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ORIGINAL ARTICLE

Comparison between rebound tonometer and Tono-Pen® in relation to Goldmann applanation tonometry and the influence of central corneal thickness on these three methods

Comparación entre el tonómetro de rebote y el Tono-Pen® en relación con la tonometría de aplanación de Goldmann y la influencia del grosor corneal central en estos tres métodos

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Abstract

Objective: *to compare intraocular pressure (IOP) measurements from two different instruments, the rebound tonometer (Icare®) and the Tono-Pen® XL (TP), with that from Goldmann applanation tonometer (GAT) and to determine the influence of central corneal thickness on these three instruments.* **Methods:** *274 eyes from 137 healthy volunteers were evaluated in this cross-sectional study. All IOP measurements were made by the same examiner who was blinded to the observed result. Icare® tonometry was performed first, followed by TP, GAT, and pachymetry in a random order.* **Results:** *a good correlation was observed between IOP measurements obtained with Icare® and GAT (r = 0.79, p = 0.000) and between TP and GAT (r = 0.69, p = 0.000). Icare® and TP measurements were consistently higher than GAT measurements. A Bland–Altman plot indicated that the 95% limits of agreement between Icare® and GAT were 0.98 ± 3.12 (mean ± SD; range, –5.14 to 7.11) mmHg, and those between TP and GAT were 1.88 ± 3.20 (range, –4.38 to 8.15) mmHg. In the group of patients with thinner corneas, Icare® overestimated IOP by 0.5mmHg compared with IOP obtained using GAT and by 1.8 mmHg compared with IOP obtained using TP. In the group of patients with thicker corneas, Icare® overestimated IOP by 1.4 mmHg compared IOP obtained using GAT and by 1.5 mmHg compared with IOP obtained using TP.* **Conclusion:** *IOP measurements obtained with Icare® and TP showed a good correlation with that of GAT. Both tonometers tend to overestimate IOP compared to GAT. In patients with thinner corneas, Icare® perfrmed better than TP.*

Key words: *Icare®. Tono-Pen®. Goldmann. Pachymetry. Corneal thickness.*

Resumen

Objetivo: *Comparar las mediciones de la presión intraocular (PIO) de dos instrumentos diferentes, el tonómetro de rebote (Icare®) y el Tono-Pen® XL (TP), con el tonómetro de aplanación de Goldmann (TAG), y determinar la influencia del grosor corneal central en estos tres instrumentos.* **Métodos:** *En este estudio transversal se evaluaron 274 ojos de 137 voluntarios sanos. Todas las mediciones de la PIO fueron hechas por el mismo examinador que estaba cegado al resultado observado.*

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La tonometría Icare® se realizó primero, seguida de TP, TAG y paquimetría en orden aleatorio. **Resultados:** *Se observó una buena correlación entre las mediciones de PIO obtenidas con Icare® y TAG (r = 0.79; p = 0.000) y entre TP y TAG (r = 0.69; p = 0.000). Las mediciones de Icare® y TP fueron consistentemente más altas que las mediciones del TAG. Un diagrama de Bland-Altman indicó que los límites del 95% de concordancia entre Icare® y TAG fueron de 0.98 ± 3.12 (media ± DE, rango, –5.14 a 7.11) mmHg, y entre TP y TAG fueron de 1.88 ± 3.20 (rango, –4.38 a 8.15) mmHg. En el grupo de pacientes con córneas más delgadas, Icare® sobreestimó la PIO en 0.5 mmHg en comparación con la PIO obtenida utilizando TAG y en 1.8 mmHg en comparación con la PIO obtenida utilizando TP. En el grupo de pacientes con córneas más gruesas, Icare® sobreestimó la PIO en 1.4 mmHg en comparación con la PIO obtenida utilizando TAG y en 1.5 mmHg en comparación con la PIO obtenida utilizando TP.* **Conclusión:** *Las mediciones de la PIO con Icare® y TP mostraron una buena correlación con las del TAG. Ambos tonómetros tendieron a sobreestimar la PIO en comparación con TAG. En pacientes con córneas más delgadas, Icare® fue mejor que TP.*

