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EFFICACY AND CORRELATION OF INTRAOCULAR PRESSURE MEASURED BY NON-CONTACT, REBOUND AND GOLDMANN APPLANATION TONOMETER WITH CORNEAL THICKNESS, TRUE IOP AND CORNEAL CURVATURE IN A TERTIARY HOSPITAL.

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Abstract

Aim: To compare the intraocular pressure (IOP) measured by Non-Contact tonometer (NCT), Rebound tonometer (RBT) and Goldmann Applanation tonometer (GAT) and their correlation with central corneal thickness (CCT), true IOP and corneal curvature.

Reliability of each tonometer.

Methods: 500 random patients aged 18 years and above were taken up for the study. Patients with anterior and posterior segment pathologies like corneal ulcer, leukoma, staphyloma, corneal lacerations, ectatic corneal conditions, corneal dystrophies, oedema, perforations, acute angle closure glaucoma, retinal detachments, vitreous haemorrhage and unwilling patients were excluded from the study. IOP was recorded using NCT, RBT and GAT after assessing the patient's visual acuity. Following IOP measurement, central corneal thickness (CCT) of each patient was measured using pachymetry. Kvalues were measured using an autorefractometer. All the data were collected and tabulated for statistical analysis to obtain results.

Results: The mean CCT in males was 0.5350 mm and in females 0.5340 mm respectively. The mean IOP measured by NCT is 16.43 mm hg whereas the mean IOP measured by GAT is 15.43 mm hg. IOP measured by NCT is significantly higher than the IOP measured by GAT ($p<0.001$). When NCT and RBT are compared NCT values are significantly higher than that of RBT($p<0.001$). Although the mean RBT IOP 15.83 mm hg is higher than the mean GAT IOP of 15.42 mm hg the values are not statistically significant. When correlated with CCT all the tonometers showed significant correlation with GAT showing the strongest correlation. NCT overestimates IOP in normal, thin and thicker corneas when compared to GAT and are statistically significant. RBT also overestimates in the normal and thick corneas when compared to GAT but their values are much closer to GAT values in thinner corneas. The IOP measured by all the 3 tonometers correlated with corrected IOP with NCT showing the best correlation followed by GAT. There was no significant correlation between K and IOP in our study.

Conclusion: From the present study we can conclude that IOP measured by NCT and RBT is higher than GAT. NCT values are significantly higher than GAT values in thin and normal corneas whereas it overestimates more in thicker corneas. RBT values are significantly higher than that of GAT in normal and thick corneas. All the tonometers show significant correlation with CCT with GAT showing the strongest correlation. So, it is always advisable to measure the corrected IOP for each patient after considering the CCT.

Keywords: Non-contact tonometer; Goldmann applanation tonometer; central corneal thickness; intraocular pressure; Rebound tonometer, True IOP, Corneal curvature.

Introduction

Intraocular pressure (IOP) measurement has an important role in case detection and management of primary open angle glaucoma. Ocular hypertension (OHT) is associated with an increased risk of developing glaucoma, and reducing IOP has been shown to lessen progressive loss of the visual field. Accurate and precise measurement of IOP is, therefore,

fundamental to management of glaucoma.

For almost 50 years Goldmann applanation tonometer has been the gold standard for intraocular pressure measurement but its values are affected by central corneal thickness, corneal curvature, axial length, previous corneal surgeries like lasik, keratoplasty, astigmatism and corneal irregularities.

Goldmann applanation tonometer gives correct readings when corneal thickness is 500 to 525-micron metre.

Non-contact, rebound tonometer have been found to be reasonable options for screening but their values should always be correlated with corneal thickness in clinical practice.

Several studies recently have found that thinner than average corneas underestimate, while thicker than average corneas overestimate the true intraocular pressure. This effect has been found to be in the effect of 1mmhg correction for every 25-micron metre deviation from a central corneal thickness of 550-micron metre.

Tonometry or the measurement of IOP, the pressure of the fluid inside the eye is usually the only modifiable factor in management of all types of glaucoma.

Aims and objectives of the study:

1. To compare the intraocular pressure readings of Non-contact, Rebound and Goldmann applanation tonometer.
2. To correlate IOP readings with corrected IOP (true IOP).
3. To correlate intraocular pressure readings with central corneal thickness in a general population.

