# Comparison of Intraocular Pressure and Pachymeter Measurements Obtained by Non Contact Tonometer-pachymeter with Goldmann Applanation Tonometer and Corneal Topography

*Duygu YALINBAS YETER[1], Mehmet Talay KOYLU[2], Yeşim GEDIK OGUZ[3], Yagmur Seda YESILTAS[3], Dorukcan AKINCIOGLU[4], Fatih GURDAL[5], Fatih Mehmet MUTLU[6]*

## ABSTRACT

**Purpose:** To compare the measurements of intraocular pressure (IOP) and central corneal thickness (CCT) by tono-pachymeter (CT-1P) with IOP measurements by Goldmann applanation tonometer (GAT), and CCT measurements by Pentacam.

**Materials and Methods:** Two hundred eighteen eyes of 109 patients were included in the study. Intraocular pressure measurements were obtained by the CT-1P and GAT, whereas CCT measurements were obtained by CT-1P and Pentacam. Blant-Altman plots for agreement, and Pearson correlation and interclass correlation (ICC) for reliability between the measurements were analyzed.

**Results:** The mean $IOP^{CT\text{-}1P}$, $IOP^{CT\text{-}1P\ adj.}$, $IOP^{GAT}$ were measured as 18.2±4.32 mmHg, 17.75±4.05 mmHg and 16.9±4.16 mmHg, respectively. The mean CCT was measured as 554.8±37.3 µm and 543.6±35.9 µm with CT-1P and Pentacam, respectively. Mean differences between devices were significantly different in terms of IOP and CCT measurement ($p<0.001$, for all). Interclass correlation coefficient confirmed the excellent reliability between devices in terms of measurement of IOP and CCT ($p<0.001$, for all). The 95% limits of agreement (LoA) for IOP were -4.24 to 3.28 mmHg between $IOP^{CT\text{-}1P\ adj.}$ and $IOP^{CT\text{-}1P}$, -3.49 to 5.14 mmHg between $IOP^{CT\text{-}1P\ adj.}$ and $IOP^{GAT}$ and -2.7 to 5.3 mmHg between $IOP^{CT\text{-}1P}$ and $IOP^{GAT}$. Also 95% LoA for CCT were -12.33 to 32.16 µm between $CCT^{CT\text{-}1P}$ and $CCT^{Pentacam}$.

**Conclusion:** Although CT-1P overestimated both IOP and CCT measurements, the device had an excellent ICC with Pentacam and GAT in terms of CCT and IOP measurements. The ability of tono-pachymeters measuring both CCT and IOP with a single device provide an important convenience in busy clinics.

**Keywords:** Central corneal thickness, Intraocular pressure, Non-contact tono-pachymeter.

## INTRODUCTION

Glaucoma is a chronic and progressive optic neuropathy which is characterized by ganglion cell loss and deterioration of visual field.[1] The etiology of glaucoma is multifactorial and the increased intraocular pressure (IOP) is the only modifiable risk factor for the prevention of disease progression.[2] Therefore, accurate and precise measuring of IOP has an important role in the diagnosis and management of glaucoma.[3] Goldmann applanation tonometer (GAT) is still accepted as the gold standard for IOP measurement.[4] However, requirement of fluorescein staining and topical anesthesia, being attached to a slit-lamp biomicroscope, risk of contamination and cooperation difficulties such as in children are the main disadvantages of applanation tonometry.[5] Non-contact tonometers (NCT) have been popular alternatives for the measurement of IOP with no need for eye drops before examination, minimal risk for transmission of infection and independent use of skilled examiners.[3,5]

1- Assistant Prof. MD, Sivas Cumhuriyet University, Faculty of Medicine, Department of Ophthalmology, Sivas, Turkey

2- Associate Prof. MD, Gülhane Training and Research Hospital, Department of Ophthalmology, Ankara, Turkey

3- Ophthalmologist, Gülhane Training and Research Hospital, Department of Ophthalmology, Ankara, Turkey

4- Ophthalmologist, Ataturk State Hospital, Antalya, Turkey

5- Asist. MD, Gülhane Training and Research Hospital, Department of Ophthalmology, Ankara, Turkey

