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Intraocular pressure behavior in the Goldmann and pneumatic tonometer during water drinking test

Comportamento da pressão intraocular no tonômetro de aplanação de Goldman e pneumático durante o teste de sobrecarga hídrica

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ABSTRACT

Objective: *To evaluate the consonance betweenthe Goldman and pneumática planation to nometers under the effect of the water drink test.* ***Methods:*** *Cross-sectional descriptive study consisting of a sample of 102 eyes from a private hospital in Goiânia (GO) from 2013 to 2015,with na evaluation of different intraocular pressures (IOP) in the Goldman and pneumatic flattening to nometers when submitted to TSH.* ***Results:*** *The average age was 52.17 (± 15.21) years old, 60.8% of the patients were female and 39.2% were male.The mean corneal thickness was 531.9(± 72.75) By linear regression the variables age and corneal thickness did not occur statistical significance between the two devices analyzed.* ***Conclusion:*** *Good agreement was observed in the measurements between the applanation devices and the tire during the water drink test, but new studies with a greater epidemiological impact were required to confirm this assertion.*

Keywords: *Intraocular pressure; Glaucoma; Pachymetry; Reproducibility; Tonometry/methods*

RESUMO

Objetivo: Avaliar a concordância entre os tonômetros de aplanação de Goldman e pneumático na realização do teste de sobrecarga hídrica (TSH). **Métodos:** Estudo descritivo transversal composto por uma amostra de 102 olhos proveniente de um hospital particular em Goiânia (GO) entre 2013 a 2016, com avaliação das diferentes pressões intraoculares (PIO) nos tonômetros de aplanação de Goldman e pneumático quando submetidos ao TSH. **Resultados:** A média de idade foi de 52,17 (± 15,21) anos , sendo que60,8% dos pacientes pertenciam ao sexo feminino e 39,2% ao masculino. A média da espessura da córnea foi de 531,9(± 72,75) micra. Por regressão linear as variaveis idade e espessura da cornea central não ocorreram significancia estatistica entre os dois dispositivos analisados. **Conclusão:** Observou-se boa concordância nas medições entre os aparelhos de aplanação e o pneumático durante o teste de sobrecarga hídrica, porém necessita-se de novos estudos de maior impacto epidemiológico para confirmação desta assertiva.

Descritores: Pressão intraocular; Glaucoma; Paquimetria; Reprodutibilidade; Tonometria/métodos

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Introduction

Glaucoma is a multifactorial disease with progressive, insidious optic neuropathology with loss of the visual field in which the main risk factor is increased intraocular pressure (IOP).[1,2] It represents the second cause of blindness in the world.[2] The estimate is that in 2020 there will be 79.6 glaucoma patients in the world.[2,3] In Brazil, its prevalence may reach 3.4%.[4] According to data from the study of Yih-Chung Than et al.[3], the number of individuals with glaucoma in the world will increase from 64.3 million in 2013 to 111.8 million in 2040, affecting mainly the African and Asian populations.

Increased IOP is the main risk factor for glaucoma progression as well as its fluctuation in primary open-angle glaucoma (POAG).[5,6] Tonometer is the apparatus used to detect the increased IOP. Despite the existence of various models, Goldman applanation is considered the golden standard for this measurement.[7-8] This method is quite accurate. However, errors can occur in the result due to fluorescein patterns, very thick corneas, excessive pressure on the eyeball, among others.[8]

The IOP measure can also be made with other kind of tonometer: the non-contact one (pneumatic or blow). It was used for the first time in 1973 by Forbes, and the advantages are: 1) no need to use eyedrops; 2) can be made by people other than doctors, 3) low risk of contamination; and 4) can be used for screening programs.[9,10]

In their study, Sanchez-Tocino et al.[11] compared the pneumatic tonometer to Goldman's, and differences between the apparatuses could occur in about 2 mmHg.

The Water Load Test (WLT) was used a lot during the decades of 1960 and 1070 to diagnose glaucoma. However, more recent studies changed the focus of this test due to its low diagnostic precision. WLT indirectly assesses the drain capacity of the aqueous humor.[6,12] Its importance is due to the fact of detecting peaks of IOP undetected during regular working hours.

The values of IOP obtained during a period of 24 hours are important data, as they are necessary to control and conduct glaucoma treatment.[13,14] In the past, WLT was frequently used to diagnose patients with this pathology. A series of studies[15,16] showed that WLT can be used as a tool to assess peak changes of IOP.

