Ocular Axial Length Measurement Using Regular Ultrasound and IOL Master for Different Refractive Errors in Egyptian Population

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Abstract

Background and Objective: The main purpose of this paper is to compare the reliability and repeatability of data obtained clinically with the IOL Master with those using a standard applanation ultrasound biometry on different refractive error types to measure axial length.

Patients and Methods: 39 patients were examined by both the IOL Master and the Sonomed for axial length measurement and IOL Master and manual Keratometer for measuring corneal curvatures. Patients were categorized into 3 groups according to refractive error.

Results: A total of 39 eyes of 39 patients; 21 (53.8%) males and 18 (46.2%) females in the mean (±SD) age of 57.4 (±7.7), range (43-75) years were assessed. Wilcoxon signed rank test p-value comparing the whole study groups as one group revealed a mean axial length measurement by IOL Master of 24.7mm with a (SD± of 2.4), a minimum of 21mm and a maximum of 30.6 mm. compared to Sonomed measurements of 24.6mm with a (SD± of 2.4), a minimum of 20.95mm and a maximum of 30.17mm. and a p-value of 0.002 which is of great statistical significance.

Conclusion: There is a favorable difference for IOL Master but Ultrasound biometry remains essential in cases of media opacities.

Key Words: Ocular axial length – IOL master – Biometry – Ultrasound biometry.

Introduction

INNOVATIVE techniques and advanced technology have greatly improved cataract surgery over the past few years. Modern techniques utilize small-incision phacoemulsification and foldable lens implantation.

Premium accommodative, toric, aspheric and multi-focal intraocular lenses (IOLs) are now widely available. There is an increased quest for accuracy, and patients are now seeking better results [1].

Axial length (AL) measurements are essential for determining the accuracy of the IOL calculation and are probably the element with the largest potential for error. Inaccurate measurements can limit the predictability of refractive outcomes. Studies have shown that an error of 100m in axial length measurement could lead to 0.28 D of post-operative refractive error [2].

Methods are still evolving, but ultrasound (US) biometry and partial coherence interferometry (PCI) are the most commonly used methods for determining the IOL power.

Preoperative biometry performed using A-scan ultrasonography uses the echo delay time to measure intraocular distances. It has a longitudinal resolution of 200m and an accuracy of 100-120m in measuring axial lengths [3].

Further, the ultrasound technique requires contact with the eye for measuring the axial length and the applanation method suffers from the disadvantage of corneal indentation during measurement.

New noncontact laser interference biometry or IOL master uses the method of partial coherence interferometry (PCI) to measure the axial length, based on reflection of the interference signal of the retinal pigment epithelium using a diode laser source [4,5].

While previous laboratory studies [6-8] have shown good agreement between PCI and ultrasound methods of measurement, the main purpose of this paper is to compare the reliability and repeatability of data obtained clinically with the IOLMaster with those using a standard applanation ultrasound method of the type employed in many previous studies on different refractive error types. In addition, corneal curvature used by the IOL Master
and regular manual keratometry readings were used to assess, the accuracy and repeatability of these methods have been examined in this study.

**Patients and Methods**

We employed a prospective, randomized, comparative case series study design on 39 eyes from 39 Egyptian patients at the International Eye Hospital in Cairo during 2013 who underwent biometry with PCI (IOL Master Carl Zeiss Meditec, Dublin, CA, USA) to calculate the IOL power.

The same patients underwent immersion US (Sonomed, Escalon pac scan 300 ap, Sonomed Escalon corp., USA) for IOL power calculation.

One drop of topical anesthetic, benoxinate hydrochloride 0.4% (Minims, Chauvin Pharmaceuticals Ltd), was instilled in each of the subject's eyes 2 minutes before ultrasound measurement. Special care was taken in aligning the transducer beam probe along the optical axis and to exert minimal corneal pressure. 5 measurements were taken for each eye and the mean calculated.