Materials and methods:

500 random patients (1000 eyes) attending the ophthalmology outpatient department above the age of 18 years from July 2017 to July 2019 were included in this study.

After taking a proper informed consent a brief history of the purpose of their visit was taken for all patients. Following history taking the distant visual acuity was checked using the Snellen's chart and the near vision was checked using the Jaeger's chart. Once the vision testing was done if the patient had any refractive error an Autorefractometer was used to find out the amount of refractive error followed by an appropriate correction was given for all patients.

Next slit lamp examination was done to rule out any anterior segment pathology. This was followed by measurement of the keratometric value using the Autorefractometer.

Then the patient's IOP was recorded first using the Non-contact tonometer followed by Rebound tonometer and Goldmann applanation tonometer and all the values were recorded in a proforma. The central corneal thickness and the corrected IOP of each patient was recorded using pachymetry.

Following these dilated fundoscopy was done using the indirect ophthalmoscope. The posterior segment was evaluated using an ultrasound (B-Scan) if the patient had any significant cataract or any other media opacities which obscured the view of the retina.

Inclusion criteria: People aged 18 years to 90 years with no sex predilection.

Exclusion criteria:

1. Patients with corneal opacities, corneal dystrophies, corneal perforations, infective pathologies like ulcers, leukoma, staphyloma, acute uveitis, corneal oedema, acute congestive glaucoma, corneal ectatic conditions.

2. Patients with posterior segment pathologies like retinal detachment, vitreous haemorrhages.

3.Patients not willing to be part of study.

RESULTS:

Table 1: *(number of male and female patients)*

Sex	Number	Percentages
Male	256	51.2
Female	244	48.8
Total	500	100.0

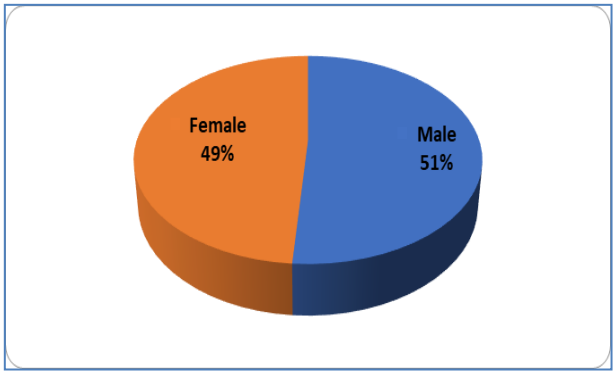

Figure 1: *(pie chart showing percentage of male and female)*

In this study 1000 eyes of 500 patients were taken up. Out of 500 patients 256 were male and 244 patients were female that is 51% were male and 49% were female participants.

Table 2: *(mean CCT in men and women)*

	Male	Female	P value
Mean	.5350mm	.5340mm	0.041
SD	.02829	.02604	

The mean central corneal thickness (CCT) in males is 0.5350mm whereas in females it is 0.5340mm, which shows that females have slightly thinner CCTs when compared to males but are not statistically significant as shown in table 2.

Table 3: *(correlation between NCT IOP and RBT IOP)*

	NCT (mm hg)	Rebound Tonometry (mm hg)	p-value
Mean	16.43	15.83	
Std. Deviation	3.851	2.70	P<0.001

In this study the mean IOP measured by Non-Contact tonometer is 16.43 mm hg whereas the mean IOP measured by Rebound Tonometer is 15.83 which is significantly lower than that of NCT(p<0.001).

Table 4: *(correlation between NCT IOP and GAT IOP)*

	NCT (mmhg)	Goldmann Applanation Tonometry (mmhg)	p-value
Mean	16.43	15.42	p<0.001
Std. Deviation	3.851	2.290	

The mean IOP measured by the Goldmann Applanation Tonometer which is considered to be the goldstandard is 15.42 mm hg which is significantly lower than the mean IOP measured using NCT which is 16.43 mm hg. Thus, when compared with Goldmann, NCT values are higher and are statistically significant in our study.