6- Prof. MD, Gülhane Training and Research Hospita, Department of Ophthalmology, Ankara, Turkey

**Received:** 13.06.2020
**Accepted:** 17.01.2021

*Glo-Kat 2021; 16:12-17*

DOİ: 10.37844/glauc.cat.2021.16.3

**Correspondence Adress:**
Duygu YALINBAS YETER
Cumhuriyet University, Department of Ophthalmology, Sivas, Turkey
**Phone:** +90 530 701 3141
**E-mail:** duyguyalinbas@gmail.com

Central corneal thickness (CCT) is one of the most important parameter that affects IOP measurement.[6] When CCT is not taken into consideration, it may lead to misdiagnosis in determining the accurate IOP measurement.[3] Hence, accurate CCT measurement and the adjust of IOP according to the measured CCT plays a crucial role in glaucoma diagnosis and follow-up. Pachymetry can be measured by numerous instruments including specular microscopy, confocal microscopy, optical biometry, ultrasonic pachymetry, corneal topography and optical coherence tomography.[7]

Currently, non-contact tono-pachymeter devices measure both IOP and CCT simultaneously and provide adjusted IOP values according to the CCT. Also, measuring both IOP and CCT in one device is an advantage that saves time and increases patient compliance.[8]

The aim of this study is to compare IOP and CCT measurements of CT-1P tono-pachymeter with IOP measurements obtained by GAT and CCT measurements obtained by Pentacam.

## MATERIALS AND METHODS

This retrospective study was approved by the Ethics Committee of the University of Health Sciences, Gülhane Training and Research Hospital and adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all enrolled patients. Two hundred eighteen eyes of 109 adult patients who had glaucoma or suspected glaucoma, age over 18 years and no ocular pathologies except primary open angle glaucoma were included in the study.

All patients were referred to glaucoma section after complete ophthalmic examination, including measurement of best-corrected visual acuity (BCVA), slit-lamp biomicroscopy, fundus examination, visual field, retinal nerve fiber layer measurement and Pentacam measurements. Detailed ophthalmic reassessment, Goldmann applanation tonometer, and CT-1P measurements were performed in the glaucoma section. Patients with corneal diseases such as ectasia, scar or edema, wearing recently contact lenses, poor cooperation to examination, higher than ±3.00 D (spherical equivalent) refractive error, irregular astigmatism or astigmatism more than 2.00 D, history of ocular trauma or refractive surgery, uveitis, iris neovascularization, pregnancy and, ocular pathologies that prevent proper fixation were excluded from the study.

### Measurements of CCT and IOP

Three consecutive measurements were obtained by each device and the arithmetic average of three measurements was taken. Central corneal thickness measurements were done by CT-1P and Pentacam, whereas IOP measurements were done by CT-1P and GAT. Goldmann applanation tonometer was performed last in order to minimize the measurement errors originated by direct contact to cornea. All measurements were taken on the same day between 09.00 am to 12.00 am to eliminate the diurnal variation effects of CCT and IOP. All devices were calibrated according to the guidelines of manufacturers.

### The non-contact tono-pachymeter, CT-1P (Topcon, Tokyo, Japan)

The device simultaneously measures CCT and IOP and determine the adjusted IOP values according the CCT. The 'CT-1P adjusted (adj.)' term in the study was used for the IOP measurements adjusted by CCT[1]. The central corneal thickness measurement is based on a specular microscope method and the IOP measurement is based on an air puff tonometry. CT-1P automatically measures CCT three times then converts into IOP measure mode and automatically measures IOP.[9] Finally, the mean IOP, CCT, and adjusted IOP values are reported.

### Goldmann Applanation Tonometer (Haag-Streit, Bern, Switzerland)

Intraocular pressure measurement by GAT was done by a slit-lamp mounted applanation tonometer. Goldmann applanation tonometer is based on the Imbert- Fick law by measuring the force necessary to flatten a certain area of the cornea.[10] After topical anesthesia, 0.5% proparacaine hydrochloride (Alcaine, Alcon), a fluorescein strip was applied to the inferior fornix of the eye. All of the measurements were taken using the cobalt blue filter of the microscope.

