Comparison of Optical Biometry and Scheimpflug Device Keratometric Readings Accuracy in Predicting Intraocular Lens Power in Cataract Surgery

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Abstract

Background: A correct preoperative intraocular lens (IOL) power measurement in cataract surgery depends on accurate assessment of axial length (AL), anterior segment parameters, and using the suitable formula for the calculation of the power. **Objectives:** To determine the accuracy of IOL power calculations using keratometric measurements of the IOL Master compared to the Pentacam and to determine whether the results obtained can be used interchangeably in clinical practice in calculating IOL power in routine cataract surgery. **Patients and Methods:** In this prospective study, the biometric data including AL, keratometric readings, and anterior chamber depth (ACD) were obtained by both the IOL Master 500 and Pentacam Scheimpflug devices added to these measures the white-to-white (WTW) distance by IOL Master and central corneal thickness by Pentacam and calculation of the IOL power using SRK/T formula for the enrolled patients who undergone uneventful cataract surgery with IOL implantation. Postoperatively, spherical equivalent refraction was measured and the mean arithmetic error and the mean absolute error (MAE) for both keratometric readings were calculated to compare the accuracy between them in calculating the IOL power. **Results:** The study evaluated 57 eyes of 57 patient, the mean K value for the IOL Master was 43.92 (D) ± 1.5 (standard deviation [SD]) and the mean K value for the Pentacam was 43.77 (D) ± 1.7 (SD) ($P = 0.62$), ACD values between the two groups, was 3.19 ± 0.44 mm measure by IOL Master compared to 3.22 ± 0.48 mm in Pentacam ($P = 0.769$), with a very strong positive correlation between the two values ($r = 0.995$, $P < 0.001$). MAE for the IOL Master was 0.230 (D) ± 0.187 (SD), while for the Pentacam was 0.255 (D) ± 0.204 (SD), with no statistically significant differences between two devices' values ($P = 0.54$). **Conclusions:** Pentacam Scheimpflug measured keratometric and ACD data had good correlation with IOL Master data with good interchangeability between two devices readings in measuring the IOL power in routine cases of cataract surgeries.

Keywords: Anterior chamber depth, intraocular lens Master 500, keratometry, Pentacam Scheimpflug

Introduction

Modern small incision cataract surgery provides more predictable refractive outcomes comparing with large incision extracapsular surgery, and with the development of the phacoemulsification surgery, a trend toward improved visual acuity with optimal safety and minimum invasiveness is expected.[1,2] These outcomes become better in large part of it due to more accurate preoperative measurements including more accurate axial length (AL) measurements with partial coherence interferometers (PCIs)[3,4] and more accurate intraocular lens (IOL) calculation formulas.[5] The variability in refractive results is now more dependent on corneal power measurement and assessment of postoperative effective lens position than AL.[6]

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Several types of different devices are present for measuring the corneal power. These include devices that measure the anterior corneal curvature and power such as automated keratometers, e.g., IOL Master (Carl Zeiss, Meditec AG) in which the total corneal power estimation occur by assuming a fixed relationship between the anterior and posterior corneal

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surface. While newer devices measure both the anterior and posterior curvatures of the corneal surface and calculate the true corneal power, without making an assumption of this fixed relationship e.g.: Pentacam (Oculus GmbH, Germany) and Galilei (Zeimer Grove).

The IOL Master 500 is a PCI. Six light spots are projected hexagonally on a 2.3 mm radius on the cornea. The device records the reflection of these images measuring the separation of the opposite pairs of light spots and calculating the corneal radii and toroidal surface curvature. By taking the mean of the three measurements, the corneal power was calculated by the device.[7] Corneal thickness and posterior corneal curvature are not directly measured, but the conventional IOL power calculation formulas incorporate an index of refraction based on the assumption regarding the corneal thickness and the ratio of the posterior to anterior corneal curvatures, which is intended to take this into account.[8,9] While the new Zeiss partial coherence interferometry device IOL Master 700 included optical coherence tomography with SWEPT technology that produce an image of the anatomical details of the complete eye in a longitudinal section, such as tilt or a decentered lens or IOL if performed in pseudophakic patients, measurement of lens thickness, central corneal thickness (CCT) and capability of measuring the posterior cornea values that was not measured previously added to the measurements that performed by the IOL Master 500 also.[10]

