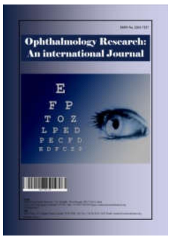

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Comparison of Axial Length Measurements with the Use of Optical Biometry (IOL Master 700) and Ultrasound Biometry (A-scan 550 Sonomed)

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Author's contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Purpose: To compare measurements of axial length obtained with A-scan and IOL Master. The study was design to collect the axial length values resulting from the application of both methods on the same eye (R.E.) and then to compare them.

Methodology Place and Duration of Study: 50 healthy patients selected randomly after visiting the clinic for daily routine examination. at the general hospital of Athens "Korgialenio – Benakio" were invited to participate in the study. The study took place in collaboration of University of West Attica Dept Biomedical Science Course Optics & Optometry with the general hospital of Athens "Korgialenio – Benakio". Axial length measurements were obtained both by contact ultrasound (A-scan 550 Sonomed, Lake Success, NY, USA) and by non-contact laser interferometry (IOL Master 700 SWEPT Source Biometry). Two sets of measurements were repeated by a single examiner for each method.

Results: A total of 50 eyes in 50 patients were evaluated. All participants volunteer to participate in this study. Estimates of axial length obtained with the two techniques were highly correlated. Axial lengths obtained with the contact method (mean 24.23mm, SD 1.64mm) were lower than those obtained with the non-contact method (mean 23.29mm, SD 1.59mm) and the difference was not

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statistically significant (p = 0.150). The coefficient of variation was lower with non-contact laser interferometry (6.58%) than with the ultrasound technique (6.76%).

Conclusion: Similar estimates of axial length are obtained using contact and non-contact techniques, with the latter producing higher measurements results than the former. The A-scan and the non-contact laser interferometry device (IOL Master 700) provide both reproducible results with similar the accuracy of measurements of axial length in the clinical setting.

Keywords: Ultrasound biometry; optical biometry; axial length.

1. INTRODUCTION

Ultrasound biometric devices incorporate a method that allows the determination of the optical axial parameters of the eye, by calculating the time required for the return of an ultrasound wave after it is reflected in an anatomical structure of the eye. Ultrasound is a sound wave with a frequency faster than human beings can perceive (approximately 20.000 cycles / second), as the human ear perceives frequencies less than 20KHz. In ophthalmology the ultrasounds used by an ultrasound biometer - A-scan device have a frequency of 8-10 MHz (1 MHz = 1.000.000 cycles / second). eye and at the same time provides excellent analysis of the small-sized ocular structures.

Ultrasound is transmitted in the form of a wave. The speed of the ultrasonic wave is completely dependent on the type and composition of the structures through which it passes. In ultrasonic biometrical devices, sound waves pass through: a) the cornea, b) the aqueous humor, c) the crystalline lens, d) the vitreous, e) the retina, f) the choroid and g) the sclera. This causes the ultrasonic waves to constantly change their speed as they propagate inside the eye, due to the different composition of its structures.

The A-scan requires the contact of the ultrasound source with the patient's eyes, which is performed through a probe. For this reason, before performing the examination, the application of a local anesthetic to the patient's cornea is required, while at the same time the patient must be directly in front of a distant point. In A-ultrasound the ultrasounds reflected from the various anatomical structures of the eye are depicted as vertical spikes on the wave propagation line.

Optical biometry with IOL Master utilizes the technique of Partial Coherence Interferometry (PCI) in order to calculate the axial length of the eye. In addition, it measures the depth of the anterior chamber using optical pachymetry, while performing keratometric measurements.

Determining the axial length of the eye is considered to be an important parameter in ophthalmological examination, as it is directly related to refractive errors [1], cataract surgery and intraocular implants [2], as well as with other pathological conditions of the eye [3]. Optical biometry - IOL Master can therefore determine the axial length of the eye with great accuracy, up to the order of ± 0.01mm using the method of partial coherence interferometry, which in turn is based on the Michelson interferometer. The Michelson interferometer initially uses a beam of light which is split in two components using a semi-reflective mirror (beam-splitter). Then each part follows its own path, until at some point the two components of the initial beam join, thus producing input images which are detected by a suitable device (photodetector).

