standardized air blast method to flatten the cornea. The device is operator-independent, does not require topical anesthesia, and also eliminates the potential risk of corneal abrasion and slow virus transmission.[1,3] However, it can frighten the patient with its blowing force

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and noise. It can aerosolize the tear film and theoretically transmit viruses through the air.[4,5]

The RBT is a newer handheld portable tonometer. It calculates IOP by measuring the parametric variation of motion after the probe strikes the cornea.[6] It can be used in challenging pediatric patients and disabled patients without the need for corneal anesthesia and fluorescein application. It is also suitable for self-measurement and for inpatients.[7-9]

RBT and NCT are painless procedures. Since RBT has disposable tips and NCT does not have direct contact with the eye, they can be used more safely in microbial infections.[3]

In this study, we aimed to compare IOP measurements provided by the iCare RBT, NCT, and GAT in healthy populations and to evaluate the correlation between the central corneal thickness (CCT) and IOP measurements of the three tonometers.

MATERIALS AND METHODS

Study Design

This retrospective study included 318 eyes of 161 patients (91 females, 70 males) aged 12 to 84 years, between February 2016 and March 2017. Ethics approval was obtained from the Haseki Training and Research Hospital Ethics Committee (284/2016) and the study complies with the principles of the Declaration of Helsinki. The data were scanned electronically, and an informed consent form was not obtained from the patients.

Patients

Patients having history of corneal diseases, rigid or soft contact lens wear, history of inflammatory eye diseases, history of cataract, refractive laser surgery or keratoplasty, intraocular surgery, patients diagnosed with glaucoma, astigmatic refractive error above ± 3dpt, and ocular trauma were excluded. Patients without any anterior or posterior segment pathologies were included in the study.

All patients' IOP readings were taken by using the NCT (NCT-10®, Shin-Nippon, Kagawa, Japan) and RBT (iCare Pro®, Vantaa, Finland Oy) before topical anesthetic administration, and by GAT (CSO® A900, Firenze, Italy) attached on a slit-lamp biomicroscope after topical proparacaine (Alcaine, Alcon, Ft. Worth, TX, USA) and sodium fluorescein administration, with a 5 minute intervals between readings. IOP measurements were performed by two doctors and one technician, unaware of each other. After then, central corneal thickness (CCT) was measured with an ultrasonic pachymeter (Tomey SP-100®, Germany). To reduce the margin of error, corneal thickness was taken as the average of eight consecutive measurements. Eight consecutive CCT values were measured and the mean of the readings was automatically calculated and recorded.

First, without topical anesthetic administration, 6 measurements were taken from the central cornea using the RBT at a distance of 4-8 mm from the central cornea; the highest and the lowest readings were discarded and then the mean value was calculated. Since RBT is a relatively new device and can be measured quickly, 6 consecutive measurements were performed to increase measurement accuracy. Then, the patient was seated at the tabletop model of NCT and without any topical anesthetic drop administration, the patient was asked to fixate at the target. An air-puff was automatically triggered when alignment was satisfactory. Three IOP readings were gained and the mean value was calculated automatically.

After the RBT and NCT readings, the patients' cornea was anesthetized with topical application of 0.5% proparacaine hydrochloride, and the tear film was stained with sodium fluorescein paper strips. Then the IOP measurement was performed 3 times by using the GAT in a sitting position. Subsequently, the average value was calculated.

The same RBT, NCT, and GAT devices were used throughout the study. All patients' IOP measurements were obtained in the sitting position. At the beginning of each study session, all the instruments were calibrated according to the manufacturer's instructions.

Statistical analysis

All statistical analyses were performed by using Statistical Package for Social Science (SPSS® 15.0 for Windows; SPSS Inc, Chicago, USA). Kolmogorov-Smirnov test was used to find out whether the study variables were normally or non-normally distributed. Association between variables was assessed by using Spearman's correlation coefficient and Mann-Whitney U test. Bland-Altman plots were constructed to assess the clinical agreement between the three different tonometers keeping GAT as a gold standard.

RESULTS

Three hundred eighteen eyes of 161 patients were included in this study. There were 91 (56.52%) female and 70 (43.48%) male in the study group. The mean age of the subjects was 42.8±14.8 years (range 12 to 84 years).

The mean IOP values of NCT, RBT, and GAT were 17.94±5.19 mmHg, 17.66±4.04 mmHg, and 15.69±3.89 mmHg, respectively. The average CCT was 530.7±40.84 µm.