Patients were then categorized into three different groups as per the severity of refractive error as assessed by the axial length; hypermetropia (>23mm), average normal (>23-25mm), and myopia (>25mm).

Type of formula used to calculate the IOL power was based upon the axial length. >22mm were calculated by the Hoffer Q formula. 22 to 24 mm axial length was calculated by Holladay formula. 24-28mm axial length was calculated by the SRK/T formula. More than 28mm axial length was calculated by Haiges formula [9].

Patients' corneal curvature was measured by the Javal-Schiötz manual Keratometer (Topcon, Capelle a/d IJssel, Netherlands).

Preoperative biometry performed using A-scan ultrasonography uses the echo delay time to measure intraocular distances. It has a longitudinal resolution of 200m and an accuracy of 100-120m in measuring axial lengths [1,10-12].

Partial coherence laser interferometry (PCLI) uses a dual beam of infrared light (780nm) of short coherence length (160m) with different optical lengths is emitted by a laser diode source. The eye to be measured and the photodetector are situated at each leg of the interferometer. Both partial beams are reflected at the corneal surface and the retina (RPE). Interference occurs if the path difference between the beams is smaller than the coherence length. The interference signal received by the photodetector is measured dependent on the position of the interferometer mirror, which could be measured precisely. This measurement gives the optical length between the corneal surface and retina. The optical distance is used to derive geometric intraocular distances by incorporating the group refractive indices of the respective ocular media (cornea, lens, aqueous and vitreous humor) [13-16].

Calculation of axial length is dependent on the refractive index of the medium in which the light travels, and therefore the optical path length is divided by the mean group refractive index (taken as n=1.3549) in order to obtain the geometrical axial length. Laser light is reflected from the retinal pigment epithelium, in contrast with ultrasound waves which are reflected from the internal limiting membrane. Hence, in order to make the IOL Master results comparable with previous ultrasound measures, a conversion factor has been incorporated into the instrument software. The A-scan applanation device calculates axial length from the time taken for ultrasound waves to reflect back to its receiver from the internal limiting membrane.

Corneal curvature measurements by the IOL Master reflects six points of light, arranged in a 2.3mm diameter hexagonal pattern (measured by digital callipers), from the air/tear film interface. The separation of opposite pairs of lights is measured objectively by the instrument's internal software and the toroidal surface curvatures calculated from three fixed meridians [10]. In comparison, the Javal-Schiötz Keratometer requires the user to align the Keratometer mires along the principal meridians and corneal curvature is measured by subjective alignment of the mires, reflected from the central 3.4mm of the cornea.

Small-incision phacoemulsification with the standard phaco-chop technique and in-the-bag implantation of the IOL was used.

25 patients were excluded from the study due to very dense cataract or corneal opacities leading to difficulty with IOL Master measurements.

Other exclusion criteria included subjects with ocular pathologies, abnormal binocular vision, and previous allergy to the topical anaesthetic benoxinate hydrochloride were excluded from the study.
Data were collected and stored in excel sheet (Microsoft Office ® 2007). After data management, data were analyzed using SPSS® version 19.0 (IBM Inc., Chicago, Illinois) and MedCalc® 11.6 (MedCalc Software bvba, Mariakerke, Belgium). Descriptive analysis was conducted in terms of Mean (±SD) for continuous variables and frequency & percentages in categorical variables. Bland-Altman plot was used to assess the agreement between different methods of assessment. The non-parametric Wilcoxon Signed rank test was used to assess the difference in measurement using different methods of assessment. Confidence intervals of 95% were considered and a corresponding p-value of <0.05 was set as a threshold level of significance.

Results

A total of 39 eyes of 39 patients; 21 (53.8%) males and 18 (46.2%) females in the mean (±SD) age of 57.4 (±7.7), range (43-75) years were assessed by both IOL Master, Sonomed and Manual Keratometer. Table (1).