To calculate the axial length of the eye, it is theoretically required to perform five correct measurements (Signal to Noise Ratio - SNR> 2.0) from which the average value is calculated, if they do not deviate from each other by more than 0.1mm. Otherwise, any divergent measurements will have to be repeated to determine the exact axial length. Theoretically, it is recommended not to perform more than 20 axial length measurements in each eye per day for safety reasons as well as to avoid measurements in retinal detached eyes.

Finally, numerous formulas have been defined for their use in combination with keratometry and axial length to calculate the dioptric power of the intraocular lens (IOL) that is suitable for each eye in case of cataract surgery. The choice of the appropriate formula depends on the emmetropia of the examined eye or its disorder. Some types additionally incorporate other parameters, such as the depth of the front chamber, to ensure a greater degree of measurement accuracy. The most widely used biometrics formula is SRK-T, while SRK-T and Holladay 1 are considered more suitable for eyes with longer axial length (from 22mm to 26mm). In large myopias where the axial lengths exceed the upper normal limit, Holladay 2, Haigis and SRK-T are recommended

[1,2]. Finally, in the case of hyperopic eyes with an axial length of less than 21.5mm, special formulas such as Hoffer Q are considered more accurate [2,3,4].

Comparison of ultrasound biometry with optical biometry - IOL master in former researches

It is important to note that an error of 100μm in measuring the axial length can cause a wrong calculation of the refractive power of 0.28 diopters, and respectively in the case of an error of magnitude 330μm the deviation reaches 1.00 diopter. These errors can occur at various stages in the performance of biometry, such as the process of measuring the keratometric characteristics of the cornea, choosing the method of performing the biometry and the formula used, the identification and processing of data as well as intraoperative complications [5]. In the biometry data, the size of the standard deviation (SD) must be evaluated in particular, which can reveal the existence of errors in the individual measurements when it takes values higher than 0.15mm and therefore produce an error probability of 0.50 diopters or more.

The performance of each biometry has characteristics that can lead to a different result. Initially the optical axis must coincide with the axis of the ultrasound in order to ensure the maximum possible accuracy. The wrong handling of the probe by the examiner, the failure of topical anesthesia, the lack of adequate hydration of the cornea, the intense pressure of the probe on the cornea can affect and vary the final value of each measurement. In addition, it should be emphasized that the repeated measurements must be independent, i.e. the pen must be momentarily removed from the cornea between the measurements. Otherwise the resulting measurements are not independent of each other and so any error is repeated thus eliminating the usefulness of repeating the measurements and leading to an unreliable result. Patients who use contact lenses do not give reliable results when their use has not been discontinued for at least 1-3 weeks before biometry [3].

Optical biometry using the IOL Master have been shown to be at least 10 times more accurate than ultrasound biometry [6,7], although both techniques lead to accurate intraocular lens calculations. As already mentioned, the IOL Master is a useful instrument for measuring axial length, which should be mentioned that it is quite easy to use in young people and especially children, while it is characterized by ease of use, speed and reliable results in cases of dense cataract. or those where the eye is filled with silicone oil. However, a major disadvantage of the above method is that in clinical use inaccurate measurements are observed in cases of opacity of the media, such as corneal scarring and vitreous hemorrhage [8]. In a study comparing the repeatability of axial length calculations with optical coherence biometry with that of ultrasound in childhood, it was observed that measurements with the IOL Master had better repeatability (95% agreement limits from -0.047 to 0.038mm) in relation to the corresponding ultrasonic biometry (95% agreement limits from -0.850 to 0.670mm), as respectively for the data concerning the depth of the anterior chamber (-0.053 to 0.073mm coherence biometrics, - 0.570 to 0.490mm A-Scan).

In addition, a comparison of contact biometry and immersion biometry shows that the differences between the measurements are in the range of 0.14 to 0.36mm (0.25 – 1.00 diopter). Comparing the immersion biometry with the optical coherence biometry, the former appears to be more ideal for highly hardening lens nuclei and its result is considered more accurate with the support of optical cohesive biometry as well.