Table 5: *(correlation between RBT IOP and GAT IOP)*

	Rebound Tonometry (mm hg)	Goldmann applanation Tonometry (mm hg)	p-value
Mean	15.83	15.42	0.40
Std. Deviation	7.866	2.290	

When Rebound Tonometer and Goldmann are compared Rebound values are higher than that measured by Goldmann but are not statistically significant and are also closer to the IOP values obtained with Goldmann. The mean IOP measured by Rebound is 15.83 mm hg whereas the mean IOP measured by Goldmann is 15.42 mm hg. The difference between the mean IOP measured by RBT and that measured by GAT is far less than the difference in the IOP values measured by GAT and NCT and NCT and RBT.

From this intercomparability study we can say IOP values obtained using Rebound tonometer are much closer to Goldmann values which is the gold standard than that obtained using NCT.

When CCT was less than 520-micron metre the mean IOP measured using RBT and GAT were 17.02 mm hg and 16.90 mm hg. Although RBT values were higher than GAT values but were not statistically significant as shown in table 6.

Table 6: *(correlation between RBT IOP and GAT IOP when CCT is <= 520 micron)*

CENTRAL CORNEAL THICKNESS <= 520-micron metre			
	RBT	**GAT**	**P value**
IOP in mm hg	17.02	16.90	< 0.15
SD	3.01	2.76	
Sample size	270	270	

When the corneal thickness was between 520 – 560micron metre mean IOP measured by RBT and GAT were 15.20 mm hg and 14.91 mm hg. The RBT values were higher than GAT and were statistically significant as shown in table 7.

Table 7: *(correlation between RBT and GAT IOP when CCT is 520-560 micron)*

CENTRAL CORNEAL THICKNESS 520- 560micron metre			
	RBT	**GAT**	**P value**
IOP in mm hg	15.20	14.91	< 0.001
SD	2.49	1.67	
Sample size	498	498	

When CCT was more than 560-micron metre mean RBT IOP was 16.56 mm hg which is higher than mean GAT value of 15.41mm hg and are statistically significant as depicted in table 8.

Table 8: (correlation between RBT and GAT IOP when CCT is > 560 micron)

CENTRAL CORNEAL THICKNESS >560-micron metre			
	RBT	**GAT**	**P value**
IOP in mm hg	16.56	15.41	<0.05
SD	3.06	3.16	
Sample size	79	79	

When CCT was less than 520-micron metre the mean IOP measured using NCT and GAT were 16.12 mm hg and 16.90 mm hg. NCT values were lower than GAT and were statistically significant.

Table 9: *(correlation between NCT and GAT IOP when CCT is <= 520micron metre)*

CENTRAL CORNEAL THICKNESS <= 520-micron metre			
	NCT	**GAT**	**P value**
IOP in mm hg	16.12	16.90	< 0.001
SD	3.98	2.76	
Sample size	270	270	

When the corneal thickness was between 520 – 560micron metre mean IOP measured by NCT and GAT were 16.23 mm hg and 14.91 mm hg. The NCT values were higher than GAT and were statistically significant.

Table 10: *(correlation between GAT and NCT IOP when CCT is 521-560micron metre)*

CENTRAL CORNEAL THICKNESS 521- 560micron metre			
	NCT	**GAT**	**P value**
IOP in mm hg	16.23	14.91	< 0.001
SD	3.33	1.67	
Sample size	498	498	

When CCT was more than 560-micron metre mean NCT IOP was 20.41 mm hg which is higher than mean GAT value of 15.41mm hg and are statistically significant as shown in table 11.

Table 11: *(correlation between NCT and GAT IOP when CCT is > 560micron metre)*

CENTRAL CORNEAL THICKNESS >560-micron metre			
	NCT	**GAT**	**P value**
IOP in mm hg	20.41	15.41	< 0.001
SD	5.35	3.16	
Sample size	79	79	

NCT IOP values increase as the CCT increases whereas GAT IOP is highest when the CCT is less than 520-micron metre. RBT and GAT overestimates IOP values more when CCT is less than 520-micron metre whereas NCT values were less than that of RBT and GAT when CCT is less than 520-micron metre.

Figure 2 is a scatter diagram showing the correlation between NCT and CCT. NCT values are correlating with CCT and is statistically significant.

