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A Study Of Correlation Between Central Corneal Thickness And Intra Ocular Pressure Measurement Using Goldmann Applanation Tonometer And Rebound Tonometer

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Abstract : *Introduction: The purpose of this study was to note the influence of central corneal thickness on the intraocular pressure measurementand to compare rebound tonometer and Goldmannapplanation tonometerduring the recent 2 years in Ophthalmology OPD of JSS Hospital.*
Objectives:

- *To compare rebound tonometer and Goldmannapplanation tonometer*
- *Influence of central corneal thickness on the intraocular pressure measurement*

Methodology:A total of 409 patients inclusive of normal controls, proven glaucoma cases and glaucoma suspects were evaluated prospectively, from October 2010 to June 2012. They were studied for their presentation, clinical features and intraocular pressure readings and central corneal thickness were measured.
Results: A total of 797 eyes were included in the study. 199 eyes were examined under glaucoma group, out of which 33 patients had closed angle glaucoma and 166 had open angle glaucoma.
Majority of the patients in the study population were males in both control and glaucoma group (54.03%). In the glaucoma group consisting of proven glaucoma cases and glaucoma suspects majority had open angle (83.41%). More number of participants belonged to the age group of 40-50 years (45%). The highest mean GAT, RBT and CCT values were obtained for the age group between 61-70 years. The minimum intraocular pressure value obtained using rebound tonometer was 9 mm Hg and maximum value was 56 mm Hg in the entire study group. The minimum intraocular pressure value obtained using Goldmannapplanation tonometer was 8 mm Hg and maximum value was 50 mm Hg in the entire study group. The minimum value for central corneal thickness was 443µm and maximum value was 675µm for the entire study group. For the entire study group intraocular pressure values obtained by rebound tonometer(14.81±2.81mm Hg in normal group and 20.55±8.74mm Hg In glaucoma group) was more than Goldmannapplanation tonometer (14.47±2.98mm hg and 19.88±8.74mm Hg). For central corneal thickness ≤ 530µm, Rebound tonometer values were more than Goldmannapplanation tonometer values in both control and control group. The mean difference was 0.4± 3.9mm Hg and 0.3 mm Hg which was not statistically significant (p values- 0.74, 0.792). For central corneal thickness ≥ 531µm, Rebound tonometer values were less than Goldmannapplanation tonometer values in both control and control group. The mean difference was 0.0811mm Hg and0.96 mm Hg which was not statistically significant (p values- 0.811,0.93). At higher corneal thickness, Goldmannapplanation tonometer gave higher values than rebound tonometer but the difference was not statistically significant. As the central corneal thickness increased the intraocular pressure value recorded by both the tonometers increased.
Conclusion:Central corneal thickness can influence the intraocular pressure recordings of both rebound tonometer and Goldmannapplanation tonometer and thicker corneas yield higher intraocular pressure values. Therefore correction for central corneal thickness will provide a more accurate IOP reading and aid in the proper management of glaucoma cases. The Rebound tonometer gave higher readings in comparison to Goldmannapplanation tonometer in thinner corneas and lesser readings in thicker corneas. There was no statistically significant difference between the two tonometers and they showed good correlation in relation to the central corneal thickness.

Keywords : *Central corneal thickness, Goldmannapplanation tonometer, Rebound tonometer*

I. INTRODUCTION

Glaucoma is one of the leading causes for blindness in the world. It is an optic neuropathy with characteristic appearance of optic disc and specific pattern of visual field defects associated frequently but not invariably with raised intraocular pressure

The important risk factors of glaucoma include intraocular pressure, heredity, myopia, race etc. But intraocular pressure is the most important factor as it is the only one which we can measure and modulate till date.

Goldmann Applanation tonometer is considered as the gold standard for the measurement of intraocular pressure. But the accuracy of measurement has limitations as it is influenced by a number of variables like axial length, corneal curvature, corneal rigidity, and corneal thickness. Goldmann and Schimdt believed that the central corneal thickness was very similar among individuals in the normal population. However they acknowledged that when large variations in central corneal thickness occur, the accuracy of Goldmann tonometer can be affected. Corneas that were thicker than the normal would require greater force to flatten and thinner corneas would require less. This meant that thicker corneas yielded an overestimation of intraocular pressure, whereas thinner corneas resulted in underestimation[1].