In a recent comparative study of the two types of biometry it was observed that the mean difference in axial length measurements between the devices was of the order of 0.117 mm, a difference statistically significant but not clinically significant, as the above difference translates to 0-29 diopters [9].

2. METHODOLOGY

The sample consists of 50 (R.E.) eyes of 50 different patients. All participants volunteer to participate in this study and their data were kept anonymous. All participants were selected having healthy eyes of which 31 were female (62%) and 19 were male (38%).

Their average age was 30 ± 2.5 years old.

2.1 Statistical Method

The data were processed and analyzed using the SPSS statistical package (version 22.0; IBM, Chicago, IL) as well as Microsoft Excel 2016, where the repeatability between the measurements was first checked by the Bland-

Altman method and then a comparison followed. of the mean valuesof the axial length for A-scan ultrasound biometry and optical biometry.

The agreement between the measurements of the two machines for the axial length determination techniques was examined with a Bland-Altman graph, where the Limits of Agreement concurrence limits were calculated at the same time. The degree of correlation of the machines for axial length determination techniques was assessed with the Pearson correlation test. In addition, the measurements were compared with the paired t test, as the differences between the observations had a normal distribution. All tests of this study were performed at a level of statistical significance of 5%.

2.2 Measurements

The measuring devices for determining the axial length used in the study were the A -Scan 550 Sonomed (Lake Success, NY, USA) for ultrasonic biometry and the IOLMaster 700 SWEPT Source Biometry for optical biometry. A-ultrasound (A-Scan 550 Sonomed, Lake Success, NY, USA), is a portable, digital A-scan contact biometrics (Fig. 1), which through diagnostic test provides information about the axial length of the eye, averaging five measurements of less than 5 ± 1μm. The combination of the high frequency, the low noise of the probe and the calculation algorithm give the results of the measurement quickly after the application of the probe to the eye.

3. RESULTS

The mean axial length measured with the A-Scan 550 Sonomed ultrasonic biometrics was found to be equal to 24.23 mm (Standard deviation = 1.64 mm), while the mean axial length measured with the IOL Master 700 optical biometrics was found to be equal to 24.29 mm (Standard deviation = 1.59 mm). The axial length distribution is quite close to a normal distribution. The following diagrams show the distribution for the axial length measured with A-scan ultrasound biometer Fig. 2, and for the axial length measured with optical biometry IOL Master Fig. 3.

A-scan biometry

IOL Master 700

Fig. 1. A-Scan 550 Sonomed, Lake Success, NY, USA and Zeiss IOL Master 700

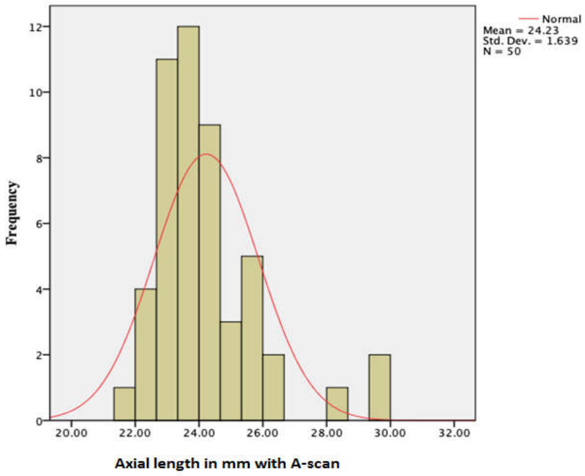

Fig. 2. Axial length distribution measured with A-Scan 550 Sonomed ultrasound biometry