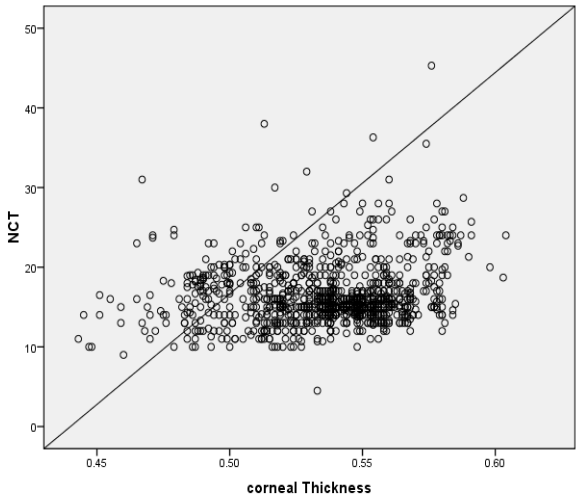

Figure 2: *(graph showing correlation between NCT IOP and CCT)*

Figure 3 shows the correlation between RBT IOP and CCT. RBT IOP correlates significantly with the CCT.

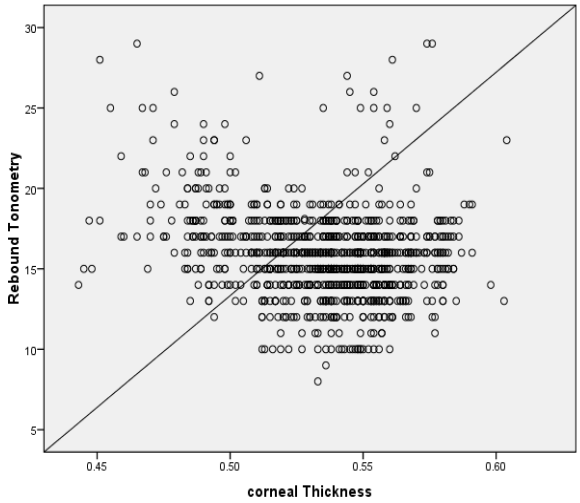

Figure 3: *(graph showing correlation between RBT IOP and CCT)*

Figure 4 shows the correlation between the IOP measured using GAT and central corneal thickness. Although all the tonometers show statistically significant correlation with CCT but GAT has shown the strongest correlation in this present study. From this we can conclude that variations in the CCT will affect GAT values more than NCT and RBT.

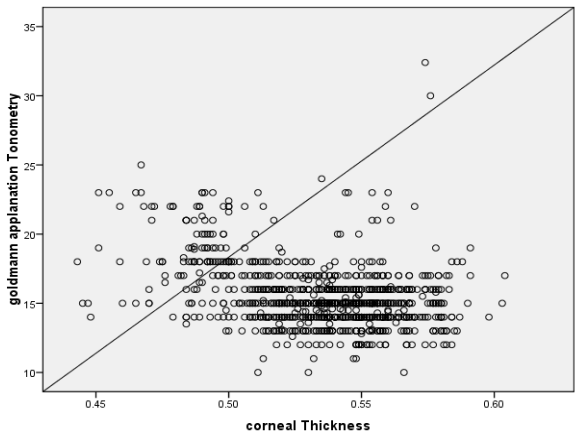

Figure 4: *(graph showing correlation between GAT IOP and CCT)*

Table 12*: (Correlation of mean NCT IOP with true IOP)*

	True IOP (mm hg)	NCT (mm hg)	p-value
Mean	17.05	16.43	P<0.001
Std. Deviation	3.651	3.851	

In this study since we intend to find out which one is the most reliable tonometer amongst NCT, Rebound and Goldmann in a general population. We measured the true IOP after considering the corneal thickness of each patient using pachymetry. The mean true IOP measured is 17.05 mm hg. The mean IOP measured by NCT correlates with the mean true IOP and is statistically significant in this study(p<0.001).

Table13: (Correlation between true IOP and RBT IOP)

	True IOP (mm hg)	Rebound Tonometry (mm hg)	p-value
Mean	17.05	15.83	
Std. Deviation	3.651	7.866	P<0.001

In this study there is also correlation between True IOP and the IOP measured using Rebound Tonometer and are statistically significant as shown in table 13.