In the 1970s, Ehlers et al performed a number of studies assessing the effect of CCT on IOP. They cannulated 29 otherwise normal eyes undergoing cataract surgery and correlated corneal thickness with the errors of GAT. They found that GAT most accurately reflected "true" intracameral IOP when CCT was 520µm and the deviation from this value resulted in under- or overestimation of IOP. Patients with ocular hypertension have been found to have a CCT of 50µm more than patients with Glaucoma and Glaucoma suspects. This means that many individuals have been falsely labeled as having ocular hypertension, when in fact they have normal IOP once CCT is taken into consideration.[1,2].

Over the years, several new instruments have been developed with the aim of determining IOP as precisely as possible. Among the most recent of these are the rebound tonometer (RBT; ICare, Tiolat Oy, Helsinki, Finland) and the Dynamic Contour, or Pascal, tonometer (DCT; SMT Swiss Microtechnology AG, Port, Switzerland).

Rebound tonometry had been used mainly in experimental models of glaucoma for noninvasive pressure measurements in animals[3]. This method has provided good results in terms of ease of use and the precision and reproducibility of marketing of a handheld tonometer, which also has been reported recently to offer reproducible IOP measurements in humans. Rebound tonometry is based on bringing a magnetized probe into contact with the eye and detecting the deceleration caused by the eye on the probe with a sensing coil. The motion parameters of the probe vary according to eye pressure and can be used to determine IOP.

The current study focuses on the influence of central corneal thickness on tonometric measurements on Goldmann applanation tonometer and rebound tonometer and also how well the two tonometers correlate with each other and whether the reproduciblity of rebound tonometer is similar to the Goldmann applanation tonometer.

II. Material And Methods

Study Setting: This study was carried out in the Department of Ophthalmology, J.S.S. Hospital, Mysore.

Source: Subjects of the study were the patients visiting the outpatient department. A total of 409 patients were included in the study out of which 101 patients diagnosed of Glaucoma were included.

Study Design: It is a 2 years prospective study.

Study period: The study was carried out from October 2010 to June 2012. Patients satisfying the following criteria were included in the study.

Inclusion criteria:

1. Patients aged 40 years and above
2. Patients diagnosed of primary Glaucoma and Glaucoma suspects
3. Normal patients

Exclusion criteria:

1. Patients below 40 years of age
2. Corneal pathology
3. History of previous intraocular surgeries
4. Corneal surgeries
5. Prolonged contact lens wearers
6. Corneal dystrophies, ectatic conditions and degenerations
7. Secondary glaucomas

Method of Collection of Data:

Patients satisfying the above criteria were included in the study. Patient was explained about the study and a written consent was taken. Using a proforma details were collected regarding the name, age, sex, presenting complaints and duration, associated systemic disorders and drug history if any. Patient was subjected

to a preliminary slit lamp examination and fundoscopy and best corrected visual acuity was recorded. Then the IOP measurements were taken using RBT and GAT and central corneal thickness was measured using ultrasonic pachymetry. In cases of glaucoma and glaucoma suspects additional investigations like gonioscopy using Goldmann 3 mirror gonio lens and visual field analysis with Humphrey field analyzer were done.

Measurement of intraocular ocular pressure

Using Goldmann Applanation Tonometer – patient is made to sit comfortably on the slit lamp chair. A drop of 4% Xylocaine is instilled into the lower fornix. The precorneal tear film is stained with fluorescien strip and the tonometer probe is brought into contact with the cornea. Cobalt blue light is focused on the probe perpendicular to the tonometer. The reading is then recorded.

Using Rebound tonometer

Patient is made to sit. Rebound tonometer with plastic probe loaded is placed at a distance of 8mm in front of the eye and then readings are taken as explained before.

Measurement of CCT

The measurements were performed using the Micropach – sonomed 200 pachymeter in the automatic mode, with the subject in the sitting position, while he or she fixated on a distant target. After instilling a drop of 4% xylocaine, the probe tip was held perpendicular and placed in contact with the central cornea. Five readings were obtained and an average of these readings was recorded in micrometers. The readings were taken in the right first and then in the left eye.

tatistical Methods Applied

Descriptive statistics

The Descriptive procedure displays univariate summary statistics for several variables in a single table and calculates standardized values. Normally distributed continuous variables were expressed as mean (range) and non-normally distributed variables were expressed as median.