### Pentacam (Oculus,Wetzlar, Germany)

The device, is based on Scheimpflug camera system which provides a three dimensional model of anterior segment, anterior and posterior corneal surface elevation maps and corneal thickness maps. Pentacam automatically provides the pupil center, apex and the thinnest point of CCT by the software.[11]

### Statistical analysis

Data obtained in the study were analyzed using Statistical Package for the Social Science software version 20 (IBM, SPSS 20 for Windows. Armonk, NY, USA). Shapiro-Wilk test was used determine the distribution of age, BVCA and measurement techniques and differences. We found that all variables distributed normally. Mean ± standard deviation and minimum-maximum values were used for numeric

variables. Categorical variables were stated as number (n) and percentage (%). Paired sample t-test was used to compare $IOP^{CT\text{-}1P}$, $IOP^{CT\text{-}1P\ adj.}$ and $IOP^{GAT}$, and $CCT^{CT\text{-}1P}$ and $CCT^{Pentacam}$ measurements for the same patient. About 95% confidence interval of the difference between the compared methods was also calculated. Blant-Altman plot was used to evaluate the agreement between devices and 95% limits of agreement (LoA) were determined for IOP and CCT measurements. Pearson's correlation coefficient (R) was calculated to estimate linear correlation between devices in terms of IOP and CCT. Reliability was analyzed by using interclass correlation coefficient (ICC). Based on the 95% confidence interval reliability was divided into four groups as follows: values less than 0.5 as low, between 0.5-0.75 as moderate, 0.75-0.9 as good and higher than 0.9 as excellent reliability. A value of $p \leq 0.05$ was considered statistically significant.

## RESULTS

We enrolled 218 eyes of 109 patients in this study with the mean age of 43.4±18.2 years (range:18-86 years). Seventy-six patients (70%) were female. The mean BCVA was 0.94±0.16. The mean $IOP^{CT\text{-}1P}$, $IOP^{CT\text{-}1P\ adj.}$, $IOP^{GAT}$ were measured as 18.2±4.32 mmHg, 17.75±4.05 mmHg and 16.9±4.16 mmHg, respectively. The mean CCT was measured as 554.8±37.3µm with CT-1P and 543.6±35.9 µm with Pentacam (Table 1). Paired sample t-test revealed that the mean difference was significantly different between $IOP^{CT\text{-}1P\ vs.\ CT\text{-}1P\ adj.}$, $IOP^{CT\text{-}1P\ vs.\ GAT}$, $IOP^{CT\text{-}1P\ adj.\ vs.\ GAT}$, and $CCT^{CT\text{-}1P\ vs.\ Pentacam}$ (Table 2, $p<0.001$, for all comparisons). Interclass correlation coefficient was found to be 0.944 with 0.927-0.958, 95% CI between $IOP^{CT\text{-}1P\ vs.\ CT\text{-}1P\ adj.}$, 0.938 with 0,919-0.952, 95% CI between $IOP^{CT\text{-}1P\ vs\ GAT}$ and 0.922 with 0.898-0.940 95% CI between $IOP^{CT\text{-}1P\ adj.\ vs.\ GAT}$ for IOP measurement. Also ICC was 0.975 with 0.967-0.981 between $CCT^{CT\text{-}1P\ vs.\ Pentacam}$ for CCT measurement. Interclass correlation coefficient confirmed the excellent reliability between devices in terms of measurement of IOP and CCT (Table 3, $p<0.001$ for all comparisons).

Figure 1 shows a Bland-Altman scatter plot compare $IOP^{CT\text{-}1P}$, $IOP^{CT\text{-}1P\ adj.}$ and $IOP^{GAT}$ and $CCT^{CT\text{-}1P}$ and $CCT^{Pentacam}$. The 95% LoA for IOP were -4.24 to 3.28 mmHg between CT-1P adj. and CT-1P, -3.49 to 5.14 mmHg between CT-1P adj. and GAT and -2.7 to 5.3 mmHg between CT-1P and GAT. Also 95% LoA for CCT were -12.33 to 32.16 µm between CT-1P and Pentacam (Figure1). Pearson correlation test showed that there was a strong correlation between $IOP^{CT\text{-}1P}$, $IOP^{CT\text{-}1P\ adj.}$ and $IOP^{GAT}$ ($R^2$:0.89 for CT-1P and CT-1P adj.; $R^2$:0.85: for CT-1P adj. and GAT and $R^2$:0.88 for CT-1P and GAT) and $CCT^{CT\text{-}1P}$ and $CCT^{Pentacam}$ ($R^2$:0.95) (Figure 2).