Table14: (Correlation between true IOP and Goldmann IOP)

	True IOP (mm hg)	Goldmann applanation Tonometry (mm hg)	p-value
Mean	17.05	15.42	
Std. Deviation	3.651	2.290	P<0.001

True IOP measured was also found to be correlating with the mean IOP measured using Goldmann Tonometer and is statistically significant in this prospective study as depicted in table 14.

Table15: (Correlation between true IOP and NCT, RBT and GAT IOP with Pearson Correlation Values)

		Pearson Correlation value	p-value
True IOP (mm hg).	NCT (mm hg)	.664*	<0.001
	Rebound Tonometry (mm hg)	.377**	<0.001
	Goldmann applanation Tonometry (mm hg)	.452**	<0.001

Table 15 shows the correlation between IOP measured by NCT, Rebound and Goldmann with the true IOP. In the present study it is found the IOP measured by all the three tonometers correlate with the true IOP. A detailed analysis of the table shows that IOP measured by NCT correlates the best with true IOP followed by Goldmann and Rebound and all are statistically significant. From this we can conclude that all the 3 tonometers can be reliably used to measure IOP in a general population with NCT and Goldmann being more reliable than Rebound tonometer when compared with the corrected IOP. Table 15 has been depicted in the form of scatter diagram in figure 5, 6 and 7.

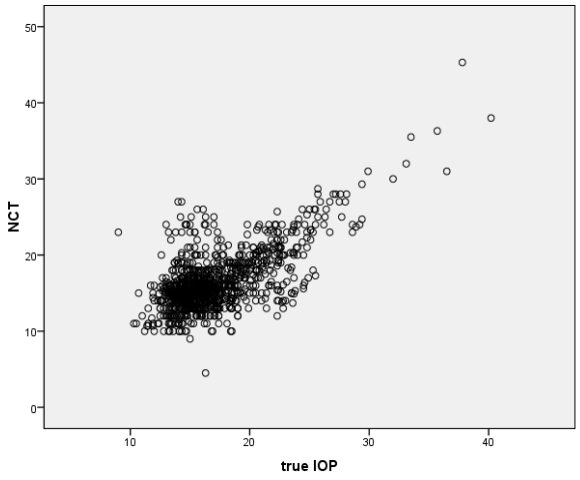

Figure 5: (Correlation between NCT IOP and true IOP)

Figure 5 is a scatter diagram showing the significant positive correlation between the IOP measured by NCT and the true IOP.

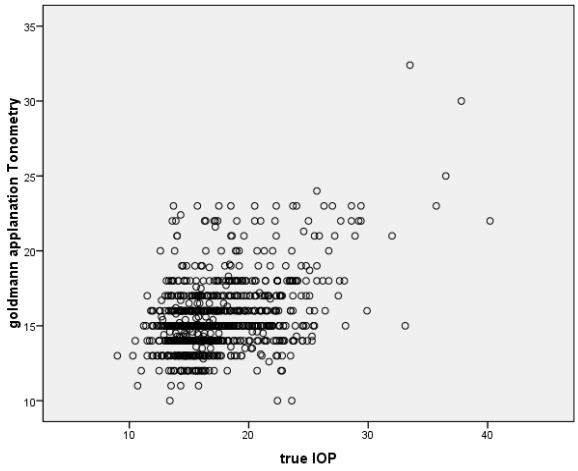

Figure 6: (Correlation between GAT IOP and true IOP)

Figure 6 is a scatter diagram showing the statistically significant correlation between the IOP measured by Goldmann and the true IOP.

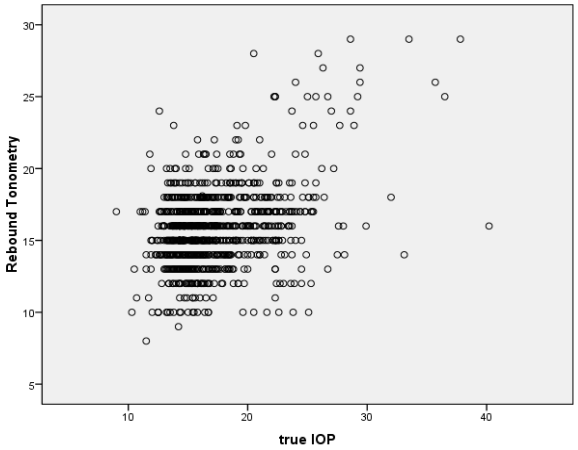

Figure 7: (Correlation between RBT IOP and true IOP)

Figure 7 shows the correlation between true IOP and the IOP measured by Rebound tonometer. The IOP measured using Rebound tonometer correlates with the true IOP and is statistically significant.