The objective of the present study is to verify the similarities between Goldman's and pneumatic applanation tonometers to measure IOP during WLT, and analyze possible variables that could directly influence these measures.

Methods

It is a cross-sectional descriptive study with review of electronic medical records of a private ophthalmological hospital in Goiânia (GO) from 2013 to 2016. The present study was submitted and approved by the research ethics committee of Pontifícia Universidade Católica de Goiás (PUC-GO).

The study comprised 102 individuals, with a sample of 102 eyes with primary open-angle glaucoma and/or suspected glaucoma. The following variable were observed: gender, age, intraocular pressure, and pachymetry. All patients underwent complete ophthalmologic examination, including Goldmann's and pneumatic tonometries.

The inclusion criteria were patients over 18 years of age, complete medical records, and individuals with suspected and/or confirmed glaucoma. Patients with suspected glaucoma had a positive family history and/or IOP above 21 mm Hg, and/or increased excavations above 0.6, and/or asymmetry between the eyes greater than 0.2. Glaucoma patients were considered with IOP above 22 mmHg, excavations greater than 0.6 with focal or diffuse loss of neuronal rhyme, open angle confirmed by gonioscopy, loss of visual field according to Anderson criteria[6,17] with minimum reproducibility of at least two visual fields. The exclusion criteria were patients under 18 years of age with incomplete data on electronic medical records, contact lens users, and/or other ophthalmological diseases and/or previous ophthalmologic surgeries and/or systemic diseases.

Patients with glaucoma and/or suspected glaucoma underwent the Water Load Test (WLT), which consists in the intake of 800 to 1000ml of water in a short period of time (about 05 minutes).[12,18] In the present study, the patient was instructed to remain in an absolute fast for 8 hours. In the morning period, pneumatic IOP was measured, followed by aplanation tonometry, and the patient was then instructed to drink 800 ml of water in a period of 5 minutes. Then the IOP measurement was performed in a sitting position every 15 minutes, until the period of 1 hour and 15 minutes was completed, thus making a total of six measurements.

All patients had the IOP measured with the pneumatic tonometer of Topcon computerized CT-80 Japan tonometer, and with the applanation tonometer of Goldmann Optilasa S.I, Spain.

After the data were collected, they were transcribed in Microsoft Excel® software. StatisticalPackage for Social Science (SPSS) version 21.0 was used to analyze the data.

The categorical variables were presented as absolute value (n) and percentage value (%). Continuous variables were presented as average ± standard deviation, median (95% CI).

The Kappa test was used to verify the possible existence of an agreement with the results obtained from the IOP in the applanation and pneumatic apparatuses. For this analysis the intraocular pressure was classified into categories. A 95% confidence level was considered for all tests, that is, $p < 0.05$ was considered significant.

Results

The average age of the patients was 52.17 ± 15, 21 years. Patients were analyzed according to the use of eyedrops, and 47 (46.1%) did not use it and 55 (53.9%) used it. The average corneal thickness (ACT) was 531.9 ± 72.75 microns (Table 1).

The analysis of the values showed the agreement between the apparatuses when comparing the categories analyzed (Table 2).

When the IOP measurement between the two apparatuses was compared, the peak pressure occurred at 8:15 (Figure 1).

Despite the significance of the measurement at 8:45, the averages and the confidence interval between them are very close in individuals with and without the use of eyedrops (Table 3).

Table 4 shows a comparative study between the peak and the fluctuation between the two devices analyzed, where the significance between the two devices is observed in corneas below 500 and between 501-550.

There were no significant differences between the devices analyzed and the categorical variables of the central corneal thickness (Table 5).

Table 6 compares the intraocular pressure between the applanation and pneumatic apparatuses in relation to the different classes of medication.

In table 7, linear regression was performed, and no statistical significance was observed between the variables analyzed.

Table 8 compares individuals suspected of glaucoma and individuals with glaucoma between pneumatic and aplanation devices.