## DISCUSSION

An accurate IOP measurement is an important step of ophthalmological examination. For glaucoma patients,

**Table 1.** *Mean IOP and CCT measurents with CT-1P, Goldmann applanation tonometer and Pentacam.*

| | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| $IOP^{CT\text{-}1P}$ | 18.2 | 4.32 | 11 | 45 |
| $IOP^{CT\text{-}1P\ adj}$ | 17.75 | 4.05 | 9 | 42 |
| $IOP^{GAT}$ | 16.9 | 4.16 | 10 | 35 |
| $CCT^{CT\text{-}1P}$ | 554.8 | 37.3 | 452 | 633 |
| $CCT^{Pentacam}$ | 543.6 | 35.9 | 433 | 657 |

**IOP:** Intraocular pressure, **CT-1P adj.:** Intraocular pressure adjusted according to central corneal thickness with CT-1P, **CCT:** Central corneal thickness, **GAT:** Goldmann applanation tonometer, **SD:** Standard deviation

**Table 2:** *Comparison of intraocular pressure and central corneal thickness according to the different devices.*

| | Mean difference | 95% Confidence Interval | P value* |
|---|---|---|---|
| IOP | | | |
| CT-1P vs.CT-1P adj | -0.48±1.92 | -0.739-0.223 | <0.001 |
| CT-1P vs. GAT | 1.29±2.05 | 1.02-1.572 | <0.001 |
| CT-1Padj vs. GAT | 0.81±2.21 | 0.51-1.111 | <0.001 |
| CCT | | | |
| CT-1P vs. Pentacam | 9.9±11.3 | 8.34-11.5 | <0.001 |

*Student-t test
**IOP:** Intraocular pressure, **CT-1P adj.:** Intraocular pressure adjusted according to central corneal thickness with CT-1P, **CCT:** Central corneal thickness, **GAT:** Goldmann applanation tonometer

**Table 3:** *Interclass correlation coefficient (ICC), 95% confidence interval and reliability of measurements.*

| Pairs-Parameters | ICC | 95% Confidence Interval | p value | Reliability |
|---|---|---|---|---|
| IOP CT-1P vs. CT-1Padj | 0.944 | 0.927-0.958 | <0.001 | Excellent |
| IOP CT-1P vs. GAT | 0.938 | 0.919-0.952 | <0.001 | Excellent |
| IOP CT-1P adj vs. GAT | 0.922 | 0.898-0.940 | <0.001 | Excellent |
| CCT CT-1P vs Pentacam | 0.975 | 0.967-0.981 | <0.001 | Excellent |

**CT-1P adj.:** Intraocular pressure adjusted according to central corneal thickness with CT-1P , **CCT:** Central corneal thickness, **GAT:** Goldmann applanation tonometer