In this study the difference between true IOP and NCT IOP is 0.62mmhg that is true IOP is 0.62mmhg more than the IOP measured by NCT. On the other hand, true IOP is 1.22mmhg more than RBT IOP and 1.63mmhg more than GAT IOP. NCT IOP shows the strongest correlation with true IOP followed by GAT and RBT.

Table 16 shows the mean corneal curvature in males and females. The mean corneal curvature(K) in females is 44.9057 whereas in males it is 44.7251. from this we can infer that females have a slightly steeper cornea than males, but the mean values of K are not statistically significant in this study.

Table 16 (Mean corneal curvature)

Sex	Mean	N	Std. Deviation
Male	44.7251	256	1.62101
Female	44.9057	244	1.37902
Total	44.8133	500	1.50899

Table 17 shows the correlation between corneal curvature and the IOP measured using NCT, RBT and GAT. In this study we didn't find any statistically significant correlation between corneal curvature and the IOP measured by NCT, RBT and GAT using the Independent Sample T-test

Table 17 (Table showing correlation between K and NCT, RBT and GAT IOP)

		NCT	Rebound Tonometry	Goldmann applanation Tonometry
Corneal curvature(K)	Pearson Correlation	.059	.014	.014
	Sig.(2-tailed)	.063	.666	.665
	N(Sample size)	1000	1000	1000

DISCUSSION:

Salim et al reported that 2.45 mm Hg overestimation of IOP by RT compared with GAT in glaucoma patients which is like what we found in our prospective study. RBT records higher IOP than GAT but the values were not statistically significant in our study. Between NCT and RBT, RBT correlates better with GAT than NCT is what we found in our study.[1]

Kim et al reported that RT and GAT have good correlation and RT measurements 1.92 mm Hg higher than GAT measurements in patients with glaucoma. The difference between mean RBT values and GAT are less than the difference between mean NCT and GAT in a general population is what we infer from our prospective study.[2]

RT and GAT having good clinical agreement was reported in the study conducted by **OzcuraF et al** and RT measurements were 1.75 mm Hg higher than GAT measurements in normal eyes and0.37mmHg higher than GAT measurements in glaucomatous eyes which is also what we found in our prospective study.[3]

Gunvant et al reported that an increase of 1 mm of mean corneal thickness was accompanied by a rise in IOP of 1.14 mmHg measured by GAT, but this effect was weak and not statistically significant.[4] It is now known that GAT values are affected by CCT. In our prospective study we found that all the tonometers

that is NCT, RBT and GAT are significantly affected by the CCT of that person with GAT showing the strongest correlation followed by RBT and NCT. So, from this we can infer that GAT values are affected more than RBT and NCT if there is variation of CCT from the normal values in a general population.

Mark suggested that a flatter cornea might lead to lower GAT measurements. In our study there was no correlation between IOP and K values.[5]

Chakrabarty L et al concluded that, NCT and GAT measurements showed good agreements proving that both are reliable methods of measuring IOP. In this study, slight overestimation of IOP measurement was found by NCT in lower IOP ranges (<12mmHg). Contrary to some studies, good correlation between GAT and NCT in higher IOP ranges was found.[6]

In our study we found that NCT values are higher compared to GAT values. NCT overestimates IOP more when CCT values are more than 560-micron metre.

Shih et al. had an objective to ascertain whether CCT affected patient management. Their study, although set within a specialist glaucoma service, showed that half their study population required an adjustment of IOP ± 1.5 mmHg. What is interesting is that 8–10% of their cohort had a change in their medication.[7]

In a study by **Ehlers et al**, a manometric, controlled closed system was used to examine the correlation between CCT and IOP measured by applanation tonometry in 29 patients. Ehlers et al reported an error of ±0.71mm Hg between real IOP and IOP measured by applanation tonometry per 10-µm difference in CCT. Corneal curvature affected IOP readings in the study by Ehlers et al.[8]

In the present study CCT correlates with NCT, RBT and GAT with GAT showing the strongest correlation which shows that CCT affects IOP measured by all the 3 tonometers with GAT being affected the most. Therefore, it is important to measure the corrected IOP after considering the CCT of that person. True IOP is 1.63mmhg more than the mean GAT IOP in our study whereas it is 0.62mmhg and 1.22mmhg more than NCT and RBT IOP respectively.