Frequencies

The Frequencies procedure provides statistics and graphical displays that are useful for describing many types of variables. The Frequencies procedure is a good place to start looking at your data.

Chi-square

The Chi-Square Test procedure tabulates a variable into categories and computes a chi-square statistic. This goodness-of-fit test compares the observed and expected frequencies in each category to test either that all categories contain the same proportion of values or that each category contains a user-specified proportion of values.

Chi-square tests were employed to find out the difference between groups of frequencies obtained for the specific statements. A P value of less than 0.005 was considered statistically significant

Cross tabs procedure

The Crosstabs procedure forms two-way and multiway tables and provides a variety of tests and measures of association for two-way tables. The structure of the table and whether categories are ordered determine what test or measure to use. All the statistical methods were carried out through the SPSS for Windows (version 17.0 SPSS Inc., Chicago, IL, USA).) and Minitab (version 11.0) for windows.

III. Observation & Results

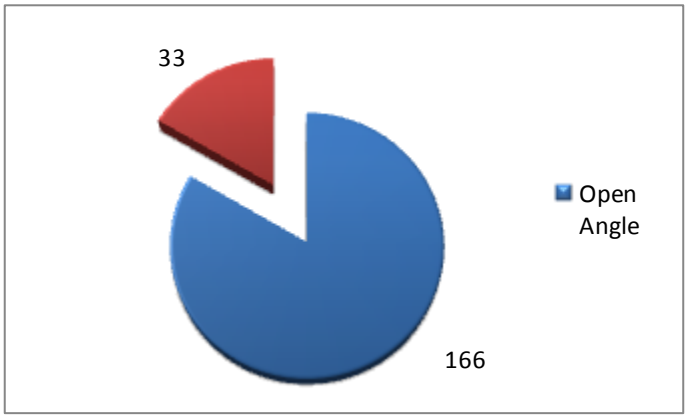
This is a prospective study carried out in JSS Hospital, Mysore. This study was carried out for 2 years from October 2010 to June 2012.

A total number of 409 patients were studied. Of these, 308 presented with insignificant ophthalmic problems, headache, presbyopic errors and were referred for fundoscopy. They were included in the control group. The remaining 101 patients were proven cases of glaucoma and glaucoma suspects who were categorized as glaucoma group.

A total of 818 eyes were examined of which 3 eyes from glaucoma group and 18 eyes from control group were excluded for previous history of cataract surgery.

Therefore a total of 797 eyes were included in the study. 199 eyes were examined under glaucoma group, out of which 33 patients had closed angle glaucoma and 166 had open angle glaucoma.

Ratio of Glaucoma cases of Open Angles to Glaucoma cases of Closed angles



GRAPH 1: GLAUCOMA CASE DISTRIBUTION

Out 199 eyes, 166(83.41%) patients had open angles among glaucoma and suspects and there 33 cases (16.58%) with closed angles

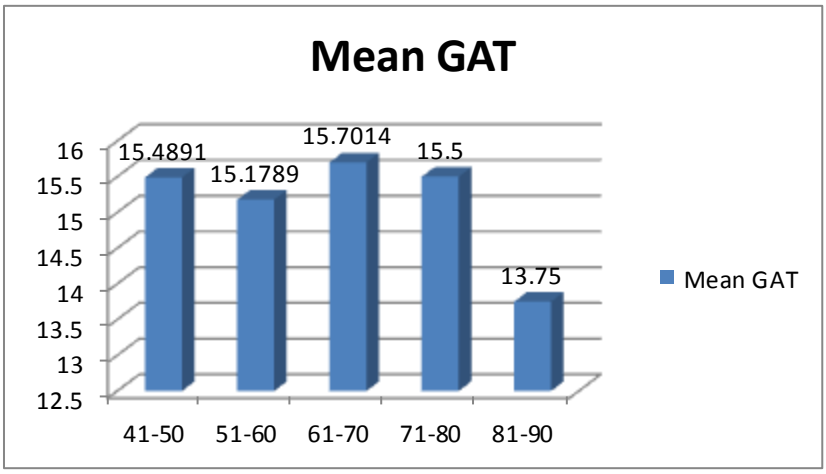
Table 1: Age distribution in the study group

Age	Frequency	Percent
41-50	184	45.0
51-60	123	30.1
61-70	72	17.6
71-80	28	6.8
81-90	2	0.5

The more number of patients in the present study are from the 41-50 age group and least from 81-90 age group.