Palabras clave: *Icare®. Tono-Pen®. Goldmann. Paquimetría. Espesor corneal.*

Introduction

Since its introduction in the 1950s, Goldmann applanation tonometer (GAT) has been considered the gold standard for determining intraocular pressure (IOP)[1]. In more recent years, a new method of tonometry was introduced in the market, the Icare® or rebound tonometer (Icare® TAO1i; Tiolat Oy, Helsinki, Finland)[2,3]. It is a portable device that enables rapid IOP measurements, by correlating the duration of the impact of a probe launched against the cornea to its stiffness, estimating the IOP. It is performed without anesthesia and the results are shown on a digital display. Some authors have reported a good correlation between Icare® and GAT measurements, both in normal subjects and in patients with glaucoma[4-7]. Another portable tonometer, the Tono-Pen® XL[8] (TP; Medtronic, Inc. Jacksonville, FL, USA), has been used clinically for some time, and it also presents good correlation with manometric measurements as well as with normal range IOP measurements obtained with GAT[9,10]. Despite the good correlation indexes, Icare®, TP, and GAT are influenced by central corneal thickness (CCT)[11-13].

This study aimed to compare Icare® with TP in relation to GAT and to determine the influence of CCT on each of these instruments.

Methods

This study was submitted and approved by an Ethics Committee in Brasilia-DF, Brazil. Two hundred eighty eyes from 140 individuals were initially included in this cross-sectional study. The volunteers were medical students or patients from the general outpatient clinic at The Brasilia Glaucomacenter, in Brasília, Brazil. Subjects who underwent eye surgery; who had corneal diseases, eye inflammation of any sort, or any other illness that hampered the reliable measurement of IOP or CCT; or who refused to sign an informed consent form were excluded. After fulfilling the elegible criteria, 274 eyes from 137 individuals signing the consent form and were eventually evaluated. All measurements with all four instruments were performed by the same experienced examiner (GMV). The tonometers were calibrated or had their calibration checked at the beginning of data collection day as per manufacturer's instructions. The volunteers underwent IOP measurement and CCT with an ultrasound pachymeter. The means of three Icare®, TP and pachymeter measurements were recorded. For GAT, only two measurement was recorded. In accordance with the manufacturers' instructions, only the Icare® measurements with satisfactory reliability indices (P, P_ and P-) and the TP measurements within 95% reliability indices were accepted. By the means of GAT, the exact position of the semicircle borders were determined. An independent observer (HCCS) read the measurements obtained using GAT. Icare® measurements were always obtained first because they can be obtained without the use of anesthetic eye drops. The order of measurements obtained using other instruments was determined by draw for every five-volunteer group. An AccuPach V pachymeter (Accutome, Malvern, PA, USA) was used to measure CCT. After the Icare® measurement, one drop of anesthetic (Oxinest, oxybuprocaine hydrochloride; Latinofarma, Cotia, SP, Brazil) was instilled in the volunteers' eyes. Goldmann applanation tonemeter measurements were preceded by the instillation of one fluorescein sodium eye drop in each eye (Fluresceina, Allergan Corp, Anaheim, CA, USA). Statistical analysis was performed using the Pearson correlation coefficient and the Bland–Altman plot. The level of significance was set at $p < 0.005$.

Table 1. Mean IOP values and the respective standard deviation (SD) for each instrument; upper limit (UP) and lower limit (LL)

	N	Mean IOP mmHg ± SD	UP	LL
Icare®	274	16.8 ± 4.6	7.0	33.5
TP	274	17.7 ± 1.5	1.5	38.3
GAT	274	15.8 ± 4.3	7.0	42.0

Icare®: Rebound tonometer; TP: Tono-Pen® XL; GAT: Goldmann applanation tonometer.

Results

In this cross-sectional study, 274 eyes from 137 individuals [mean age, 34.4 ± 1.3 (range, 17–82) years] were evaluated. Eighty-nine volunteers (65%) were females and 48 (35%) were males.

Table 1 shows the mean IOP values obtained using all instruments. A Pearson correlation coefficient (r) of 0.79 was found between Icare® and GAT measurements and r = 0.69 was found between TP and GAT measurements. Both correlations were statistically significant ($p < 0.001$). Figure 1 shows the Bland–Altman plot for the correlation between Icare® and GAT measurements, indicating an agreement within a 95% confidence interval between them, with a mean difference of 0.98 ± 3.12 (mean ± SD; range, –5.14 to 7.11) mmHg (Fig. 1). Figure 2 shows the Bland–Altman plot for the correlation between TP and GAT measurements, indicating an agreement within a 95% confidence interval between them, with a mean difference of 1.88 ± 3.20 (range, –4.38 to 8.15) mmHg (Fig. 2).