The Pentacam uses a rotating Scheimpflug camera to image the anterior segment. The device acquires 25–50 images depending on the settings during a single scan and calculates 138,000 elevation points for the anterior and posterior surfaces across the entire cornea. The repeatability of the measurements has been shown to be consistent.[11] It measures the corneal radius based on the acquired images of the cornea using a triangulation technique, the correct positioning automatically evaluated and begins taking Scheimpflug images as soon as the right alignment is obtained.[12] The device generates a variety of K readings. Anterior corneal power (known as simulated keratometry on some versions of the Pentacam) is measured with a 3.0 mm corneal diameter and so supposed to be comparable with automated keratometry. This is a computerized value determined by calculating the mean power along the 3.0 mm central ring of the anterior cornea. The Pentacam provides the anterior and posterior corneal surfaces elevation maps, pachymetry maps and biometric measurements of the anterior segment and calculates the anterior and posterior corneal power.[13]

The use of the equivalent keratometric reading (EKR) in IOL power calculations in postcorneal refractive surgery cataract patients has been assessed and its accuracy is still being refined. More recent studies assess the use of the EKR for patients who have not undergone corneal refractive surgery. The assumption that the EKR should be as accurate as a standard keratometer or topographer measurement in normal eyes needs to be true if the EKR is to be effective in IOL power calculations postcorneal refractive surgery. This assumption has been questioned in some studies.[7,14,15]

The goal of this study was to determine the accuracy of IOL power calculations using keratometric measurements of the IOL Master compared to the Pentacam and to determine whether the results obtained can be used interchangeably in clinical practice in calculating IOL power in routine cataract surgery.

Patients and Methods

This was a prospective observational study conducted in Ibn Al-Haitham Teaching Eye Hospital during the period from the March 1, 2018, to March 31, 2019.

All the included patients in the current study were had an uncomplicated phacoemulsification surgery with foldable IOL implantation.

Informed consent was obtained from all the patients. All personal information was kept anonymous.

Preoperative assessment

- After taking a clinical history, all patients had Snellen visual acuity, refraction, and measuring the intraocular pressure by air puff
- Slit-lamp assessment for the anterior segment, the visually significant cataract, and dilated fundus examination applied for all patients
- Eligible patients in the study were sent for optical biometry by IOL Master 500 (Zeiss, Jena, Germany) for measuring AL, keratometry, anterior chamber depth (ACD), white-to-white (WTW) distance, and IOL power using SRK/T formula and they were also sent for corneal topography by Pentacam (Oculus® GmbH, Germany) Scheimpflug camera to determine the keratometric and mean keratometric readings for the central cornea, ACD measured from the epithelium and CCT.

Automatic measurement mode was used on the IOL Master 500 machine, in which three consecutive keratometric measurements were taken and the mean of these was used. While for the AL five measurements were acquired automatically and the mean value of these measurements was used. For the Pentacam, the patient was asked to look at the fixation target in the scanning slit light and the images were taken automatically. If the measurement status was ‘ok,’ it was considered satisfactory.

Inclusion criteria

- No evidence of corneal guttate by specular microscopy
- Any of visually significant cataract types including (nuclear sclerotic, posterior subcapsular, and cortical) cataract
- Acquisition of measurements using IOL Master 500 and Pentacam Scheimipflug camera with good quality scans
- AL within the range from 22 mm to 24.5 mm by IOL Master measurements.

Exclusion criteria

- Retinopathy (diabetic or Hypertensive)
- Pseudoexfoliation syndrome or pigment dispersion syndrome
- Glaucoma
- Any previous history of trauma, uveitis
- Any corneal pathology or scar
- Previous refractive surgery
- Keratoconus
- Previous intraocular surgery
- Any posterior segment pathology
- AL <22 mm or >24.5 mm by IOL Master measurements
- Pentacam readings with "red" quality output
- Keratometric readings <(34) D or more than (48) D.

Surgery

A standard phacoemulsification surgery was done by one experienced surgeon for all patients in the study by using Alcon® Constellation vision system (Fort Worth, USA).

All patients received retrobulbar anesthesia. Main near clear corneal incision of 2.8 mm width was made using a sharp keratome at the axis of 120°, continuous curvilinear capsulorhexis of 5.5–6 mm diameter was done and after completing the cataract phacoemulsification a single piece Auorolab® (Auroflex) hydrophilic of P-HEMA material foldable IOL of A-constant (118) was implanted in the capsular bag and the wound sealed finally by stromal hydration.

Regarding the power of the implanted IOLs, they were chosen by the surgeon from the biometric measurements by the IOL Master 500 that have been done for all patients preoperatively with next (0.5) diopter step of IOL power higher than emmetropic power.