Table 2:Mean IOP values for GAT in different age groups

Age group	N	Mean GAT	Std. dev	Std. error
41-50	368	15.4891	4.94712	0.25789
51-60	246	15.1789	5.08865	0.32444
61-70	144	15.7014	7.57164	.63097
71-80	56	15.5000	8.05210	1.07601
81-90	4	13.7500	9.10586	4.55293
Total	818	15.4254	5.78881	0.20240

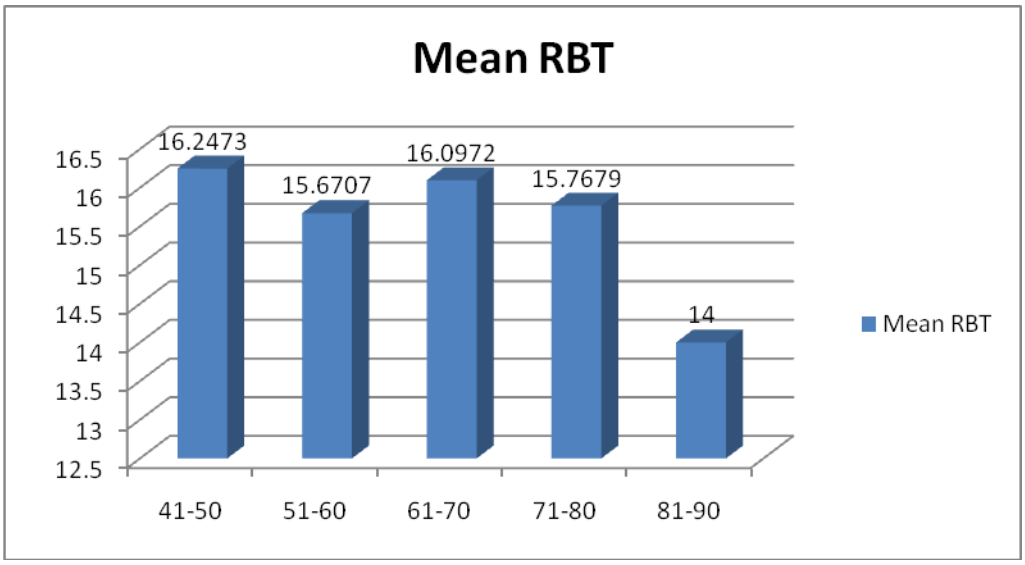


GRAPH 2: MEAN IOP VALUES FOR GAT IN DIFFERENT AGE GROUPS

The mean GAT IOP values were found to be high in the age group of 61-70 years which was 15.7±7.57m Hg. The least was 13.75±9.10mm Hg was in the age group 81-90 years.

Table 3: Mean IOP values for RBT in different age groups

Age group	N	Mean RBT	Std. dev	Std. error
41-50	368	16.2473	6.97846	.36378
51-60	246	15.6707	5.34535	.34081
61-70	144	16.0972	7.99591	.66633
71-80	56	15.7679	8.67597	1.15937
81-90	4	14.0000	9.27362	4.63681
Total	818	16.0037	6.86315	.23996