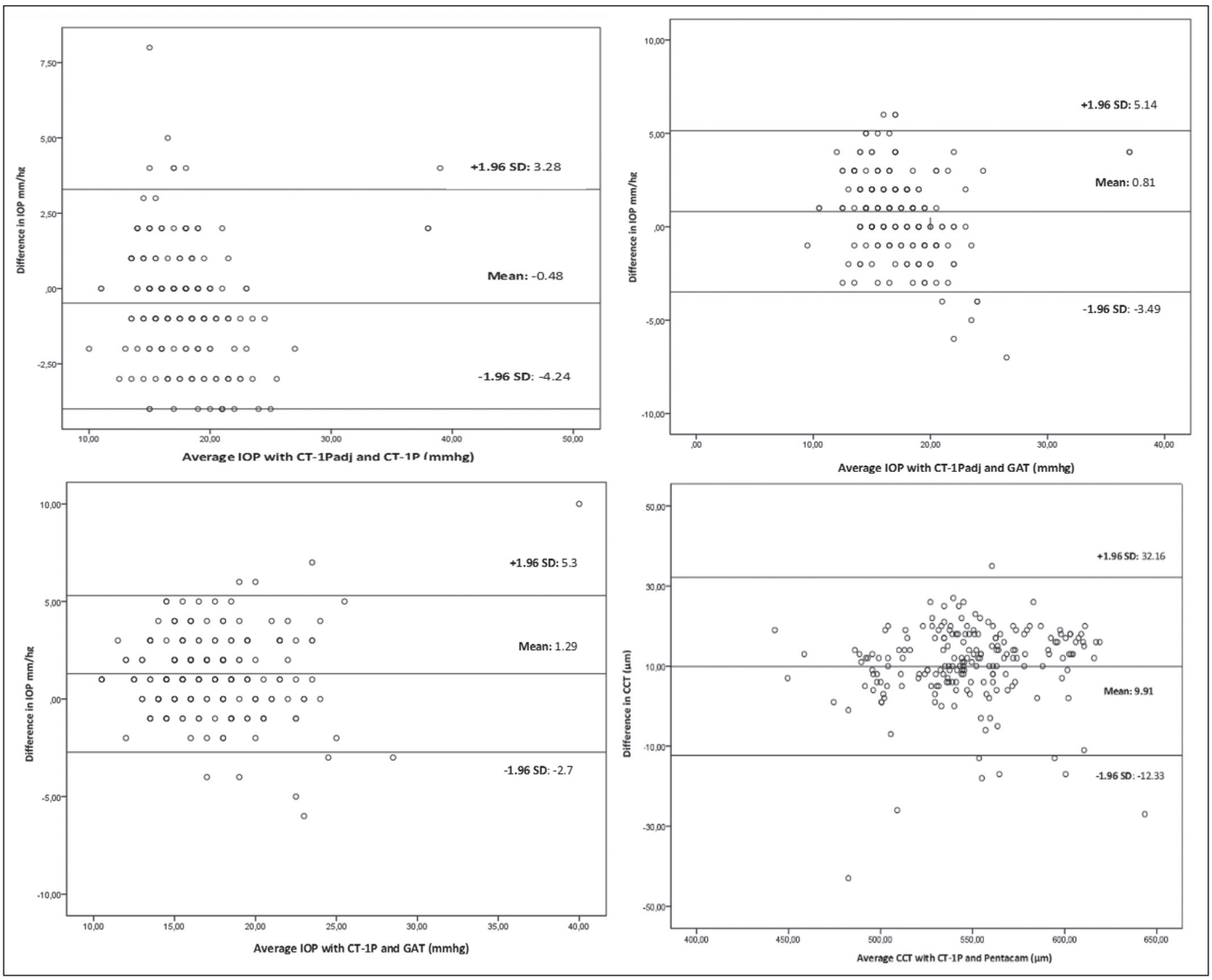


**Figure 1:** *Blant-Altman plots for the mean differences between IOPCT-1P, IOPCT-AP adj. and IOPGAT and the mean differences between CCTCT-1P and CCTPentacam. Also 95% limits of agreement for comparisons were determined.*

IOP evaluation with CCT is essential because, there is a significant relationship between increase in corneal thickness and increased IOP.[12] Tono-pachymeters combine a non-contact tonometer and pachymeter into one device and provides two measurements at the same time. In this study, we compared the reliability of the IOP and CCT measurements of a non-contact tono-pachymeter, CT-1P, with GAT and Pentacam respectively. In the literature, there is no study which evaluate both CCT and IOP measurements of CT-1P together to our knowledge. In the current study, the mean IOP measurement with CT-1P was significantly higher than GAT. Although CT-1P adj. provided approximate IOP measurements to GAT, the difference was still significantly higher. In other words, CT 1-P overestimated the IOP when compared with GAT. Also the mean CCT measurement with CT-1P was higher than