All patients were followed up at 1st day, 1st week, and 4 weeks postoperatively. On 4th week visit when the refraction was considered to be stable,[16] all patients were sent for measuring Snellen uncorrected and corrected distance visual acuity and refraction with autorefractometer by the same optometrist.

Definition of variables

For all patients in this study, the SRK/T formula were used for measuring the predicted spherical equivalent refractions for the IOL powers utilizing Pentacam keratometric readings and AL that was measured by the IOL Master 500.

For both IOL Master and Pentacam devices, the mean arithmetic error (ME) of refractive outcome was calculated by subtracting the predicted spherical equivalent refractions that were measured by SRK/T formula, from the measured spherical equivalent refraction postoperatively.

$$\mathrm{ME} = x_i - x$$

ME: Mean arithmetic error.

X_i: Measured spherical equivalent refraction value.

X: Predicted spherical equivalent refraction value.

While the mean absolute error of refraction (MAE) which means the distance of the mean refraction from the zero, and it is the absolute value of the mean prediction error were calculated also to be used for statistical comparison.[15]

$$\mathrm{MAE} = |\, [x_i - x] \,|$$

MAE: Mean absolute error.

X_i: Measured spherical equivalent refraction value.

X: Predicted spherical equivalent refraction value.

Data analysis was done by the use of IBM© SPSS© (Statistical Package for the Social Sciences) Software Version 23. (SPSS Inc., Chicago, IL, USA) Normal distribution of numerical variables was tested by Anderson–Darling test, and only M. E and MAE did not follow the normal distribution, and Mann–Whitney *U*-test was used to compare between them, while independent samples *t*-test was used to compare other variables that followed the normal distribution. Pearson's correlation was used to study the possible correlation between variables. $P < 0.05$ was considered statistically significant throughout data analysis.

Ethical clearance

This study was approved by by the ethical committee of Iraqi board for medical specialization.

To ensure adherence to ethical guidelines, several measures were adopted while conducting this study:

1. No incentives were offered to the participants in return for their participation.
2. Verbal consent was obtained from the participants before filling the questionnaire.
3. Participants were informed that their participation in this study is voluntary, no incentives or compensations will be offered in return, and that they have the right to withdraw from the study at any stage. The scientific value of their participation was explained in the verbal consent.
4. The contact information of the principal investigators was provided for participants.
5. All the participants' information was kept private by keeping it in a secured folder in a password-protected computer owned by the study investigators. No information was shared with any other individuals or entities.

Table 1: Basic characteristics of the study sample (*n*=57)

Variables	*n* (%)
Age (years) (mean±SD)	57.79±10.83
Gender	
Male	30 (52.6)
Female	27 (47.4)
Laterality	
Right	34 (59.6)
Left	23 (40.4)

SD: Standard deviation

Results

The records of 75 patients' 75 eyes were included in the study (eighteen eyes of 18 patients with either incomplete data points or failure to attend the postoperative visits were excluded) as they met the inclusion criteria, with a mean age of 57.79 ± 10.83 years, and there were 30 (52.6%) males and 34 (59.6%) right eyes, as shown in Table 1.

Regarding the IOL Master, there were no statistically significant correlations between ME or MAE with AL, ACD, and WTW distance, as there were very weak correlations between MAE with AL (r = −0.083) and ACD (r = −0.021), while it was positive but also very weak with WTW distance (r = 0.143).

Regarding Pentacam, there were no statistically significant correlations between ME and MAE with ACD and CCT as shown in Table 2.

Regarding the IOL Master and Pentacam, there were no statistically significant correlations between ME or MAE with keratometry or IOL power, as there was a very weak negative correlation between K-mean and MAE for IOL Master and Pentacam (r = −0.099, −0.166) respectively, while the latter had a positive correlation with IOL power for both devices ($r_{IOL\ MASTER}$ = 0.156) ($r_{PENTACAM}$ = 0.10) [Table 3].

There was no statistically significant difference in ACD values between the two groups, as it was 3.19 ± 0.44 mm measure by IOL Master compared to 3.22 ± 0.48 mm in Pentacam, with a very strong positive correlation between the two ACD values (r = 0.995, P < 0.001). Furthermore, regarding keratometric readings, there were no statistically significant differences between the two methods, with good correlations between their values.

The same was for the IOL power measured by the two methods; there was no statistically significant difference, with good correlation between them (r = 0.821, P < 0.001).