GRAPH 3: MEAN IOP VALUES FOR RBT IN DIFFERENT AGE GROUPS

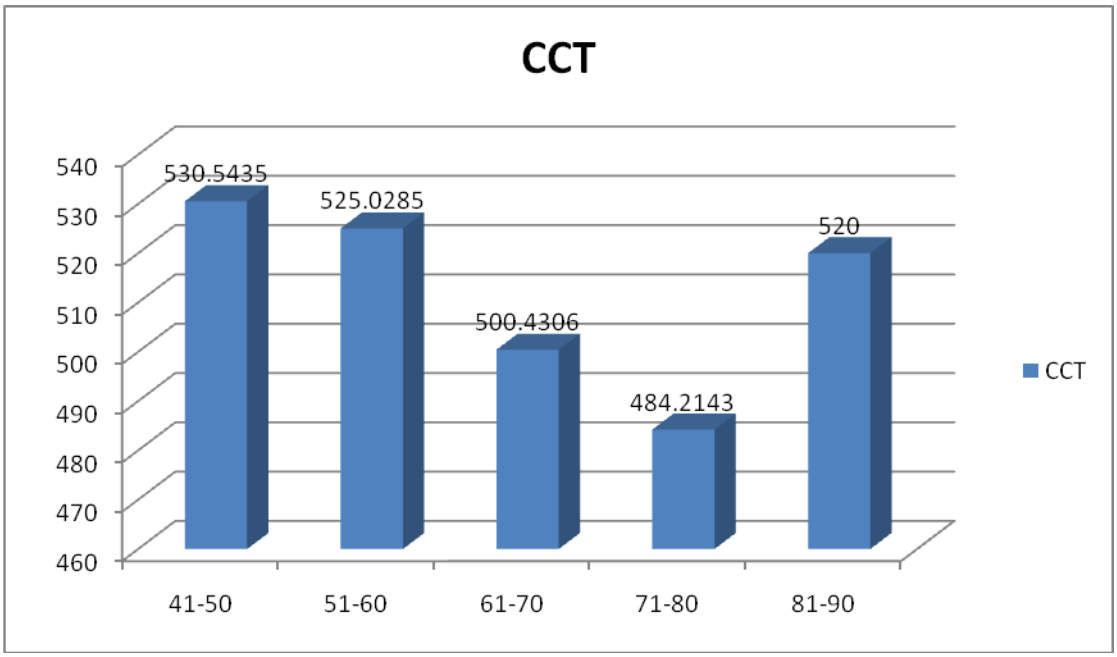
The highest mean RBT value was 16±0.9mm Hg in the age group 61-70 years. The least value was 14±6.8mm Hg in the 81-90 years age group.

It is noted that the IOP values are increasing with increase in age from the above two tables. The less IOP values in the 71-90 years age group may be due to insufficient sample size for comparision.

Table 4: Mean CCT values in different age groups

Age group	N	CCT	Std. dev	Std. error
41-50	368	530.5435	47.43190	2.47256
51-60	246	525.0285	54.04574	3.44583
61-70	144	500.4306	123.27731	10.27311
71-80	56	484.2143	157.03650	20.98489
81-90	4	520.0000	14.69694	7.34847
Total	818	520.3606	80.12668	2.80156

The mean highest CCT value was 530.54±47.43µm in the age group of 41-50 years. From the above table it can be noted that as the age increased the CCT value decreases except for 81-90 years age group. This might be due to less number of eyes in that age group.



GRAPH 4: CCT DISTRIBUTION IN AGE GROUPS

Classification of the control group and glaucoma group according to CCT

The eyes were divided into two groups according to CCT. In the control group, there were 281 eyes with CCT less than 530µm and in glaucoma group there were 75 eyes.

CCT ≥ 531µm were found in 317 eyes in control group and 124 eyes in glaucoma group. A total of 356 eyes had CCT ≤ 530 µm and 441 eyes had CCT ≥ 531µm.

Table 5: Group classification according to CCT

CCT	Control	Glaucoma	Percentage
< 530µ	**281**	**75**	**44.7%**
>531µ	**317**	**124**	**55.3%**
Total	**598**	**199**	**100%**

Table 6: IOP measured by GAT and Rebound tonometer and CCT in normal patients

IOP	Min	Max	Mean	SD
RBT	9	23	14.81	±2.81
GAT	8	23	14.47	±2.98
CCT	457	626	530.20	±25.63

Table 7: IOP measured by GAT and Rebound tonometer and CCT in glaucoma patients and Glaucoma suspects

IOP	Min	Max	Mean	SD
RBT	8	56	20.55	±8.74
GAT	8	50	19.88	±8.74
CCT	443	675	533.66	±28.90

The mean IOP value obtained were 14.81±2.81 mm Hg for RBT ranging between 9mm Hg to 23mm Hg. The mean IOP value for GAT was 14.47±2.98mm Hg ranging between 8mm Hg to 23 mm Hg. The mean

CCT value was 530.20±25.63µm ranging between 457µm to 626µm. The difference between RBT and GAT was 0.54mm Hg.