The mean CCT from 274 individuals was 539.4 ± 38.2 µ (range, 426–650). All three methods were assessed for a possible correlation with CCT (Figs. 3, 4, and 5). A small but statistically significant correlation between tonometry and pachymetry was observed for Icare® (r = 0.35; $p < 0.001$), TP (r = 0.20; $p < 0.001$), and GAT (r = 0.25; $p < 0.001$).

To evaluate the influence of CCT on the IOP measurements obtained with each instrument, the samples were divided into two groups: CCT < 530 µ (thin corneas) and CCT > 560 µ (thick corneas). The first group included 118 eyes, with mean pachymetry of 504.9 ± 22.5 µ (range, 458–529). The mean IOP values obtained using Icare® and TP were 0.5 mmHg and 1.8 mmHg higher than that obtained using GAT, respectively. The second group included 83 eyes, with mean pachymetry of 583.1 ± 19.6 µ (range, 562–650). The mean IOP values obtained using Icare® and TP were 1.5 mmHg and 1.4 mmHg higher than that obtained using GAT, respectively. Tables 2 and 3 show the mean IOP values obtained using each instrument in thin and thick corneas.

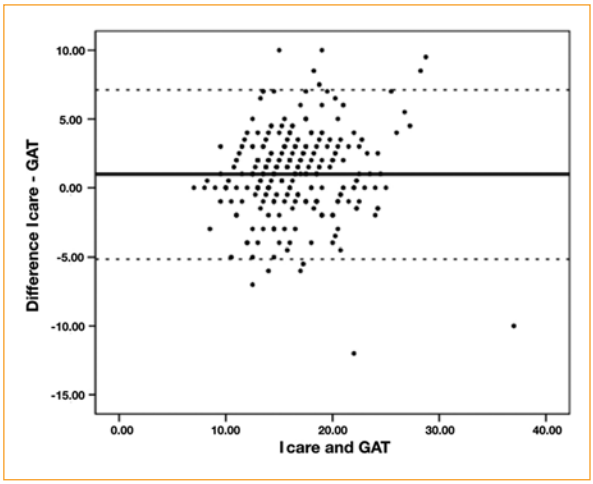

Figure 1. Bland–Altman plot for the correlation between Icare® and GAT measurements. GAT: Goldmann applanation tonometer.

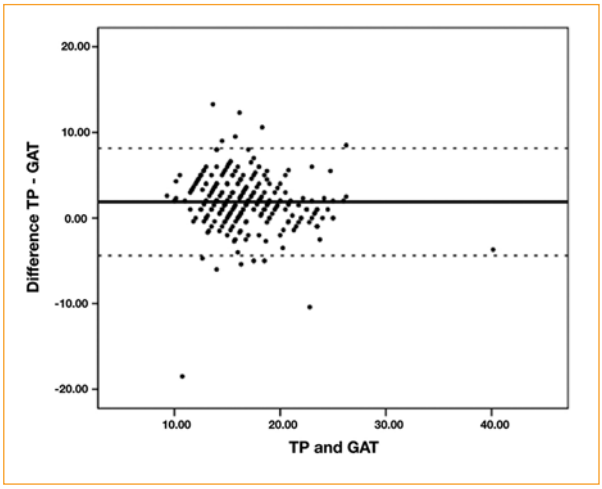

Figure 2. Bland–Altman plot for the correlation between TP and GAT measurements. GAT: Goldmann applanation tonometer. GAT: Goldmann applanation tonometer; TP: Tono-Pen®.