There was no significant difference between the IOP measured by the NCT and RBT (Mann-Whitney U test, p=0.822). There was a significant difference between the IOP measured by the RBT and GAT (Mann-Whitney U test, p<0.001). There was a significant difference between the IOP measured by the NCT and GAT (Mann-Whitney U test, p<0.001) (Table 1).

Table 1. *Comparison of measurement methods*

Measurement methods		Significance
NCT 17,94±5,19 (mmHg)	RBT 17,66±4,04 (mmHg)	p=0,822
RBT 17,66±4,04 (mmHg)	GAT 15,69±3,89 (mmHg)	p<0,001*
GAT 15,69±3,89 (mmHg)	NCT 17,94±5,19 (mmHg)	p<0,001*

NCT: non-contact tonometer, RBT: rebound tonometer, GAT: Goldmann applanation tonometer
* Statistically significant difference p <0.05 (Mann-Whitney U test)

A significantly positive correlation was found between RBT, NCT, GAT measurements, and CCT (Table 2).

Table 2: *Correlation of CCT and intraocular pressure measurements*

		p	r
CCT	RBT	0.007	0.523^
	NCT	0.116	0.560^
	GAT	0.219	0.417^

CCT: central corneal thickness, NCT: non-contact tonometer, RBT: rebound tonometer, GAT: Goldmann applanation tonometer
Statistically significant difference p <0.05
^ Spearman's correlation analysis

The agreement of the obtained IOP values by the three methods was observed by estimating the 95% limits of agreement. The limits of agreement between RBT-GAT (Figure 1A) and NCT-GAT (Figure 1B) measurements were presented in a Bland–Altman plot.

DISCUSSION

IOP measurement is a very important method in the diagnosis and treatment of glaucoma. GAT continues to be considered as a more appropriate and dependable technique for intraocular pressure measurement.[1] GAT, which is widely used in clinical practice today, has encouraged physicians to seek alternatives due to disadvantages such as the necessity of slit-lamp biomicroscopy, need for topical anesthetic and fluorescein instillation, difficulties in use in pediatric age and disabled patients, risk of local trauma

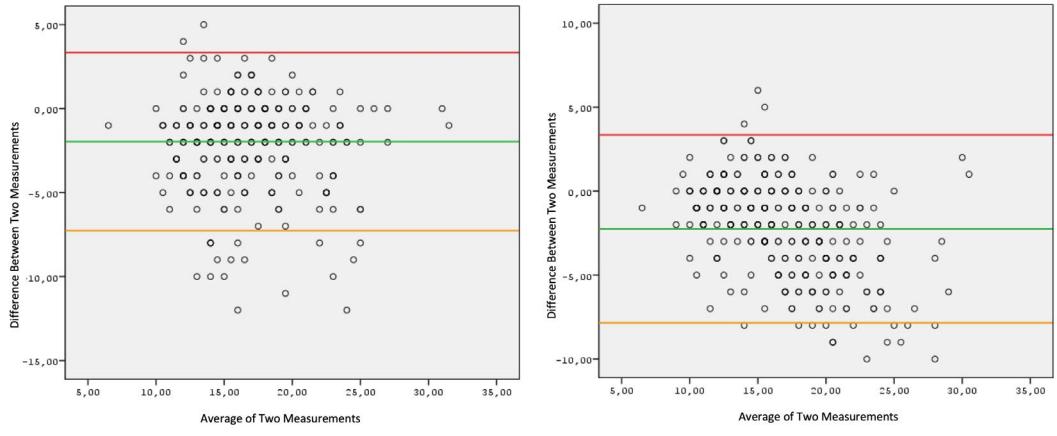

Figure 1: *Bland–Altman plot showing agreement between the RBT (1A) and NCT (1B) values with GAT obtained in our study.*

**IOP: intraocular pressure, RBT: rebound tonometer, GAT: Goldmann applanation tonometer, NCT: non-contact tonometer*

in the cornea, and allergic reactions.[10] From this point of view, various alternatives have been developed for IOP measurement.[11,12] RBT and NCT are some of these.