Table 1
Distribution of patients according to gender, age, use of eyedrops and corneal thickness

Variables	Number of patients	
Gender	N	%
Female	62	60.8
Male	40	39.2
Use of eyedrops		
No	47	46.1
Yes	55	53.9
Age (average)	52.17±15.21	
Central corneal thickness (average)	531.9±72.75	

Table 2
Agreement test and distribution of pressure categories in the 102 eyes analyzed, measured by applanation and pneumatic in patients at certain hours

Applanation	Pneumatic (n. of patients)			K	P value
	≤ 10	11 - 21	≥ 22		
7:45 am	n=9	n=86	n=7		
≤ 10 (n=9)	6	3	-		
11– 21 (n=85)	3	81	1	0.69	< 0.001*
≥ 22 (n=8)	-	2	6		
8:00 am n=8	n=80	n=14			
≤ 10 (n=7)	4	3	-		
11 – 21 (n=79)	4	71	4	0.544	< 0.001*
≥ 22 (n=16)	-	6	10		
8:15 am n=5	n=82	n=15			
≤ 10 (n=1)	1	-	-		
11 – 21 (n=77)	4	68	5	0.370	< 0.001*
≥ 22 (n=24)	-	14	10		
8:30 am n=5	n=85	n=12			
≤ 10 (n=4)	4	-	-		
11 – 21 (n=84)	1	76	7	0.49	< 0.001*
≥ 22 (n=14)	-	9	5		
8:45 am n=9	n=84	n=9			
≤ 10 (n=6)	6	-	-		
11 – 21 (n=87)	3	80	4	0.62	< 0.001*
≥ 22 (n=9)	-	4	5		
9:00 am n=10	n=84	n=8			
≤ 10 (n=11)	7	4	-		
11 – 21 (n=83)	3	78	2	0.66	< 0.001*
≥ 22 (n=8)	-	2	6		

K = Kappa test, p = statistical significance, * Significant p <0.05; n = number of eyes

Table 3
Comparison of intraocular pressure in 102 eyes analyzed between patients who used eyedrops and those who did not use eyedrops at different times

Variable	Use of eyedrops		P value
	No (n=47)	Yes (n=55)	
Applanation			
7:45:00 am	16.0 (15.2 – 17.6)	15.0 (13.9 – 15.9)	0.084
8:00:00 am	18.0 (16.6 – 19.3)	16.0 (15.4 – 17.7)	0.079
8:15:00 am	19.0 (17.6 – 20.2)	18.0 (16.3 – 18.6)	0.106
8:30:00 am	17.0 (16.8 – 19.2)	16.0 (15.4 – 17.4)	0.083
8:45:00 am	17.0 (16.1 – 18.5)	16.0 (14.8 – 16.6)	0.024*
9:00:00 am	16.0 (15.5 – 17.8)	15.0 (14.6 – 16.7)	0.116
Pneumatic			
7:45:00 am	17.0 (15.4 – 18.2)	16.0 (14.6 – 16.8)	0.342
8:00:00 am	18.0 (16.1 – 19.0)	16.0 (15.3 – 18.0)	0.192
8:15:00 am	18.0 (16.9 – 19.8)	17.0 (16.0 – 18.6)	0.216
8:30:00 am	17.0 (16.2 – 18.9)	17.0 (15.9 – 18.2)	0.708
8:45:00 am	16.9 (15.6 – 18.2)	16.0 (14.8 – 17.1)	0.241
9:00:00 am	17.0 (15.4 – 18.0)	16.0 (14.9 – 17.4)	0.347

Test: Mann-Whitney, p = statistical significance, * Significant p <0.05; n = number of eyes

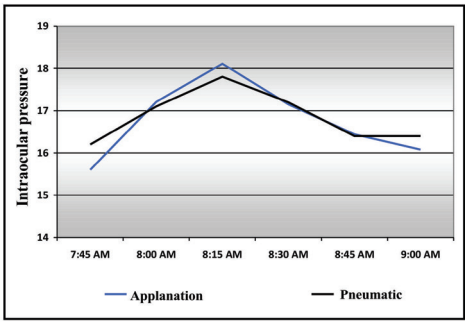

Figure 1: Average intraocular pressure in 102 eyes analyzed according to the type of apparatus at the given moments.