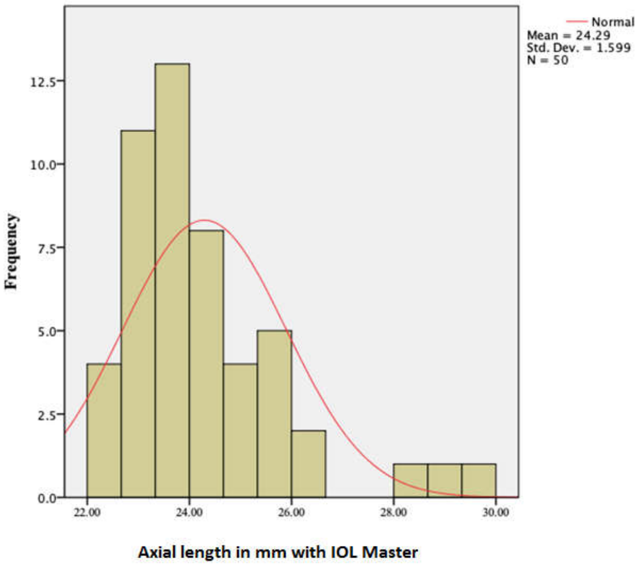

Fig. 3. Axial length distribution measured with IOL Master 700 optical biometry.

The following table summarizes the range and mean values of the mean axial length measurements (in mm) for the 50 examinees (50 eyes).

The normality of the two distributions allows the calculation of the Pearson correlation coefficient ($r = 0.98$, $p < 0.001$), which indicates an almost perfectly positive linear relationship between the axial length measured with the A-scan ultrasound biometer and the axial length measured with the IOL Master optical biometrics, as can be seen from the following scatter plot.

The test t for correlated values (Table 2) showed that there is no statistically significant difference between the mean values for the axial length with the A-scan ultrasound biometrics and the IOL Master optical biometrics (Mean difference= -0.0666; Mean standard deviation = 0.04558 mm, p = 0.150). The dashed lines in the following Bland - Altman diagram (Fig. 5) define the 95% agreement limits within which A-scan ultrasound biometrics overestimates or underestimates the mean axial length of the eye relative to IOL Master optical biometrics, where in in this case the 95% confidence interval ranges from -0.698 mm to 0.565 mm.

Table 1. The range and mean values of the mean axial length

	N	Minimum	Maximum	Mean	SD
A-scan	50	21.96	29.63	24.2262	16.389
IOL Master	50	22.06	29.76	24.2928	15.994

Table 2. Paired t test

Paired t test	
A-scan vs IOL Master	
Mean	-0.0666
Std. Deviation	0.32229
Std. Error Mean	0.04558
95% Confidence Interval of the Difference	
Upper limit	-0.15819
Lower limit	0.02499
t test	-1.461
df	49
p	0.150

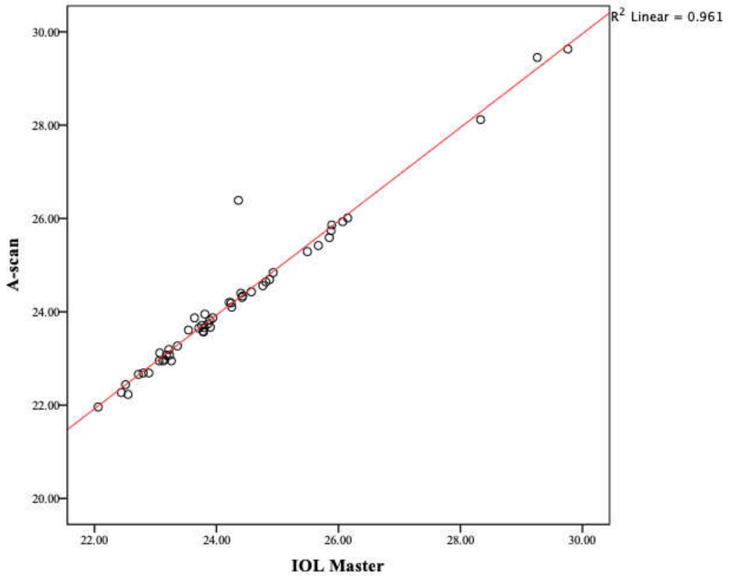

Fig. 4. Scatter diagram between axial lengths measured by A-scan ultrasonic biometry and IOL Master 700 optical biometry