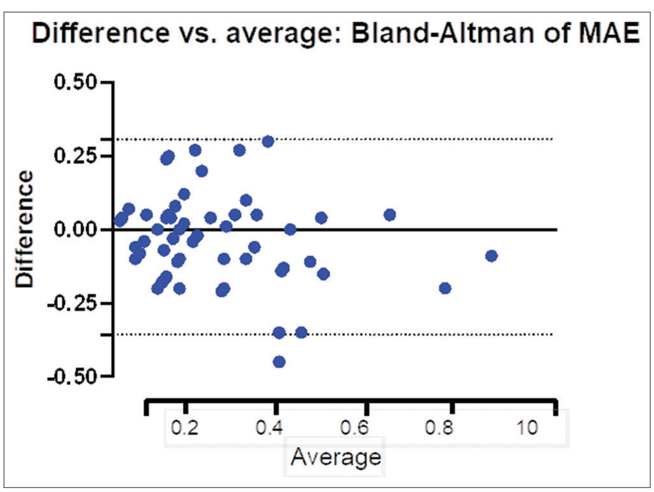

Figure 1: Bland–Altman plot showing the different values compared to average of mean absolute error between intraocular lens master and Pentacam. MAE: Mean absolute error

There were no statistically significant differences between ME or MAE calculated for IOL Master and Pentacam, as shown in Table 4.

Bland–Altman analysis revealed very similar results, as the bias between the two methods was −0.025 being lower in IOL Master compared to Pentacam (95% confident interval range from −0.36 to 0.31), as illustrated in Figure 1.

Discussion

A correct preoperative measurement of the implanted IOL power in cataract surgery need a good assessment for the

Table 2: Correlation between mean arithmetic error and mean absolute error in IOL Master with axial length, anterior chamber depth, and white-to-white and in Pentacam with anterior chamber depth and central corneal thickness

Groups	Variables	ME		MAE	
		r	*P*	*r*	*P*
IOL Master	AL (mm)	0.127	0.345	−0.083	0.537
	ACD (mm)	0.184	0.171	−0.021	0.879
	WTW distance (mm)	−0.102	0.450	0.143	0.288
Pentacam	ACD (mm)	0.047	0.726	−0.047	0.728
	CCT (μm)	−0.082	0.544	0.141	0.295

ME: Mean arithmetic error, MAE: Mean absolute error, IOL: Intraocular lens, AL: Axial length, ACD: Anterior chamber depth, WTW: White to white, CCT: Central corneal thickness

Table 3: Correlation between mean arithmetic error and mean absolute error in IOL Master and Pentacam with keratometry and intraocular lens power

Groups	Variables	ME		MAE	
		r	*P*	*r*	*P*
IOL Master	K1 (D)	−0.117	0.388	−0.058	0.667
	K2 (D)	−0.085	0.534	−0.132	0.326
	K-mean (D)	−0.103	0.446	−0.099	0.465
	IOL power (D)	0.019	0.889	0.156	0.246
Pentacam	K1 (D)	−0.099	0.462	−0.160	0.235
	K2 (D)	−0.085	0.540	−0.147	0.275
	K-mean	−0.077	0.567	−0.166	0.218
	IOL power (D)	0.039	0.774	0.10	0.460

ME: Mean arithmetic error, MAE: Mean absolute error, IOL: Intraocular lens

Table 4: Difference of mean arithmetic error between IOL Master and Pentacam

	Variables	Range	Minimum	Maximum	Mean±SD	*P*
ME	IOL Master	1.46	−0.65	0.81	−0.013±0.298	0.082
	Pentacam	1.75	−0.85	0.90	−0.116±0.307	
MAE	IOL Master	0.81	0	0.81	0.230±0.187	0.547
	Pentacam	0.90	0	0.90	0.255±0.204	

Mann–Whitney *U*-test. ME: Mean arithmetic error, MAE: Mean absolute error, IOL: Intraocular lens, SD: Standard deviation

AL and the anterior segment parameters and using the appropriate formula for the calculation of the power, many devices have been introduced with these functions and it is important to know which one of these devices produce more reliable and interchangeable data and Scheimpflug Pentacam keratometry started to have already a place in the preoperative assessment of the cataractous eyes who had previous corneal refractive surgery or corneal irregularities or in toric IOL calculation which cannot be measured by IOL Master.

