Comparative analysis and repeatability assessment of IOL Master 500 versus IOL Master 700 biometry in cataract patients

Estudio comparativo entre los biómetros ópticos IOL Master 500 versus IOL Master 700 en pacientes con catarata y análisis de repetibilidad

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Abstract

Purpose: To assess the repeatability of the swept-source optical coherence tomography (SS-OCT) biometer (IOL Master 700) and evaluate its agreement with a partial coherence interferometry (PCI) biometer (IOL Master 500) in patients undergoing routine cataract surgery. **Design:** This is a prospective, comparative study. **Methods:** Axial length (AL), keratometry (K), anterior chamber depth (ACD) and white-to-white distance (WTW) values were obtained by PCI-based biometer and compared with those obtained by SS-OCT. A Student's t-test was used variables. Pearson's correlation coefficient and Bland-Altman plots were obtained to describe the correlation and limits of agreement between platforms. **Results:** The study included 55 eyes with a mean age of 69 ± 11 years of age. The mean differences between swept-source and PCI-based biometry for AL, keratometry, ACD and WTW distance were $0.16 \text{ mm} \pm 2.30$, $0.06 \text{ D} \pm 0.38$, $1.2 \text{ mm} \pm 0.12$ and $0.15 \text{ mm} \pm 0.67$, respectively. There were statistically significant differences between biometers in two parameters: AL ($p = 0.0003$) and ACD ($p = 0.038$). **Conclusion:** SS-OCT biometry showed high repeatability for all biometric parameters. Keratometry and WTW distance values showed a good level of agreement between SS-OCT and PCI-based biometry. However, AL and ACD measurements showed statistically significant differences between the two optical biometers.

Key words: Swept-source optical coherence tomography. IOL Master 700. Partial coherence interferometry. IOL Master 500. Biometry.

Resumen

Objetivo: Evaluar la repetibilidad del IOL Master 700, biómetro basado en tomografía de coherencia óptica de fuente de barrido, así como del IOL Master 500, biómetro basado en interferometría de coherencia parcial, además de evaluar su correlación y concordancia, en pacientes candidatos a cirugía de catarata. **Diseño del estudio:** Comparativo y prospectivo. **Métodos:** Se obtuvieron los valores de la longitud axial (LA), queratometrías (K), profundidad de cámara anterior (ACD) y distancia blanco-blanco (WTW) con el IOL Master 500, y se compararon con los obtenidos con el IOL Master 700. Se realizó la prueba de t de Student para comparar variables continuas. La correlación de Pearson y el análisis de Bland-Altman se usaron para describir la correlación y el límite de acuerdo entre plataformas. **Resultados:** El estudio incluyó 55 ojos de

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55 pacientes con edad promedio de 69 ± 11 años de edad. La diferencia promedio de LA, K, ACD y WTW fue de $0.16 \text{ mm} \pm 2.30$, $0.06 \text{ D} \pm 0.38$, $0.02 \text{ mm} \pm 0.12$ y $0.15 \text{ mm} \pm 0.67$, respectivamente. Existen diferencias estadísticamente significativas entre los biómetros para dos parámetros: LA ($p = 0.0003$) y ACD ($p = 0.038$). **Conclusiones:** La biometría óptica mostró una alta repetibilidad para todos los parámetros en ambos equipos. Los valores de K y WTW mostraron un buen nivel de acuerdo; sin embargo, la LA y la ACD mostraron diferencias estadísticamente significativas entre biómetros ópticos.

Palabras clave: Tomografía de coherencia óptica de fuente de barrido. IOL Master 700. Tomografía óptica de coherencia parcial. IOL Master 500. Biometría.

Introduction

Ultrasound biometry requires direct contact with eye structures to correctly measure axial length¹. Optical biometry, based on A-mode technology, was introduced with the IOLMaster device². Partial coherence interferometry (PCI) does not require contact with the eye, avoiding possible risks of corneal pathology and, in addition, yields better results regarding axial length measurement compared to ultrasound biometry^{2,3}.