Axial length (measured by the IOL Master and Sonomed) and corneal curvatures (K1 and K2 readings assessed by both IOL Master and the manual Keratometer) readings and results were statistically compared for potential differences. Table (2).

There were 3 (33.3% of the whole group) males in the hypermetropia group, 9 (64.3%) in the normal average group and 9 (56.3%) in the myopia group with a total of 21 males (53.8%).

There were 6 (66.7% of the whole group) females in the hypermetropia group, 5 (35.7%) in the normal average group and 7 (43.8%) in the myopia group with a total of 18 females (46.2%).

There were 6 (66.7% of the whole group) right eyes in the hypermetropia group, 8 (57.1%) in the normal average group and 9 (56.3%) in the myopia group with a total of 23 right eyes (58.9%).

There were 3 (33.3% of the whole group) left eyes in the hypermetropia group, 6 (42.9%) in the normal average group and 7 (43.8%) in the myopia group with a total of 16 left eyes (41.1%).

Mean age of patients in the hypermetropia group was 55.9 with a SD± of 9.6, 57 (SD± of 7.5) in the normal average group and 5 8.7 (SD± of 7.1) in the myopia group with a range from 43 to 75 years.

Figures (1-6) show results in graph and scatter gram for average axial length measurements and corneal curvatures obtained from the IOL Master, the Sonomed and the manual Keratometer.

Average total axial length measured by IOL Master in the hypermetropia group was 22.1 mm (SD± of 0.6) compared to 22.0mm (SD± of 0.6) measured by Sonomed; with a p-value of 0.074 which is of critical or approaching significant statistical value.

Average total axial length measured by IOL Master in the normal average group was 23.7mm (SD± of 0.5) compared to 23.6mm (SD± of 0.6) measured by Sonomed; with a p-value of 0.779 which is of no significant statistical value.

Average total axial length measured by IOL Master in the myopia group was 27.2mm (SD± of 1.8) compared to 27.0mm (SD± of 1.7) measured by Sonomed; with a p-value of 0.374 which is of no significant statistical value.

Average K1 readings measured by IOL Master in the hypermetropia group was 43.2Dmm (SD± of 1.8) compared to 43.3mm (SD± of 2.3) measured by manual Keratometer; with a p-value of 0.014 which is of significant statistical value.

Average K1 readings measured by IOL Master in the normal average group was 43.2Dmm (SD± of 1.4) compared to 43.3mm (SD± of 1.7) measured by manual Keratometer; with a p-value of 0.551 which is of no significant statistical value.

Average K1 readings measured by IOL Master in the myopia group was 43.0Dmm (SD± of 1.9) compared to 43.2mm (SD± of 2.2) measured by manual Keratometer; with a p-value of 0.096 which is of no significant statistical value.

Average K2 readings measured by IOL Master in the hypermetropia group was 43.9Dmm (SD± of 2.1) compared to 44.1 mm (SD± of 1.9) measured by manual Keratometer; with a p-value of 0.196 which is of no significant statistical value.

Average K2 readings measured by IOL Master in the normal average group was 43.9Dmm (SD± of 1.6) compared to 43.9mm (SD± of 1.6) measured by manual Keratometer; with a p-value of 0.642 which is of no significant statistical value.

Average K2 readings measured by IOL Master in the myopia group was 44.5Dmm (SD± of 2.7) compared to 44.4mm (SD± of 2.6) measured by manual Keratometer; with a p-value of 0.836 which is of no significant statistical value.

Wilcoxon signed rank test p-value comparing the whole study groups as one group revealed a mean axial length measurement by IOL Master of 24.7mm with a (SD± of 2.4), a minimum of 21mm and a maximum of 30.6mm. compared to Sonomed.
measurements of 24.6mm with a (SD± of 2.4), a minimum of 20.95mm and a maximum of 30.17mm, and a p-value of 0.002 which is of great statistical significance.