In the glaucoma group, the minimum values of RBT, GAT and CCT were 8mm Hg, 8mm Hg and 443 µm respectively. The maximum values obtained using RBT, GAT and pachymetry were 56mm Hg, 50mm Hg and 675µm respectively. The mean IOP value obtained were 20.55±8.74 mm Hg for RBT and 19.88±8.74mm Hg. the mean CCT value was 533.66±28.90µm. The difference between RBT and GAT was 1.67 mm Hg.

The Mean IOP Values Of RBT And GAT In Eyes Having CCT < 530µm In The Control Group.

Table 8: IOP distribution in control group with CCT < 530µm

Tonometers	N	Mean (mm Hg)	Std. Deviation	P value	GAT-RBT
GAT	**280**	14.3571	2.83367	0.74	-0.42
RBT	**280**	14.7815	2.90696		

The Mean IOP Values Of RBT And GAT In Eyes Having CCT > 530µm In The Control Group.

Table 9: IOP distribution in control group with CCT > 530µm

Tonometers	N	Mean (mm Hg)	Std. Deviation	P value	GAT- RBT
GAT	**441**	16.3888	5.93462	0.81	0.081
RBT	**441**	16.3078	5.41992		

The mean IOP value for GAT was 14.35±2.83mm Hg and for RBT was 14.78± 2.90mm Hg in the eyes having CCT ≤ 530µm. The RBT values were found to be more than the GAT values.

The mean difference between RBT and GAT values was 0.4± 3.9mm Hg which was not statistically significant (p value – 0.74).

The mean IOP value for RBT was 16.3±5.41mm Hg and for GAT was 16.3± 5.9mm Hg for CCT values ≥ 531µm. The IOP values were similar in both the groups.

The difference between RBT and GAT was 0.8±7.10mm Hg which was not statistically significant (p value – 0.81).

The Mean IOP Values Of RBT And GAT In Eyes Having CCT >531µm In Glaucoma Group.

Table 10: IOP distribution in glaucoma group with CCT > 530µm

Tonometers	No.	Mean (mm Hg)	Std. Deviation	P value	GAT- RBT
GAT	**124**	21.0242	8.42418	0.93	0.967
RBT	**124**	20.0565	8.19211		

The Mean IOP Values Of RBT And GAT In Eyes Having CCT < 530µm In Glaucoma Group.

Table 11: IOP distribution in glaucoma group with CCT < 530µm.

Tonometers	No.	Mean(mm Hg)	Std. Deviation	P value	GAT-RBT
GAT	**75**	18.0133	7.29401	0.79	-0.36
RBT	**75**	18.3733	9.59416		

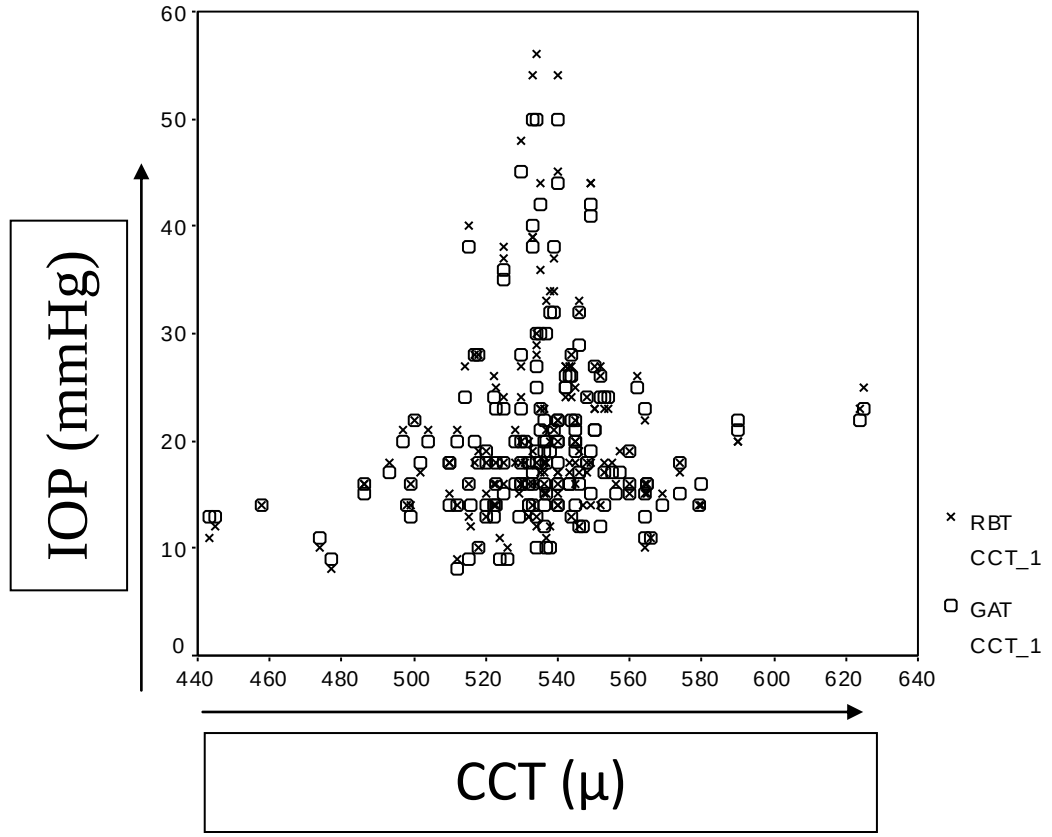
The mean IOP value for RBT was 21±8.42mmm Hg and for GAT was 20.05±8.19mm Hg for CCT values ≤ 531µm. The IOP value of RBT was more than GAT.