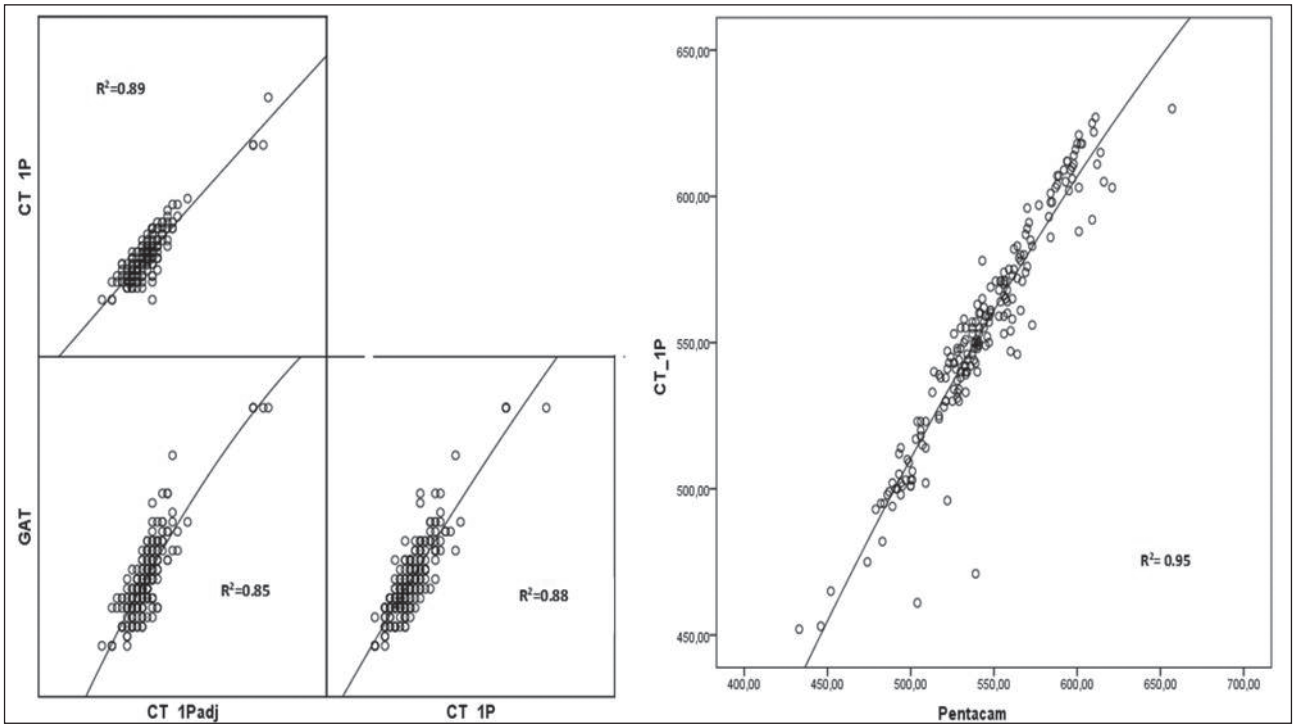


**Figure 2:** *Pearson correlation co-efficiency between devices for intraocular pressure and central corneal thickness measurements (p<0.001, for all correlations).*

Pentacam. CT 1-P overestimated the corneal thickness when compared with Pentacam. However, IOP and CCT measurements with CT-1P seems to be interchangeable with GAT and Pentacam.

Applanation tonometer is regarded as the gold standard for IOP measurement.[13] However, the use of non-contact tonometers (NCTs) increases especially in busy clinics due to their easy and low invasive application. Various NCTs for the IOP measurement have been developed.[13] In the literature, several studies have compared IOP measurements obtained by different NCTs and GAT and controversial results have been reported in different IOP ranges.[3,14,15] Lee et al.[16] showed good agreement (ICC:0.784, 95%CI: 0.695–0.849) between the tono-pachymeter (NT-530P; Nidek, Gamagori, Japan) and GAT, however Lomorellio et al.[13] reported moderate agreement (ICC: 0.64, 95%CI: 0.32–0.80) between same devices. Both studies suggested that tono-pachymeter overestimated IOP measures.[13,16] Similar to other studies, CT-1P overestimated the IOP measurement when compared to GAT in this study. However, our results demonstrated that IOP measurement had excellent agreement between CT-1P and GAT (ICC:0.944, 95% CI:0.927-0.958). Bang et al.[17] compared three different NCTs (two of them tono-pachymeters) and GAT. They reported that IOP measurements with CT-1P tono-pachymeter tended to be higher than GAT as we found in our study, but lower with NT530P tono-pachymeter than GAT conversely to Lee and Lomorellio's studies. [13,16,17] The difference between these studies may be due to the fact that they were measured in different populations.