Table 4
Comparison between the peak and fluctuation of intraocular pressure in 102 eyes analyzed between the Applanation and Pneumatic devices regarding the central corneal thickness and the use of eyedrops

Variables	Aparattus		P value
	Applanation	Pneumatic	
Peak			
Central corneal thickness			
≤ 500 (n=18)	17.6 ± 4.3	16.6 ± 3.8	0.039*
501 – 550 (n=38)	19.5 ± 4.0	20.0 ± 4.6	0.137
> 550 (n=45)	19.4 ± 4.4	20.2 ± 5.1	0.156
Use of eyedrops			
No (n=47)	19.8 ± 4.4	19.7 ± 4.9	0.595
yes (n=55)	18.6 ± 4.1	19.3 ± 4.9	0.062
Fluctuation			
Central corneal thickness			
≤ 500 (n=18)	4.6 ± 2.4	4.3 ± 1.3	0.915
501 – 550 (n=38)	4.7 ± 2.8	5.9 ± 3.1	0.002*
> 550 (n=45)	4.4 ±1.8	4.5 ± 2.6	0.874
Use of eyedrops			
No (n=47)	4.4 ± 2.1	4.8 ± 2.2	0.398
yes (n=55)	4.7 ± 2.6	5.2 ± 3.1	0.204

Test: Mann-Whitney, p = statistical significance, * Significant p <0.05; n = number of individuals

Table 5
Comparison between the intraocular pressure in 102 eyes analyzed between the Applanation and Pneumatic apparatuses regarding the central corneal thickness at different times

Corneal thickness	Aparattus		P value
	Applanation	Pneumatic	
7:45:00 am			
≤ 500 (n=18)	14.5 (12.4 – 16.4)	14.0 (11.7 – 15.7)	0.645
501 – 550 (n=38)	16.0 (14.4 – 16.5)	16.0 (14.7 – 16.9)	0.591
> 550 (n=45)	16.0 (14.9 – 17.7)	17.0 (15.9 – 18.9)	0.247
8:00:00 am			
≤ 500 (n=18)	16.5 (13.3 – 17.9)	14.5 (12.4 – 16.3)	0.417
501 – 550 (n=38)	17.0 (16.0 – 18.4)	16.0 (15.3 – 18.0)	0.552
> 550 (n=45)	18.0 (16.2 – 19.2)	18.0 (16.8 – 20.1)	0.790
8:15:00 am			
≤ 500 (n=18)	16,5 (14.6 – 18.8)	16.0 (12.9 – 16.6)	0.220
501 – 550 (n=38)	19.5 (17.2 – 19.9)	18.0 (16.4 – 19.6)	0.395
> 550 (n=45)	18.0 (16.9 – 19.5)	17.0 (17.2 – 20.1)	0.784
8:30:00 am			
≤ 500 (n=18)	15.5 (13.2 – 17.6)	16.0 (12.4 – 16.7)	0.582
501 – 550 (n=38)	16.0 (16.0 – 18.6)	18.0 (15.9 – 18.7)	0.983
> 550 (n=45)	17.0 (16.5 – 18.6)	17.0 (16.9 – 19.5)	0.652
8:45:00 am			
≤ 500 (n=18)	15.5 (13.1 – 16.8)	15.0 (12.0 – 16.2)	0.568
501 – 550 (n=38)	16.0 (15.8 – 18.4)	16.5 (15.2 – 18.3)	0.715
> 550 (n=45)	16.0 (15.4 – 17.5)	16.0 (15.7 – 18.0)	0.530
9:00:00 am			
≤ 500 (n=18)	15.0 (12.5 – 16.1)	14.5 (12.0 – 15.4)	0.513
501 – 550 (n=38)	16.0 (12.5 – 16.1)	16.0 (15.5 – 18.8)	0.851
> 550 (n=45)	16.0 (14.8 – 16.9)	16.0 (15.5 – 17.9)	0.352

Test: Mann-Whitney, p = statistical significance, * Significant p <0.05; n = number of eyes

Discussion

Glaucoma is a serious ocular health problem, since it has a high incidence and prevalence, being the main cause of irreversible blindness in the world.[1,2,5] Some studies report that females may be the most affected, accounting for 55% of primary open-angle glaucoma in the year 2020.[2,19] This data is in agreement with the sample of the present study, since 60.8% are female and 30.9% male, thus showing a higher prevalence among women. Some studies have shown that males have a great resistance to the demand for health services, highlighting the incompatibility of time and/or the fragility, morbidity and mortality of the disease.[20,21] In this specific study, we cannot corroborate this statement, since the sample analyzed was of convenience. Therefore, high-impact studies are recommended to corroborate the data found here.