The difference between RBT and GAT IOP values was 0.9± 11.51mm Hg. the difference between the two instruments was not statistically significant (p value – 0.93).

The mean IOP value for GAT was 18.0±7.29mm Hg and for RBT was 18.3±9.59mm Hg for eyes having CCT value less than 530µm.

The difference between RBT and GAT value was 0.3mm Hg which was statistically not significant (p value – 0.79).
It was also noted that as the CCT increased the IOP also increased.
The overall IOP values of both RBT and GAT were found to increase with increase in CCT and this relation was found to be statistically significant (P value – 0.00). But the correlation between IOP values of RBT and GAT for CCT of <530µ and >530µ were not statistically significant.

GRAPH 5: SCATTER PLOT OF CCT AGAINST RBT AND GAT



From the above scatter plot it can be noted that there is clustering of points representing IOP values for CCT values ranging between 520 to 560 µm

IV. Discussion

Goldmann applanation tonometry is today the gold standard for IOP measurement. However, since its early days it has been known that readings can be distorted by several physical properties of the eye such as corneal curvature, axial length, and central corneal thickness. Goldmann himself admitted that the physical assumptions on which his tonometer was based were calculated for a central corneal thickness of 500 µm, and that readings for corneas thicker or thinner than this value could be less precise. Several studies subsequently have corroborated this limitation, and differences in corneal thickness have proven to be one of the main sources of error in applanation tonometry measurements.

Several new tonometers designed to avoid some of the limitations of conventional tonometry have appeared on the market. One of them being rebound tonometer.

This study included a total of 409 patients. A total 797 eyes were examined. Out of these, 199 eyes of 101 patients were included in the glaucoma group. There were166 eyes with open angle glaucoma and glaucoma suspects and 33 eyes with closed angle glaucoma.

The present study can be compared with a similar studies by Jose Martinez et al and Brusini et al. Jose Martinez et al examined 146 eyes out of which 67 patients had POAG and 34 had ocular hypertension.

In the study done by Brusini et al, 178 patients with POAG were included in the study.

Table 12: Comparison of participants in different studies – Glaucoma patients

Study	N	Mean Age	Mean RBT (mm Hg)	Mean GAT (mm Hg)	Mean CCT(µm)	RBT-GAT
Present study	101	56±11.73	20.55±8.74	19.88±8.13	533.66±28.90	1.67
Jose Martinez et al	90	61±14.4	20.5±5.3	19.1±5.1	550±43.2	1.4±2.7
Paolo Brusini et al	178	67±13	18.4±5.2	19.4±5.4	552±39	1.0±3.5

From the above table it can be seen that the number of participants in different studies ranged between 101 to 178 people. Our sample size is comparable to Jose Martinez et al.
In the present study, age ranged between 40 and 82 years. The age group in Brusini et al study ranged between 30 to 93 years.
In Martinez et al study, the IOP values of RBT were more than GAT in both CCT groups. But the mean IOP value for RBT was less compared to GAT value in Brusini et al study. In the present study, the IOP values of RBT were more than GAT when CCT was less than 530µm and less than GAT values when CCT was more than 531µm.