Optical biometry has been described as a useful method for intraocular lens (IOL) calculation in 90% to 95% of cataract cases (excepting dense cataracts, patients with poor fixation, vitreous condensation or hemorrhage, posterior capsule opacities, among others)². The IOLMaster 500 measures the axial length (AL) using PCI, keratometry (K), white-to-white distance (WTW) and anterior chamber depth (ACD) from the corneal epithelium to the anterior surface of the lens, using image analysis. Each measurement requires the instrument to be aligned with the visual axis³⁻⁵.

The measurement technique of most current commercially available equipments is based on time-domain interferometry³. Currently, there is a new optical coherence tomography (OCT), called swept-source (SS-OCT). This technology uses the IOLMaster 700⁶, an equipment that measures AL, K, ACD, WTW, lens thickness and central corneal thickness values^{2,3}.

The objective of this study is to analyze the repeatability of biometry measurements with SS-OCT and, additionally, to estimate the level of agreement for the biometric measurements (AL, ACD, WTW and K) using SS-OCT and time-domain OCT in patients undergoing routine cataract surgery.

Methods

The Internal Evaluation Committee of the Asociación para Evitar la Ceguera en México approved this study. All procedures were carried out in accordance with the Declaration of Helsinki. Written informed consent was obtained from all patients who participated

in the study after explaining the procedures and possible complications.

This is a prospective and comparative study that included patients who attended the Dr. Luis Sánchez Bulnes Hospital of the Asociación para Evitar la Ceguera en México, of both genders, over 18 years of age, with cataract diagnosis of any degree according to the lens opacities classification system (LOCS) III⁷ that evaluates nuclear opalescence (classification 0 to 6), nuclear color (classification 0 to 6), cortical opacity (classification 0 to 5) and posterior subcapsular opacity (classification 0 to 5), when it is possible to perform slit lamp biomicroscopy.

The exclusion criteria included presence of any corneal pathology, contact lens wearers, diagnosis of glaucoma, ocular trauma or surgery, as well as the use of any ocular treatment other than lubricant for a minimum period of one month.

Statistical analysis

A descriptive analysis of the variables included in the demographic data (including age and gender) was carried out. For mean comparisons between continuous variables with normal distribution, a paired Student's t-test was performed, and for non-normal continuous variables, the Wilcoxon signed-rank test was used. The Pearson correlation coefficient (r) between groups was obtained for all the variables. Additionally, the level of agreement between the platforms was evaluated through the Bland-Altman analysis⁸.

Database distribution was reviewed using the Kolmogorov-Smirnov test. To determine SS-OCT repeatability, two indicators were used: standard deviation and coefficient of variation, with a mixed model for 3 repeated 2-way measurements.

A sample size of 55 patients was considered necessary to compare means between groups, with a significance level of 0.05 (two-tailed α , β , 0.2), 80% power, and 0.95 standard deviation in the population. Statistical analysis was carried out using the

Figure 1. **A:** Pearson correlation plot for AL values between platforms ($r = 0.997$, $p < 0.0001$). **B:** Bland-Altman plot of the difference vs. average of the AL values with a level of agreement of 95%.

Statistical Package for Social Sciences, version 20.0 (SPSS, Inc., Chicago, IL) and Graph-Pad Prism 2015 version 6.0.

Results

In this study 55 eyes of 55 patients were evaluated; 61.8% ($n = 34$) were female and 32.8% ($n = 21$) were male, with an average age of 69 ± 11.12 years (range 58 to 80 years); 26 (47%) right eyes and 29 (53%) left eyes.

There were 16 eyes with nuclear opalescence (NO) grade 1, 20 eyes NO2, 8 eyes NO3, 8 eyes NO4, and no eyes with NO5 or NO6; 23 eyes had posterior sub-capsular opacities (P1 = 9 eyes, P2 = 4 eyes, P3 = 8 eyes, P4 = 1 eye, P5 = 1 eye) and 23 eyes had cortical opacities (C1 = 6 eyes, C2 = 12 eyes, C3 = 1 eye, C4 = 3 eyes, C5 = 1 eye).