According to some authors,[22,23] the prevalence of POAG increases with age. In the present study, the average age of suspected and/or glaucoma was 52.17, which corroborates the literature data.

Changes in the corneal structure cause changes in the IOP measurements, and this can be due to Goldman's applanation tonometer.[2,10,23] These measurements can generally hypothesize measurements in corneas with reduced thickness, and as a consequence increase the risk of optic nerve damage as a result of an increased real IOP.[11,24]

Other authors,[2,5,10] suggest that IOP in patients with thicker corneas may be overestimated with applanation tonometry and less influenced with the pneumatic one.[11] Due to that, these patients are exposed to a lower risk of progression of the IOP-related glaucomatous lesion. The present study showed that even with the possible corneal deformities the general corneal thickness did not influence the IOP reproducibility between the two apparatuses during WLT. The possible justification for this fact could be related to the fact that the average found for the pachymetric value is compatible with the global average, and thus would be less influenced by distortions when measured. When we analyzed the isolated peak and fluctuation variables, there was a slight discrepancy between the two devices. It is observed that the peak is slightly more underestimated in thinner corneas with the pneumatic tonometer, and a greater fluctuation in this device. It is worth mentioning that corneal thickness is an important factor influencing the IOP measurement alone. [2,5,10,24] Intrinsic factors such as biomechanics[25], besides the thickness itself, could influence this result, and thus we recommend specific studies for

Table 6
. Comparison between the intraocular pressure in 102 eyes analyzed between the Applanation and Pneumatic apparatuses regarding the class of eyedrops at different times

Class	Aparattus		P value
	Applanation	Pneumatic	
7:45:00 am			
1	14.0 (13.1 – 16.4)	16.0 (15.2 – 17.8)	0.102
2	16.0 (14.8 – 18.7)	18.0 (14.7 – 19.2)	0.988
3	14.0 (11.8 – 14.7)	14.0 (11.5 – 15.6)	0.967
8:00:00 am			
1	16.0 (14.4 – 17.9)	16.0 (15.0 – 18.8)	0.661
2	18.0 (16.5 – 21.3)	19.0 (15.3 – 21.4)	0.682
3	14.0 (12.8 – 16.1)	14.0 (12.5 – 16.3)	0.770
8:15:00 am			
1	18.0 (15.8 – 19.1)	17.5 (15.9 – 19.1)	0.870
2	20.0 (16.9 – 21.5)	18.0 (16.3 – 22.1)	0.682
3	16.0 (13.7 – 17.3)	14.0 (13.2 – 17.1)	0.630
8:30:00 am			
1	16.0 (14.9 – 17.9)	18.0 (15.8 – 18.7)	0.383
2	18.0 (15.4 – 19.6)	17.0 (15.8 – 20.1)	0.872
3	16.0 (13.8 – 17.2)	15.0 (13.4 – 18.7)	0.802
8:45:00 am			
1	16.0 (14.2 – 16.8)	16.5 (15.4 – 18.5)	0.164
2	16.0 (14.9 – 18.8)	16.0 (14.4 – 18.5)	0.837
3	14.0 (13.3 – 16.5)	14.0 (12.1 – 17.0)	0.502
9:00:00 am			
1	15.5 (13.6 – 16.4)	16.0 (14.9 – 17.8)	0.147
2	16.0 (14.6 – 18.9)	15.0 (14.1 – 19.2)	0.826
3	14.0 (12.4 – 16.5)	14.0 (11.7 – 17.4)	0.770

Test: Mann-Whitney, p = statistical significance; * Significant p <0.05. 1 = one class of antiglaucomatous medication (In use of only one of the following medications: Prostaglandin analog, selective β-blockers, non-selective β-blockers or α 2 -adrenergic agonist), 2 = two different classes of antiglaucomatous medication (In combination with two of the following medications: non-selective β-blockers, α2 adrenergic agonist, carbonic anhydrase inhibitor, prostaglandin analogue, and 3 = three different classes of antiglaucomatous medication (Using the combination of three of the following medications: α2 adrenergic agonist, non-selective β-blockers, carbonic anhydrase inhibitor or prostaglandin Analogue).