In the current study, the mean keratometric readings for the Pentacam was (43.77 ± 1.7) diopter which was not significantly different from the mean keratometric readings of the IOL Master (43.92 ± 1.5) diopter, with good correlation between two methods, these results were consistent to Shammas *et al*.[14] study where the mean of both automated and simulated K readings was similar (43.49 ± 1.75 D) (43.49 ± 2.00D) respectively, Studies using multiple devices including Nidek automated keratometer, Zeiss IOL Master 500, oculus Pentacam, Keratograph 4M and Haag-Streit Lenstar LS900 to compare between keratometric readings showed no statistically significant differences between them regarding the keratometric readings and the corneal powers between these different devices.[17,18]

In the current study, the difference in the ME and the MAE values between IOL Master (0.204) and Pentacam (0.307) were not statistically significant, the same result found in another study.[18] in which SRK/T formula with optimization of the A-constant did not showed a statistically significant difference between both instruments with higher (standard deviation) for the Pentacam variables which was (0.688, 0.517) respectively, which they interpreted as indicative of variability of measurements of Pentacam. The latter reason was also suggested by Savini *et al*.[7] who proposed that the relatively longer time taken by Pentacam (2 s vs. 0.5 s taken by IOL Master) was the cause of this variability and higher values with Pentacam that might affect the measurements accuracy as the patient lost fixation despite the good quality indicator of their readings.

Shammas *et al*.[14] used different formulas for calculating the IOL power including the SRK/T formula using the simulated K from Pentacam and K values from automated keratometry showed higher MAE values for the Pentacam keratometric readings (0.5 ± 0.36) versus (0.41 ± 0.27) for automated keratometry but with no statistically significant differences.

The current study showed no statistically significant difference in ACD values between the IOL Master and Pentacam measurements, with mean values being 3.19 ± 0.44 mm 3.22 ± 0.48 mm, respectively, and very strong positive correlation between the two ACD values ($r = 0.995$, $P < 0.001$). These findings were in agreement with several clinical studies used the same equipment,[19,20] while Domínguez Vicent *et al*.[21] study found that deeper ACDs were obtained using a Scheimpflug Pentacam than with IOL Master, the mean difference was (0.07 ± 0.10) mm which was significant statistically but this range was not clinically relevant to IOL power calculation, so they concluded that both devices can be used interchangeably to calculate IOL power. This difference from the current study results may be related larger number of patients included in their study or the use Pentacam HR device which has higher resolution/scanning speed than the Pentacam that was used in the current study.

When using measurements from the IOL Master in the current study, we did not confirm any statistically significant correlations between ME or MAE with AL, ACD, keratometry and WTW distance, as there were very weak correlations between MAE with AL ($r = -0.083$), ACD ($r = -0.021$) and K-mean ($r = -0.099$) while it was positive but also very weak with WTW distance ($r = 0.143$). This agrees to Jeong *et al*.'s[22] study that revealed the same correlation state for the MAEs, none of the preoperative biometric measurements showed significant correlations including AL ($r = -0.075$), ACD (0.054) and K-mean (0.155), while for the WTW there was no reported studies about its correlation with MAE.

For calculations using Pentacam measurements, there were no statistically significant correlations between ME and MAE with ACD and CCT. This agrees to Utine *et al*.[23] study which showed no statistically significant correlation between MAE and the measured ACD Pentacam also ($r = -0.13$), while for the keratometry the MAE had a very weak negative correlation with K-mean ($r = -0.166$) like the IOL Master which was not significant statistically, while a positive correlation of MAE with IOL power for both devices ($r_{IOL\ MASTER} = 0.156$) ($r_{PENTACAM} = 0.10$) but with no statistically significant correlation as in many studies.[7,14]

Limitation and drawbacks of the current study was the small number of patients' sample which might decrease the statistical power of the study. This was due to exclusion a significant number of patients due to failure of attending follow-up visits and the version of the involved Pentacam device in the study restricted the evaluation and the effect of other keratometric measurements of Pentacam like the EKRs in different zones of the cornea and the true net power of the cornea K_{TNP} in the calculation of IOL power, exclusion of corneas with irregularities and opacities, postrefractive surgeries and wider range of ALs.

Conclusions

Pentacam Scheimpflug measured keratometric data had good correlation with IOL Master, with good interchangeability between two devices readings in measuring the IOL power in routine cases of cataract surgeries. The same was for the ACD measures in both devices showed good correlation that might be dependable in other formulas used in calculating the IOL power in cataract surgeries. It is recommended for further study of eyes with abnormal corneas or wider range of ALs or with toric IOLs implantation to expand the use of Pentacam where the keratometry may not be measurable.

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Conflicts of interest

There are no conflicts of interest.

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