Previous reports have suggested that Pentacam has high reliability in terms of CCT measurement.[9,18] Lee et al.[16] showed that there was inter-device agreement among tono-pachymeter (NT-530P) using the Scheimpflug-based system and Pentacam with good inter-class correlation (ICC:0.891, 95%CI:0.842-0.925) but wider 95% limits of agreement -31.8 to 28.3 (width of LoA:60.1µm) in terms of CCT measurements.[16] While Lee et al.[16] suggested tono-pachymeter CCT measurement may not be interchangeable with ultrasonography pachymeter (USP), Lomoriello et al. [13] indicated that CCT measurements of the same tono-pachymeter were interchangeable with USP. The operating principles of the device that Lee et al.[16] used in their study (Scheimpflug-based system) was different that we used (specular microscope method) in the current study. Sagdik et al.[19] found similar agreement with broad %95 LoA between CT-1P, USP and optical biometry for CCT measurements. But they did not use Pentacam for comparison. Gonzales–Perez et al.[9] compared CCT measurements between CT-1P and Pentacam and they reported that CT-1P had moderate ICC values with significant mean CCT difference. Also, they detected that CT-1P underestimated the CCT measurements when compared with the Pentacam, however in our study we found that the mean CCT with CT-1P was thicker than Pentacam. But they conducted the study with relatively low number of patients (52 eyes) without different pathologic conditions.[9] The different operating systems of each device (Pentacam with Scheimpflug-base system and CT-1P with a specular microscope method) may be one of the reasons

of this difference. Previous studies had conflicting results in terms of CCT measurement between various specular microscopes and Pentacam.[20,21] Our results showed that CT-P1 and Pentacam had excellent ICC with less width of 95%LoA (44.49 µm) than the study that conducted Gonzales–Perez et al. (120.6 µm with width of 95%LoA).[9]

Beside its easy usage, another advantage of tono-pachymeters is that they provide adjusted IOP measurement according to CCT. In the current study, we found that adjusted IOP measurement according to CCT obtained from CT-1P tended to be closer to IOP measurement with GAT. It is important to note that, Yaoeda et al.[1] reported that adjusted IOP according to CCT depends on the measurement instrument itself rather than the adjustment method. Therefore, in line with our findings, the adjusted IOP measurements according to CCT with tono-pachymeters, which were practical for busy clinics, could provide closer results to the gold standard applanation tonometer.

Our study has some limitations. First of all, study population was heterogeneous. Therefore, this could lead to extremely high or low IOP and/or CCT values, which could affect the results. However, the number of participants was relatively high. Second, we did not assess IOP measurement of GAT adjusted to CCT. So, we could not compare two devices in terms of IOP measurement adjusted by CCT and we could not evaluate the effect of CCT on the IOP measurements.

In conclusion, CT-1P had excellent agreement with Pentacam and GAT in terms of CCT and IOP measurements. The ability of tono-pachymeters to measure both CCT and IOP with a single device provide an important convenience especially in busy clinics. However, the fact that the tono-pachymeters may overestimate the IOP and CCT measurements than the methods which are considered as gold standard. It should be kept in mind that while the patient is being followed up in the clinics, repeated measurements should be performed by the same method.