Wilcoxon signed rank test p-value comparing the whole study groups as one group (Table 3) revealed a mean K1 measurement by IOL Master of 43.1mm with a (SD± of 1.7), a minimum of 38.88mm and a maximum of 46.30mm; compared to manual Keratometer measurements of 43.2mm with a (SD± of 1.9), a minimum of 39mm and a maximum of 47.25mm; and a p-value of 0.567 which is of no statistical significance.

Wilcoxon signed rank test p-value comparing the whole study groups as one group revealed a mean K2 measurement by IOL Master of 44.2mm with a (SD± of 2.2), a minimum of 39.24mm and a maximum of 49.85mm; compared to manual Keratometer measurements of 44.4mm with a (SD± of 2.1), a minimum of 40mm and a maximum of 49.25mm; and a p-value of 0.562 which is of no statistical significance.

Bland-Altman plot shows that there is relatively acceptable association between measurements done by both methods of assessment. However, there were some outliers that may prove actual differences between groups. The overall pattern shows that the two methods are not quite valid to be used interchangeably due to clear systematic bias.
Table (1): Patient demographics.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Category</th>
<th>Mild (23mm)</th>
<th>Moderate (&gt;23-25mm)</th>
<th>Severe (&gt;25mm)</th>
<th>Total</th>
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<tr>
<td></td>
<td></td>
<td>N=29</td>
<td>N=14</td>
<td>N=16</td>
<td>N=39</td>
</tr>
<tr>
<td></td>
<td>No. (%)</td>
<td>No. (%)</td>
<td>No. (%)</td>
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<td></td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
<td>3 (33.3)</td>
<td>9 (64.3)</td>
<td>9 (56.3)</td>
<td>21 (53.8)</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>6 (66.7)</td>
<td>5 (35.7)</td>
<td>7 (43.8)</td>
<td>18 (46.2)</td>
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<td>Laterality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>OD</td>
<td>6 (66.7)</td>
<td>8 (57.1)</td>
<td>9 (56.3)</td>
<td>23 (58.9)</td>
</tr>
<tr>
<td></td>
<td>OS</td>
<td>3 (33.3)</td>
<td>6 (42.9)</td>
<td>7 (43.8)</td>
<td>16 (41.1)</td>
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</table>

Table (2): Statistical differentiation between groups.

<table>
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<tr>
<th>Variable</th>
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<th>Moderate (&gt;23-25mm)</th>
<th>Severe (&gt;25mm)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Mean (±SD)</td>
<td>Mean (±SD)</td>
<td>Mean (±SD)</td>
</tr>
<tr>
<td>Age</td>
<td>55.9 (9.6)</td>
<td>57 (7.5)</td>
<td>58.7 (7.1)</td>
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<tr>
<td>Axial length</td>
<td>Master</td>
<td>Sonomed</td>
<td>Master</td>
</tr>
<tr>
<td></td>
<td>22.1 (0.6)</td>
<td>22 (0.6)</td>
<td>23.7 (0.5)</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.074</td>
<td>0.779</td>
</tr>
<tr>
<td>K 1 Reading</td>
<td>Master</td>
<td>Sonomed</td>
<td>Master</td>
</tr>
<tr>
<td></td>
<td>43.2 (1.8)</td>
<td>43.3 (2.3)</td>
<td>43.2 (1.4)</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.014</td>
<td>0.551</td>
</tr>
<tr>
<td>K 2 Reading</td>
<td>Master</td>
<td>Sonomed</td>
<td>Master</td>
</tr>
<tr>
<td></td>
<td>43.9 (2.1)</td>
<td>44.1 (1.9)</td>
<td>44.1 (1.6)</td>
</tr>
<tr>
<td></td>
<td>p</td>
<td>0.196</td>
<td>0.642</td>
</tr>
</tbody>
</table>

Table (3): Comparison between all study groups as a whole.