Ismail et al reported that in eyes that had undergone penetrating keratoplasty, GAT measurements may be less precise than non-applanation tonometry because all these patients will not have normal CCT post-surgery. These findings are also like what we found in our study that GAT values are affected by CCT and although it is the gold standard true IOP should be recorded in all patients so that the CCT of that particular person is also taken into account.[9]

Kirwan et al, found that the mean GAT IOP decreased 3.7+/-2.3 mm Hg following LASIK, and a similar decrease was observed following LASEK.[10]

Milla et al. found an optimal agreement between DCT and GAT when the CCT was between 540 and 545 µm. As the CCT and the IOP increase, the difference between both tonometers also increases.[11]

There have been studies like the one conducted by **Francis et al** showed that K values affect DCT readings whereas **Medeiros et al** showed that K values do affect GAT values. In our study K values didn't affect IOP readings.[12,13]

Iliev, Goldblum, Katsoulis et al concluded that agreement of IOP readings between rebound and GAT was moderate to good. There was a systemic trend of rebound tonometer to higher readings +/-3mm hg from GAT.CCT seems to influence IOP readings in rebound tonometry as it does in GAT.[15]

In our study RBT values although higher than that recorded with GAT are not statistically significant and values are closer to GAT IOP values when compared with NCT.

S. Nagarajan et al concluded that both Schiotz and NCT showed significant correlation with the gold standard technique over a range of IOP and CCT with the Schiotz tonometer performing better than NCT.[16]

In two studies in which the Reichert NCT was used (**Jorge et al**.2002; **Jorge et al**.2003) both in normal subjects and patients with glaucoma, excellent agreement with GAT measurements was observed which is contrary to what we found in our study where there was significant difference between NCT and GAT readings with NCT readings being significantly higher than GAT readings in a general population as CCT increases.[17]

In our study NCT IOP shows good correlation with the corrected IOP.

However, **Domke et al**. 2006 noted that measurements of Reichert NCT are conditioned by CCT. which is similar to our findings where NCT readings were influenced by CCT.[18]

NCT values were higher as CCT increases (for thicker corneas) whereas RBT and GAT overestimates or

shows higher IOP values when CCT is less than 520-micron metre which is what we found in our study.

It is well known that GAT is affected by CCT (**Whitacre et al.** 1993), and some recent studies have shown similar results for I-Care (**Brusini et al.** 2006; **Iliev et al**. 2006; **Nakamura et al.** 2006) which is in accordance to what we found in our study.[15,20,21,22,23]

Tamcelik et al reported an overestimation of I-Care analysis in the low GAT-measured IOPs, whereas I-Care underestimated IOPs in high pressure ranges.[24]

A higher IOP with I-Care than with GAT has generally been found in most previous studies (**Fernandes et al**. 2005; **Davies et al**. 2006; **Iliev et al**. 2006; **Nakamura et al**.2006), although inconsistent results exist (Brusini et al. 2006).[15,19,21]

Parker et al. compared NCT and GAT and found results were concordant between the two devices which is different from what we found in our large prospective study where NCT values were significantly higher than GAT values.[26]

In another study, **Tonnu et al**. compared NCT, TPXL, and GAT and reported that all three devices showed homologous results.[25]

Farhood showed that NCT and GAT were not well correlated, and NCT measurements gave higher IOP results regardless of the patient's age or sex. When the GAT measurement exceeded 24 mmHg, the difference in readings between the two instruments increased. Farhood reported that the lower the IOP as measured by GAT, the more reliable the corresponding NCT readings.[27]This is in accordance to what we reported in our study.

The NCT and TPXL are easier and faster to use than the GAT, but suspicions about their results still exist. **Yilmaz et al.** found no significant differences between these three devices in normotensive patients.[28]

Feng et al. also found the rebound and noncontact tonometry to overestimate IOP relative to GAT for thicker CCT.[33]

We also found that NCT overestimates IOP when compared with GAT for CCT values greater than 560-micron metre.