The standard deviation between subjects and the coefficient of variation of the parameters obtained with the IOLMaster 500 and the IOLMaster 700 are shown in Table 1.

AL, K, ACD and WTW values obtained by both biometers are presented in Table 2.

Figure 1 shows Pearson correlation coefficient (r), as well as the Bland-Altman plot, showing the difference versus the average of axial length measurements obtained with both biometers. Additionally, a statistically significant difference was observed between the values obtained with SS-OCT based biometry, that were higher compared with those obtained partial coherence interferometry biometry ($p < 0.0003$).

Figure 2 shows Pearson correlation (r) plots between K values obtained with both biometers, as well as the Bland-Altman plot. There is no statistically significant difference in the values between groups ($p = 0.271$).

Table 1. Standard deviation of repeatability and coefficient of variation by parameters between biometers

Parameter	Standard deviation		Coefficient of variation (%)	
	PCI	SS-OCT	PCI	SS-OCT
AL (mm)	2.18	2.44	0.09	0.10
Km (D)	1.65	1.60	0.03	0.03
ACD (mm)	0.43	0.43	0.14	0.13
WTW (mm)	0.47	0.52	0.03	0.04
CCT (m)	-	36.21	-	0.06
LT (mm)	-	0.45	-	0.10

ACD: anterior chamber depth; AL: axial length; LT: lens thickness; CCT: central corneal thickness; K: average keratometry; WTW: white-to-white distance; PCI = partial coherence interferometry (IOLMaster 500); OCT: optical coherence tomography (IOLMaster 700).

Figure 3 shows the correlation plots between ACD measurements obtained with the IOLMaster 500 and the IOLMaster 700, as well as the Bland-Altman plot. ACD measurements acquired with the IOLMaster 700 were significantly higher than those obtained with the IOLMaster 500 ($p < 0.038$).

Figure 4 describes the correlation plot between WTW measurements obtained between groups, as well as the Bland-Altman plot. There were no statistically significant differences between WTW values between groups ($p = 0.276$).

Discussion

The advent of new technologies in the design of intraocular lenses and surgical techniques has increased patients expectations to obtain a postoperative visual

Table 2. Measures obtained by the IOLMaster 500 and the IOLMaster 700

Parameter	IOLMaster 500		IOLMaster 700		p
	Average $\pm$ SD	Range	Average $\pm$ SD	Range	
AL (mm)	23.94 $\pm$ 2.16	21.33, 33.00	24.10 $\pm$ 2.44	21.11, 32.02	0.0003*
K (D)	43.55 $\pm$ 1.65	39.94, 47.07	43.61 $\pm$ 1.60	39.98, 46.73	0.271
ACD (mm)	3.08 $\pm$ 0.43	2.23, 4.05	3.11 $\pm$ 0.43	2.24, 4.08	0.038*
WTW (mm)	11.93 $\pm$ 0.47	10.08, 13.00	11.78 $\pm$ 0.52	10.09, 13.00	0.276

*Statistically significant.

ACD: anterior chamber depth; AL: axial length; SD: standard deviation; K: keratometry; WTW: white-to-white distance.

Figure 2. A: Pearson correlation plot of K values between platforms ($r = 0.972$, $p < 0.0001$). B: Bland-Altman plot of the difference vs. average of K values with a level of agreement of 95%. **Figure 3.** A: Pearson correlation plot of ACD values between platforms ($r = 0.959$, $p < 0.0001$). B: Bland-Altman plot of the difference vs. average of ACD values with a level of agreement of 95%.

acuity without the need of a refractive correction; therefore, an adequate IOL power calculation has a fundamental role⁹.