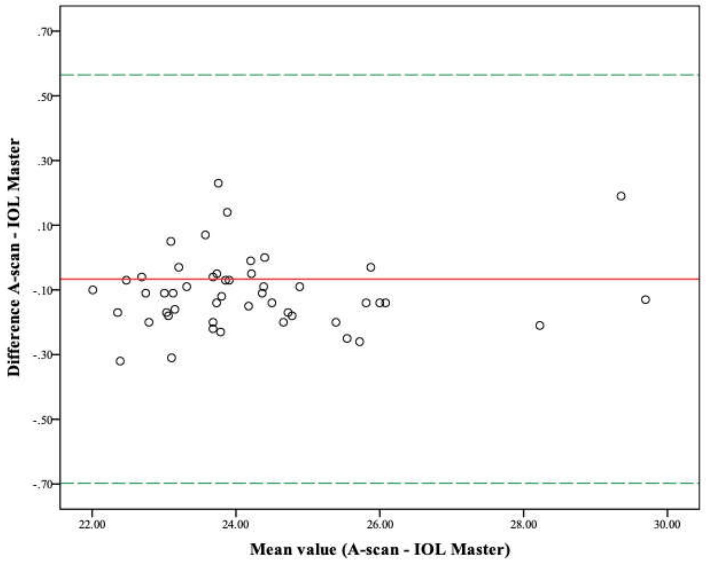

Fig. 5. Bland - Altman diagram for the agreement of the axial length measurements of the eyes from the A-scan ultrasound biometrics and the IOL Master optical biometrics

4. DISCUSSION

A similar study by Amany R Wissa et al. Also showed good agreement between optical biometrics and contact / ultrasound biometrics (Sonomed A / B Scan 5500, Lake Success, NY), with a mean difference in measured axial length of 0.10mm (width −0.47mm). - 0.72mm) [10].

Hitzenberger and colleagues found that the values of axial length measurements obtained by optical biometrics were 0.18mm higher than those obtained by A-ultrasound by dipping technique and 0.47mm higher than those obtained with A-ultrasound with contact technique [11]. At the same time, Kiss and his colleagues reported a mean difference in the measured axial length obtained with optical biometrics and A-ultrasound with a 0.22mm dip technique (range −0.24 - 0.57mm) [11].

In contrast to the above studies, Németh et al., In a study of 208 eyes, observed that axial length values measured by A-scan and IOL Master were significantly correlated (r = 0.985, P = 0.001). However, the values obtained with optical coherence biometrics were statistically significantly higher than those of A-ultrasound (mean difference = 0.39 ± 0.36 mm) [12]. The above study and other studies with similar results led to the calibration of the optical biometrics software - IOL Master so that the measured value is adjusted, using a regression model, to the value measured by A-ultrasound with immersion technique [13].

In addition, literature review has shown that eyes with long axial lengths tend to be more compressible when measuring axial length with A-contact ultrasound, where the relationship between compression size and axial length is linear [14]. The above observation could generally lead to the modification of the IOL Master software to accept axial length measurements with A-ultrasound to calculate the power of the intraocular lens. At this point it should be borne in mind that poor alignment with the optical axis in the case of A-contact ultrasound can cause a deviation in the measurements of the axial length and the depth of the anterior chamber.

More studies showed that the two devices were comparable with regard to mean IOL power, mean AL, K, and ACD measurements. Results showed that optical biometry IOL and AL measurements were not significantly different from the US measurements. Analysis also demonstrated good agreement between the two methods [14-21].

In conclusion, although axial length measurements with optical coherence biometry (IOL Master) are considered more accurate, A-scan measurements are required to be taken, in cases such as tear membrane abnormalities, corneal pathology, mature and thick subcapsular cataract, opaque vitreous, retinal detachment etc. [22,23], in order to better compare and correlate the two biometrics techniques.

5. CONCLUSION

We conclude that although the operating principles of the two axial length measuring devices are different, it is clear that the results of the measurements coincide to a great extent.

Axial length approach in normal eyes in which the two methods of measuring it - A-scan ultrasound biometrics and IOL Master optical biometrics - do not differ statistically from each other. The mean difference in measured axial length between A-scan ultrasound biometrics and IOL Master optical biometrics was 0.06mm in absolute value with a range of -0.158mm - 0.025mm.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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