Some studies have suggested that these devices may be used interchangeably in a routine clinical setting. They even found the IOP readings to be quite compatible with those obtained with the GAT. However, they also stated that pachymeter should be taken into account in terms of CCT effects.[13-15] Kim KN et al. evaluated the clinical usefulness of RBT in glaucoma patients and RBT showed a good correlation with GAT despite the provided higher IOP values than GAT. RBT was found to be a reliable method.[16] Şahin et al. compared RBT with GAT in glaucoma patients and evaluated the effect of CCT on IOP measurements obtained by the two methods.[17] They found that RBT slightly overestimated IOP compared to GAT and was more affected by CCT. Galgauskas et al. found that RBT overestimated IOP when compared with GAT.[18] They concluded that RBT could be used instead of GAT since there was no significant difference between their results. In our study, we found higher values in RBT measurements than GAT measurements ($p<0.01$). However, there was a strong correlation between the measurements. There was a positive correlation between both measurements and CCT values.

Gomez et al. emphasized that RBT is effective as a reliable tool for IOP measurement and glaucoma management in healthy patients and patients undergoing myopic laser-assisted in situ keratomileusis (LASIK) surgery.[19] Krolo et al. have shown that RBT can be measured via soft contact lenses and the results are feasible and accurate.[20] In these results, RBT may be a priority method, especially for post-operative patients because of its less traumatic nature. However, in our study, we found a significant difference between IOP measured by RBT and GAT in non-operated patients ($p<0.001$).

While there was no significant difference between NCT and GAT measurements in some studies, NCT values were found to be higher than GAT in some publications.[21-23] In Farhood's study, a significant difference was found between the NCT and GAT measurements, but the correlation was not examined. In our study, NCT measurements were found to be higher than GAT measurements. In addition, when we looked at the correlation in our study, there was a significant difference between IOP results measured by NCT and GAT ($p<0.001$).

Martinez-de-la-Casa et al. compared RBT, NCT, and GAT methods.[3] They obtained similar IOP measurements with RBT and NCT compared to GAT. They also found that RBT and NCT were similarly affected by CCT. These results supported our results. In our study, there was no significant difference between IOP measured by NCT and RBT ($p=0.822$). Also, we found a positive correlation between CCT thicknesses between tonometers. Kim et al. stated that as the CCT value increases, the difference between IOP results measured by GAT and NCT also increases.[24] However, it should be noted that while our study was conducted with data from healthy individuals, Kim et al. studied patients with glaucoma.

Tamçelik et al. evaluated RBT, NCT and GAT on patients who applied to the glaucoma outpatient clinic and showed the correlation between these three methods.[25] They found the concordance between RBT and GAT measurements higher in the 9-22 mmHg IOP range. They noted that the variability of RBT and GAT measurements was minimal over a wide range of CCTs. In addition, the correlation with CCT was found to be significant. In our study, a positive correlation was found with CCT measurement in all three different IOP measurement methods.

RBT and NCT seem to be more advantageous than GAT in measuring IOP in the pediatric age group. Grigoryan F et al. reported that RBT is more easily tolerated in children and reduces the need for examination under anesthesia for the evaluation of pediatric glaucoma.[26,27]

Although RBT measurements do not give exactly the same results as GAT measurements, some authors state that RBT can be used as a screening test because of the good correlation between them.[28,29] López-Caballero et al. compared RBT with GAT in the glaucoma unit. Considering that RBT often overestimates IOP compared to GAT, they stated that it can be used in a clinical setting and suggested that RBT should be used in glaucoma screening programs because of its advantages.[28]

A recent study found that reusing iCare probes up to 5 times once disinfected did not compromise the accuracy of IOP measurements.[30] This finding is important in terms of cost-effectiveness of iCare. In our study, we used iCare probes only once.

In patients with thyroid-related orbitopathy, NCT significantly overestimates IOP compared with GAT and iCARE. In contrast, iCARE rebound tonometry provides IOP measurements comparable to the gold standard GAT in these patients.[31] These results are similar to the results we obtained on healthy individuals in our study.

Although this study has limitations such as its retrospective nature and not evaluating corneal biomechanics, it is anticipated that it will shed light on studies comparing tonometers with different working principles and ease of use.

In conclusion, GAT is an important measurement method in IOP measurement in the diagnosis and follow-up of patients with glaucoma. In cases with high IOP, the same findings may not be obtained between tonometers. However, in routine outpatient screening, tonometers like RBT may be considered as an alternative to GAT because of their advantages such as ease of measurement and low risk of infection. On the other hand, the 2 mmHg difference between the measurement results should also be taken into account. Therefore, we think that it would be appropriate to use RBT especially for screening purposes, and to confirm the diagnosis with GAT when necessary. In addition, our article is important in terms of showing the data from the Turkish population.

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