There was a significant agreement between the RT and the GAT measurements. RT can be considered as a reliable alternative when IOP measurement with GAT is not feasible has been stated by Kyung **Sik Lee et al**.[34]

OzcuraF et al found a weak and statistically insignificant correlation between CCT and IOP measurements in all type tonometers in all group.[3]

Loewen et al reported that AXL had a significantly negative correlation with 24 h IOP fluctuation.[29]

Lee SY et al said in their study central corneal thickness (CCT), corneal curvature (CC), and axial length (AXL) demonstrated significant correlation with GAT fluctuation in the high IOP fluctuation group, and AXL showed significant correlation with DCT fluctuation in the low IOP fluctuation group. We only found CCT to significantly affect IOP readings in all the 3 tonometers used by us namely NCT, RBT and GAT.[30]

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 which is again contrary to what we found in the present study.[35]

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.[36]

Although NCT is also widely used the correlation observed between measurements obtained using this type of tonometer and conventional applanation tonometer has never been particularly good (**Vernon 1995**; **Tonnu et al**. 2005; **Lafaut et al**. 2007; **Ogbuehi & Almubrad** 2008).[25,37,38,39,40]

Several studies have evaluated the RBT and most of these have detected slight overestimation with respect to GAT and a similar influence of corneal thickness on its measures (**Lopez Caballero et al.** 2007; **Pakrou et al.** 2008; **Johannesson et al.** 2008; **Abraham et al**. 2008).[41,42,43,44]

Studies conducted by (**Grieshaber MC et al**, **Kamppeter BA et al**, **Kaufmann C et al**) have reported a significant positive correlation between GAT and CCT which is similar to our findings .[45,46,47]

On the other hand, studies conducted by **Schneider E et al**, **Kniestedt C et al**, **Ku JY et al** found no correlation between GAT values and central corneal thickness.[48,49,50]

Y. Harada et al found central corneal thickness significantly correlated with IOP measured by NCT and that measured by GAT.[51]

Punit Singh et al concluded that IOP measured by both NCT and GAT was significantly correlated with CCT. NCT readings were significantly higher in the thicker group (CCT>or=530 micron) than in the thinner group (CCT<530 micron). GAT readings had no difference between the thicker and thinner groups.[52]

In our study NCT overestimates IOP when CCT is more than 560-micron metre whereas GAT overestimates IOP when CCT is less than 520-micron metre.

Babalola et al and **Tonnu et al** also showed that changes in IOP measured with NCT are more dependent on CCT than IOP measured by Goldmann tonometer.[25,53]

In our study IOP measured by GAT was found to be more affected by changes in CCT than NCT and RBT.

Behrooz Kouchaki et al found a linear relationship between IOP and CCT.[54]

CONCLUSION:

IOP measurement is one of the most important investigation that an ophthalmologist will do in his daily practice. It has got immense importance as it is one of the risk factors of glaucoma and is also the only modifiable risk factor in glaucoma. So, an accurate measurement of the IOP is of paramount importance in the general population in order to say whether the person is at risk of developing glaucoma.

Goldmann applanation tonometer has been the gold standard for measuring IOP since it was discovered. Although it has been the gold standard it has its own advantage and disadvantages. Many other tonometers are there which work on the applanation principle as well as on other principles but has not been able to replace Goldmann as the goldstandard.

It has been well documented in literature that Goldmann values are affected by CCT and there are disadvantages like chances of infection and there is a learning curve to mention a few.

We conclude that NCT values were higher than that of GAT and RBT and were statistically significant. NCT values were higher for thicker CCT whereas RBT and GAT values were higher for thinner CCT. RBT values were also higher than that of GAT but the values were not statistically significant. Also, the mean RBT IOP value was closer to the mean GAT IOP value. Also, CCT significantly correlates with all the three tonometer values with GAT showing the strongest correlation. When compared with the true IOP all the tonometers showed good correlation with NCT showing the best correlation followed by GAT. So, from the present study we can conclude that all the 3 tonometers are reliable and can be used in the daily practice of an ophthalmologist. When CCT was considered we found it affected GAT readings the most followed by RBT and NCT. So, it is always advisable to calculate the corrected IOP in all patients so that we can get the exact IOP for a person.

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