Table 7
Linear regression of the difference of intraocular pressure in 102 eyes analyzed between the Applanation and Pneumatic apparatuses at different times regarding age and the central corneal thickness

Variable	R^2	B	P value
Age/Time			
7:45:00 am	0.027	-0.011	0.099
8:00:00 am	0.036	-0.024	0.055
8:15:00 am	0.025	-0.018	0.111
8:30:00 am	0.019	-0.015	0.162
8:45:00 am	0.008	0.008	0.373
9:00:00 am	0.001	0.003	0.746
Corneal thickness /Time			
7:45:00 am	0.004	0.003	0.522
8:00:00 am	0.004	0.003	0.532
8:15:00 am	0.011	0.005	0.305
8:30:00 am	0.015	0.005	0.229
8:45:00 am	0.001	-0.001	0.798
9:00:00 am	0.022	0.005	0.140

R^2 = Coefficient of determination, B = Slope of the line, p = statistical significance, * Significant p <0.05.

Table 8
Comparison of intraocular pressure in 102 eyes analyzed between the Applanation and Pneumatic devices regarding suspected Glaucoma (n = 73) and Glaucoma (n = 29)

Glaucoma	Aparattus		P value
	Applanation	Pneumatic	
7:45			
Suspected glaucoma	16.5 ± 3.9	17.4 ± 4.2	0.004*
Glaucoma	13.4 ± 3.3	13.2 ± 3.6	0.673
8:00			
Suspected glaucoma	18.2 ± 4.5	18.2 ± 4.9	0.747
Glaucoma	14.8 ± 3.5	14.2 ± 3.7	0.191
8:15			
Suspected glaucoma	19.1 ± 4.2	18.9 ± 4.8	0.693
Glaucoma	15.7 ± 3.5	14.9 ± 3.7	0.077
8:30			
Suspected glaucoma	17.9 ± 3.9	18.1 ± 4.4	0.976
Glaucoma	15.2 ± 3.5	15.2 ± 3.9	0.965
8:45			
Suspected glaucoma	17.1 ± 3.9	17.2 ± 4.1	0.841
Glaucoma	14.7 ± 3.0	14.3 ± 4.2	0.377
9:00			
Suspected glaucoma	16.7 ± 4.1	17.1 ± 4.6	0.055
Glaucoma	14.5 ± 3.2	14.5 ± 3.9	0.954

Test: Mann-Whitney, p = statistical significance, * Significant p <0.05; n = number of eyes

later analysis. Literature[6,12] discusses the influence that a particular class of hypotensive medication could influence both peak and fluctuation of IOP during TSH. When we compared the effect of the medication between the two devices in the isolated form (peak and fluctuation), the medication class, and the general average at different times, the agreement between the devices was maintained. It is always worth mentioning the importance of the hypotensive medications for the stability and reduction of the IOP measured during the WLT with the applanation tonometer, since it is the gold standard for measurement.

In figure 2, a greater increase in the IOP of the third measure between the two apparatuses is observed. One hypothesis to consider is that IOP values are subject to cyclical fluctuations throughout the day, and the average fluctuation in normal individuals may vary from 3 to 6 mmHg.[2] This variation is generally higher in glaucoma patients.

The pattern of the daily IOP fluctuation cycle describes the pressure peaks in the early hours of the morning, which can be observed in approximately 40% of the cases.[2] Another possible hypothesis for the increase of IOP in the third measurement in the two devices during WLT would be the maximum effect of the water intake action, which would reduce its action after the other measurements.

Some studies[5,25-27] show that the variation of IOP may be an important risk factor for the progression of glaucoma, since it is believed to be the main characteristic of the disease. Therefore, the physician should give more attention during this exam, so that there is no escape from the third measure, whose maximum value may directly influence the IOP variability. It is interesting to note that only the measurement at 7:45 showed a lower agreement between the applanation and pneumatic devices in suspect patients, which may be justified by the use or not of eyedrops, or biomechanical effects on the cornea during the sleep period.

Despite the agreement between the devices during WLT, it is recommended to use applanation tonometry for such measurements. We must emphasize the limitations of this study. A proposal for future studies would be to carry out longitudinal, double-blind and randomized studies to observe this possible reproducibility, especially when the IOP measurements or corneal thickness have extreme maximum and minimum values.

Conclusion

The present study demonstrated that although the Goldman applanation tonometer is considered gold standard for the IOP measurement, there is good agreement of the IOP measurement between the devices during the water overload test.

New studies with greater epidemiological impact should be performed in this area to identify the degree of agreement between the devices, especially if the IOP extreme values and corneal thickness would have the same degree of agreement.

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