## REFERENCES


1. Yaoeda K, Fukushima A, Shirakashi M, et al. Comparison of intraocular pressure adjusted by central corneal thickness or corneal biomechanical properties as measured in glaucomatous eyes using noncontact tonometers and the Goldmann applanation tonometer. Clin Ophthalmol. 2016;10:829.
2. Gordon MO, Beiser JA, Brandt JD, et al. The Ocular Hypertension Treatment Study: baseline factors that predict the onset of primary open-angle glaucoma. Arch Ophthalmol. 2002;120:714-720.
3. Mansoori T, Balakrishna N. Effect of central corneal thickness on intraocular pressure and comparison of Topcon CT-80 non-contact tonometry with Goldmann applanation tonometry. Clin Exp Optom. 2018;101:206-12.
4. Kass MA. Standardizing the measurement of intraocular pressure for clinical research: guidelines from the Eye Care Technology Forum. Ophthalmology. 1996;103:183-5.
5. Pagoulatos DD, Kapsala ZG, Makri OE, et al. Comparison of intraocular pressure using Goldmann applanation tonometry versus non-contact tonometry in eyes with high-viscosity silicone oil. Eur J Ophthalmol. 2020;30:494-9.
6. Ko Y, Liu C-l, Hsu W-M. Varying effects of corneal thickness on intraocular pressure measurements with different tonometers. Eye. 2005;19:327-32.
7. Doğan M, Ertan E. Comparison of central corneal thickness measurements with standard ultrasonic pachymetry and optical devices. Clin Exp Optom. 2019;102:126-30.
8. Fujimura F, Kamiya K, Fujiwara K, et al. Repeatability and reproducibility of measurements using a NT-530P noncontact tono/pachymeter and correlation of central corneal thickness with intraocular pressure. Biomed Res Int. 2013;2013:370592.
9. González-Pérez J, Queiruga Piñeiro J, Sánchez García Á, et al. Comparison of central corneal thickness measured by standard ultrasound pachymetry, corneal topography, tono-pachymetry and anterior segment optical coherence tomography. Curr Eye Res. 2018;43:866-72.
10. Stamper RL. A history of intraocular pressure and its measurement. Optom Vis Sci. 2011;88:E16-E28.
11. Özyol E, Özyol P. Comparison of central corneal thickness with four noncontact devices: An agreement analysis of swept-source technology. Indian J Ophthalmol. 2017;65:461-5.
12. Kouchaki B, Hashemi H, Yekta A. Comparison of current tonometry techniques in measurement of intraocular pressure. J Curr Ophthalmol. 2017;29:92-7.
13. Lomoriello DS, Lombardo M, Tranchina L, et al. Repeatability of intra-ocular pressure and central corneal thickness measurements provided by a non-contact method of tonometry and pachymetry. Graefes Arch Clin Exp Ophthalmol. 2011;249:429-34.
14. Popovich KS, Shields MB. A comparison of intraocular pressure measurements with the XPERT noncontact tonometer and Goldmann applanation tonometry. J Glaucoma. 1997;6:44-6.
15. Ogbuehi KC. Assessment of the accuracy and reliability of the Topcon CT80 non-contact tonometer. Clin Exp Optom. 2006;89:310-4.
16. Lee YG, Kim JH, Kim NR, et al. Comparison between Tonopachy and other tonometric and pachymetric devices. Optom Vis Sci. 2011;88:843-9.
17. Bang SP, Lee CE, Kim YC. Comparison of intraocular pressure as measured by three different non-contact tonometers and goldmann applanation tonometer for non-glaucomatous subjects. BMC Ophthalmol. 2017;17:199.
18. González-Pérez J, González-Méijome JM, Ares MTR, et al. Central corneal thickness measured with three optical devices and ultrasound pachometry. Eye Contact Lens. 2011;37:66-70.
19. Sagdik HM, Aktas S, Tetikoglu M, et al. Comparison of ultrasonic pachymetry, with a new optical biometry and tono-pachymetry. Med Sci. 2017;6:22-5.
20. Karaca I, Yilmaz SG, Palamar M, et al. Comparison of central corneal thickness and endothelial cell measurements by Scheimpflug camera system and two noncontact specular microscopes. Int Ophthalmol. 2018;38:1601-9.
21. De Bernardo M, Borrelli M, Mariniello M, et al. Pentacam vs SP3000P specular microscopy in measuring corneal thickness. Cont Lens Anterior Eye. 2015;38:21-7.