Table 13: Mean intraocular pressure values in different studies according to corneal thickness

Study	Sample size (n)	CCT(µm)	Mean GAT(mm Hg)	Mean RBT(mm Hg)
Present study	101	<530	18.01±7.29	18.37±9.59
		>531	21.04±8.42	20.05±8.19
Martinez et al	146	<531	17.4±5.6	17.8±5.2
		>565	19.9±4.1	21.4±4.6

It was also noted that in both groups the IOP value increased with increase in CCT.
The mean difference between RBT and GAT values in Martinez et al study was 1.4±2.7 mmHg. The P value was 0.218.
In the present study the mean difference between RBT and GAT (GAT-RBT) was 0.96±11.51mm Hg in CCT ≥ 531µm and 0.36±11.7mm Hg in CCT group of ≤ 530µm.The P value was0.351and 0.792 respectively. In both the groups the difference between the instruments was not statistically significant.

Table 14: Comparison of Participants in Different Studies – Control (Normal) Patients

Study	N	Mean Age(years)	Mean RBT (mm Hg)	Mean GAT (mm Hg)	Mean CCT(µm)	RBT-GAT
Present study	308	53.44±9.9	20.55±8.74	19.88±8.13	533.66±28.90	1.67
M E Iliev et al	28	50.38±23.58	20.5±5.3	19.1±5.1	550±43.2	1.4±2.7
Nima Pakrou et al	153	59.6±21.2	18.4±5.2	19.4±5.4	552±39	1.0±3.5

From the above table it is seen that the sample size in different study groups ranged between 28 to 308 patients. The present study had the maximum number of participants. The age of the patients ranged between 40-82 years.
The mean GAT values of all the three studies are similar. In all the three studies the IOP values increased with increase in CCT. The mean CCT value of the present study was less compared to the other two studies.
Only the patients who belonged to group 1 in the M E Iliev study are taken for comparison with the present study as the group 2 of M E Iliev study includes postoperative patients which comes under the exclusion criteria of the present study.
In the Nima Pakrou study, the p value obtained was 0.09 which was not statistically significant. The author has mentioned that the relation of RBT with CCT was statistically significant (P value- 0.05, 0.01). but GAT was found not be affected much by CCT value(P value – 0.25).
In ME Iliev study, the author has used regression analysis for analysis of data. RBT values were found to increase with increase in CCT. A small but statistically significant difference was noted between GAT and RBT.
In the present study, the difference between RBT and GAT ranged between 0.42 to 0.0811in CCT of ≤ 530µm group and CCT of ≥531µm group respectively (P value – 0.074 and 0.811).
In conclusion, the present study correlated the rebound tonometer values with Goldmann applanation values and found that there was no statistically significant difference in the measurements obtained by the two instruments. It was also noted that when central cornea thickness was less, RBT recorded higher values than GAT but the difference was not statistically significant. When CCT increased, the IOP values of both the instruments

increased but GAT recorded higher values than RBT. The difference between their IOP values was again not statistically significant.

LIMITATIONS OF THE STUDY

Post operatives cases were excluded from the study and all the secondary glaucomas were excluded from the study. This limits the knowledge about variations in the IOP values of RBT and GAT and influence of CCT on them.

The population of the study comprised only those patients who visited the outpatient department of JSS hospital and did not cover people from different region to comment on the variation of CCT, RBT and GAT in them.

Other corneal compounding factors such as corneal hysteresis, corneal resistance factor, corneal curvature affecting IOP measurement are not evaluated and other tonometers are not compared.

The IOP values in the present study have not been corrected for the CCT values according to the available correction factor nomograms

V. CONCLUSION

Central corneal thickness influences the intraocular pressure recordings of both rebound tonometer and Goldmann applanation tonometer and thicker corneas yield higher intraocular pressure values. The Rebound tonometer gave higher readings in comparison to Goldmann applanation tonometer in thinner corneas and lesser readings in thicker corneas. There was no statistically significant difference between the two tonometers and they showed good correlation in relation to the central corneal thickness.

Therefore correction for central corneal thickness will provide a more accurate IOP reading and aid in the proper management of glaucoma cases. Further studies are needed taking into consideration different values of CCT to derive an accurate correction factor.

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