The IOLMaster, based on partial coherence interferometry, was the first available biometer. It is currently considered the gold standard for preoperative assessment

in cataract surgery¹⁰. In our study, SS-OCT based biometry demonstrated an excellent repeatability for all parameters and a good level of agreement for K and WTW values, in agreement with previous reports by Kurian, et al.¹¹. K and WTW measurements obtained in this study showed a good correlation between equipments, in

Figure 4. **A:** Pearson correlation plot of WTW values between platforms ($r = 0.110$, $p = 0.545$). **B:** Bland-Altman plot of the difference vs. average of WTW values with a level of agreement of 95%.

Table 3. Comparative results between authors

	AL (mm)	K (D)	ACD (mm)	WTW (mm)
Shammas, et al. ²	0.02	0.18	0.06	-----
Srivannaboon, et al. ¹²	0.02	0.01	0.04	0.10
Akman, et al. ⁹	0.005	0.05 flat 0.08 curve	0.08	-----
Kurian, et al. ¹¹	0.01	0.02	0.03	-----
Saucedo-Urdapilleta, et al. 2016	0.16	0.06	0.02	0.15

ACD: anterior chamber depth; AL: axial length; K: average keratometry; WTW: white-to-white distance.

agreement with recent reports by Akman, et al.⁹ and Srivannaboon, et al.¹²; however, there was a statistically significant difference regarding AL and ACD.

AL values obtained with the IOLMaster 500 showed statistically significant differences compared to those obtained with the IOLMaster 700 ($p = 0.0003$). The average difference found in our study coincides with that reported by Shammas, et al.² Based on optical calculations, a difference of 0.16 mm would result in a 0.40 D error in the final refraction (in eyes with average AL and K) that could be clinically significant and, contrary to other authors reports, we should consider it. Our results are contrasted with previous studies in Table 3.

The differences regarding AL are probably due to the mechanism by which SS-OCT measures this variable; SS-OCT has a scan depth of 44 μm , with a 22 μm resolution in the tissues, which allows a rapid acquisition of images (2000 A-scans/s), unlike the IOLMaster 500 that uses a 780 nm diode laser⁵.

There is no significant difference between the K values measured with both equipments and, as previously

mentioned, the measurements taken with the IOLMaster 700 showed a high correlation with those taken with the IOLMaster 500. Average difference was of 0.06 D, which results in a postoperative refractive error of approximately 0.04 D, a value without clinical significance.

Regarding anterior chamber depth, there is a statistically significant difference ($p = 0.038$) between biometric measurements, although the average difference was only of 0.02 mm. This is probably due to the fact that the IOLMaster 500 bases its measurement on a slit image through the anterior chamber, which could result in an unfocused measurement^{13,14}. In comparison, the IOLMaster 700 measures ACD, lens thickness and central corneal thickness in a single OCT image, aligned with the visual axis. This parameter does not affect IOL calculation using most formulas¹³⁻¹⁵; however, the fourth-generation Haigis formula¹⁶ results in a difference of 0.06 mm in the ACD that changes the final refraction in 0.05 D¹⁷, which is not clinically significant; however, the study of corneal and lens thickness is important for new formulas and useful in the future for IOL power calculation.

White-to-white distance is only necessary in some formulas and is particularly useful in the calculation of phakic lenses^{18,19}.

Although the repeatability of corneal and lens thickness with the IOLMaster 700 is high and easy to measure, it is not considered in commonly used formulas; however, it is relevant for recently developed formulas, like Holladay 2 and Olsen^{20,21}.

One limitation of this study is the small sample size, so a larger sample would be convenient to confirm the accuracy of the measurements. In addition, patients with hyperopia or short eyes or patients with ocular pathology different from cataracts were not included.

Conclusions

SS-OCT based optical biometry has proven to be a valuable tool for calculating IOL power before cataract surgery in our population. Additionally, the level of agreement between biometers was good, showing high repeatability.

Conflicts of interest

The authors declare no conflicts of interest.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

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