Discussion

Icare®, also called impact or rebound tonometer, is the latest portable tonometer in the market. However, its concept is not new; it derived from theories introduced over 60 years ago and refined approximately

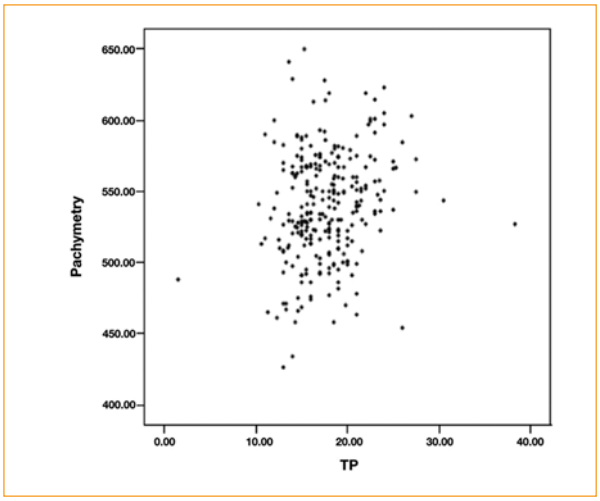

Figure 3. Correlation between pachymetry and TP. TP: Tono-Pen®.

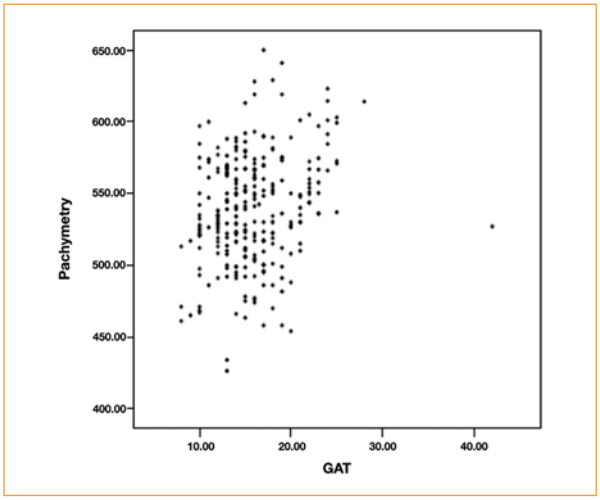

Figure 4. Correlation between pachymetry and GAT. GAT: Goldmann applanation tonometer.

30 years ago.[14] This method is based on monitoring the speed of an object that collides with the eye. This object decelerates faster when the IOP is high and slower when the IOP is low. Thus, as the IOP increases, the duration of impact decreases and vice versa. The impact with the cornea is light and fast (0.3 s) and often does not even generate a corneal reflex. Icare® is a portable and battery-operated instrument like TP, although it is heavier (Icare®: 155 g; TP: 56 g). Its biggest advantages stem from the fact that it is not operator-dependent, is easy to use, and allows IOP measurement's without using anesthetic drops, which makes it very

Table 2. Mean IOP ± SD values obtained using different tonometers in volunteers with CCT of <530 µ

	N	Minimum	Maximum	Mean IOP (mmHg) ± SD
Icare®	118	8.0	24.0	15.4 ± 3.8
TP	118	10.0	23.0	16.7 ± 3.7
GAT	118	8.0	24.0	14.9 ± 4.1

Icare®: Rebound tonometer; TP: Tono-Pen® XL; GAT: Goldmann applanation tonometer.

Table 3. Mean IOP ± SD values obtained using different tonometers in volunteers with CCT of >560 µ

	N	Minimum	Maximum	Mean IOP (mmHg) ± SD
Icare®	83	8.0	24.0	18.2 ± 5.2
TP	83	13.0	22.0	18.1 ± 3.8
GAT	83	10.0	24.0	16.7 ± 4.4

Icare®: Rebound tonometer; TP:= Tono-Pen® XL; GAT: Goldmann applanation tonometer.

feasible. The use of anesthesia is not only unnecessary but also contraindicated by the manufacturer because it underestimates IOP.

This study showed an excellent degree of agreement between Icare® and GAT measurements (r = 0.79; $p < 0.001$) and between TP and GAT measurements (r = 0.69; $p < 0.001$). Both Icare® and TP presented a trend to overestimate IOP (0.98 ± 3.12 and 1.88 ± 3.20, respectively) compared with GAT, although this difference was smaller for Icare®.

Martinez-de-la-casa recently showed a correlation between Icare® and GAT measurements of 0.864 and 0.865, respectively, in two different studies. Consistent with our results, there was also a trend of Icare® to overestimate IOP compared with GAT[6,15].