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Minimum</th>
<th>Maximum</th>
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</thead>
<tbody>
<tr>
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<td>24.7</td>
<td>2.4</td>
<td>21.00</td>
<td>30.60</td>
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<tr>
<td>Master K I</td>
<td>43.1</td>
<td>1.7</td>
<td>38.88</td>
<td>46.30</td>
</tr>
<tr>
<td>Master K II</td>
<td>44.2</td>
<td>2.2</td>
<td>39.24</td>
<td>49.85</td>
</tr>
<tr>
<td>Sonomed axial length</td>
<td>24.6</td>
<td>2.4</td>
<td>20.95</td>
<td>30.17</td>
</tr>
<tr>
<td>Keratometer K I</td>
<td>43.2</td>
<td>1.9</td>
<td>39.00</td>
<td>47.25</td>
</tr>
<tr>
<td>Keratometer K II</td>
<td>44.1</td>
<td>2.1</td>
<td>40.00</td>
<td>49.25</td>
</tr>
</tbody>
</table>

Discussion

Cataract surgery is no longer just for visual rehabilitation but has also become a form of refractive surgery in which the final refractive result can define visual outcome. IOL power calculation was essential for determining the success of cataract surgery. Small biometric errors can limit IOL performance and cause patient dissatisfaction and frustration. An incorrect lens power calculation is the main cause for dissatisfaction and lens exchange in modern cataract surgery [17].
The main purpose of this paper is to compare the reliability and repeatability of data obtained clinically with the IOL Master with those using a standard applanation ultrasound method of the type employed in many previous studies on different refractive error type. In addition, corneal curvature used by the IOL Master and regular manual keratometry readings were used to assess the accuracy and repeatability of these methods have been examined in this study.

39 patients were subjected in this study to preoperative examination by IOL Master and Sonomed for measurement of axial length and manual Keratometer and IOL Master for measurement of corneal curvature.

Our results show that there were no significant difference between all groups in the study except in corneal curvature readings in the hypermetropic group were it showed statistically significant difference between both machines.

Other studies have also showed the same results. We found high precision and reproducibility with both methods.

The high accuracy level of both technologies was also demonstrated by Packer et al., [8], Kiss et al., [16], and Haigis et al., [9].

Although most studies like Eleftheriadis et al., [18], and Findl et al., [19], showed that IOL Master gave better axial length measurement for high myopia, in our study there was no statistically significant difference in the myopia group as the study by Hwang et al., [20]; which might be explained by the small number employed in the study. The p-value of 0.074 is what is called a critical p-value or “approaching” meaning that although it is not significant, yet it is very close to turning significant if the sample size increased a bit.

Although when the whole stratum of patients were evaluated as one group, there were statistically significant difference showing that the IOL Master is superior to the Sonomed.

It has been suggested that IOL Master also is more precise and useful in problematic eyes, including high myopia, pseudophakia [15], staphyloma, or SO-filled eyes [17].

The advantages of the new technology include high precision, noncontact and noninvasive measurements, speed, and superior patient comfort.

On the contrary, the ability to maintain proper fixation during repeated measurements is likely to affect the accuracy and reproducibility of measurements. Factors that might affect fixation include old age, dense opacities in the ocular media, lid abnormalities, poor preoperative visual acuity, and preoperative refraction. Dense opacities in posterior capsule, or macular degeneration or eccentric fixation. Also high cost of the equipment; lid abnormalities, and eyes with poor fixation.

Further, the ultrasound technique requires contact with the eye for measuring the axial length and the applanation method suffers from the disadvantage of corneal indentation during measurement but it remains essential in cases of media opacities.

In conclusion:

A more extensive study with more extended number of patients is highly recommended for further evaluation. There is a favorable difference for IOL Master but Ultrasound biometry remains essential in cases of media opacities.

References

9- HAIGIS W., LEGE B., MILLER N. and SCHNEIDER B.: Comparison of immersion ultrasound biometry and partial coherence interferometry for intraocular lens