Nakamura and Schreiber, in 45 and 102 eyes, respectively, assessed Icare® and TP in relation to GAT and also obtained a good correlation among the instruments. Consistent with our results, they observed a greater correlation between IOP and CCT obtained with Icare® than that with other tonometers[16,17]. Garcia-Resua et al. compared Icare® with TP and Perkins tonometer in 65 individuals were able to show a good correlation, but with a trend for the first two instruments to overestimate IOP compared to the last instrument[18].

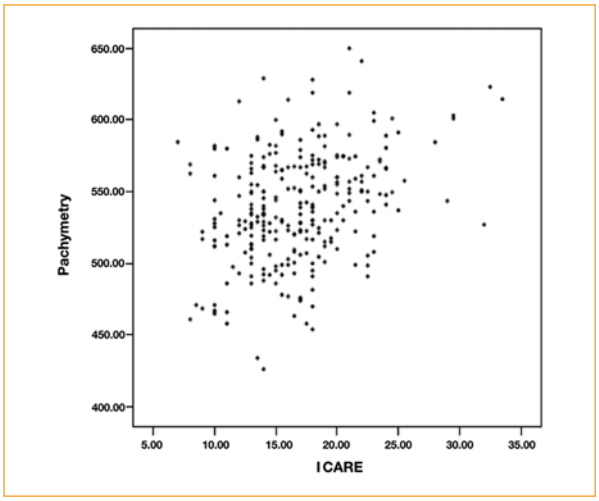

Figure 5. Correlation between pachymetry and Icare®.

Our study sample included 274 eyes, which, to the best of our knowledge, is the highest number in the literature. Icare® exhibited a slightly better correlation than TP in relation to GAT (0.79 vs 0.69), and there was a trend for both of them to overestimate IOP. The correlation values obtained for Icare® were slightly lower than those obtained by Martinez-de-la-casa, perhaps because we accepted measurements with a lower reliability index ("P" and "P-") than the index accepted by that author (who only accepted "P"). The values were slightly over one SD, and the effect on the results was probably irrelevant. On the other hand, in clinical practice, measurements with "P" and "P_" are easier to obtain, thereby reducing the time of measurement taken by Icare®. In addition, our sample had consecutive individuals, four of them with IOP greater than 24.0 mmHg (three with 25.0 mm Hg and one with 42.0 mmHg). These higher IOPs may have led to a decrease in correlation because both Icare® and TP tend to underestimate very high IOPs measured by GAT[18,19].

We also analyzed the relationship between the three tonometers and pachymeter and observed a positive association between all three tonometry measurements and CCT. Icare® proved to be, on average, more susceptible than the other two instruments (r = 0.35, 0.20, and 0.25 for Icare®, TP, and GAT, respectively). However, when we divided the sample according to CCT, Icare® proved to be less susceptible to variation in thin corneas than TP, with the measurements being closer to those obtained using GAT (15.4, 16.7, and 14.9 mmHg for Icare®, TP, and GAT, respectively). In thick corneas, however, both tonometers were equally affected and overestimated IOP compared with GAT. The higher susceptibility of Icare® to CCT was also observed in other studies[7,15,20,21]. However, some authors have reported that Icare® measurements are statistically equal in the center (where the cornea is thinner) and in the periphery (where it is thicker)[22] and that these measurements are influenced by the corneal viscoelastic properties[23,24]. Therefore, it appears that the biomechanical characteristics of the cornea–sclera are more determinant than CCT in measurements using Icare®.

Patient comfort and the speed with which a reliable IOP measurement is obtained are greater using Icare® than other instruments,[20,25] and although it was not assessed in this study, the convenience and confort of this instrument are easily perceived by an examiner with experience in these three methods. In addition, its precision and the fact that it does not require anesthetic drops make Icare® an extremely practical instrument for daily clinical use. Another potential advantage of Icare® is the possibility of its use at home by individuals with minimal training[26]).

In summary, IOP measurements obtained using the two tonometers analyzed showed similar and good correlations with that obtained by GAT, with Icare® exhibiting a slightly better performance. The three instruments were influenced by CCT, and this influence was slightly more pronounced on the Icare®. This study confirmed that both Icare® and TP are reliable tonometers for patients with IOPs within the normal range or with slight alterations.

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Conflicts of interest

None of the authors have any potencial conflict of interest to disclose.

Ethical disclosures

Approved by the following research ethics committe: Hospital de Base do Distrito Federal (CAAE: 62374115.6.0000.5650)

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