



Research Article

The Accuracy of Optical Biometric Measurements in Predicting the Refractive Outcome After Phacoemulsification in Ibn AL-Haitham Teaching Eye Hospital, Baghdad

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Received: 20 September 2025; Revised: 20 November 2025; Accepted: 23 November 2025

Abstract

Background: Cataract surgery is one of the commonest surgeries done globally. Accurate biometry is a prerequisite for optimal outcome. Optical biometry devices are considered the gold standard for measurements. **Objective:** To compare the concordance and accuracy in ocular biometric measurements and IOL power calculations using LenStar 900 and IOLMaster 500 with 5 preinstalled formulas. **Methods:** In a longitudinal prospective comparative study of candidates undergoing phacoemulsification, biometry was done by IOLMaster 500 and LenStar 900, and 5 formulas were used to predict the postoperative spherical equivalent. A comparison was done between these equations, and the actual postoperative spherical equivalent obtained 4 weeks post-surgery to assess the performance of each equation. **Results:** Ninety-four patients were eligible for comparison. Linear regression showed excellent correlation for axial length and keratometry ($R^2 > 0.9$); the correlation was good for anterior chamber depth ($R^2 = 0.885$). Significant differences were seen between axial length, steepest keratometry, mean keratometry, and anterior chamber depth. In most patients, the actual postoperative refraction was more myopic than predicted; SRK/T by IOLMaster gave a more myopic shift than LenStar, and Holladay 1 by IOLMaster gave a more hyperopic shift than LenStar. Barrett predicted more myopic shift than the rest. **Conclusions:** Statistically significant differences were found between the two devices in some parameters, yet they can be negligible in practice and can be used interchangeably. All the formulas resulted in more myopic shift than expected in most patients with comparable performance.

Keywords: Biometry, Cataract, Intraocular lens, Phacoemulsification.

دقة القياسات البيومترية البصرية في التنبؤ بالنتيجة الانكسارية بعد عملية استئصال العدسة في مستشفى ابن الهيثم التعليمي للعيون في بغداد

الخلاصة

الخلفية: جراحة الماء الأبيض هي واحدة من أكثر العمليات شيوعاً التي تجرى على مستوى العالم. القياس البيومتري الدقيق هو شرط أساسي لتحقيق أفضل نتائج. تعتبر أجهزة القياس الحيوية البصرية المعيار الذهبي للقياسات. **الهدف:** مقارنة التوافق والدقة في قياسات البيومترية البصرية وحسابات قوة العدسة داخل العين باستخدام LenStar 900 و IOLMaster 500 مع 5 معادلات مثبتة مسبقاً. **الطرائق:** في دراسة مقارنة طولية مستقبلية للمرضى المرشحين لإجراء عملية الفاكو، تم إجراء القياسات الحيوية بواسطة IOLMaster 500 و LenStar 900، وتم استخدام 5 صيغ للتنبؤ بالمكافئ الكروي بعد العملية. تم إجراء مقارنة بين هذه المعادلات، والمكافئ الكروي الفعلي بعد العملية الذي تم الحصول عليه بعد 4 أسابيع من الجراحة لتقييم أداء كل معادلة وتمت المقارنة بناءً على متوسط الخطأ العددي ومتوسط الخطأ المطلق. **النتائج:** كان أربعة وتسعون مريضاً مؤهلين للمقارنة. أظهر الانحدار الخطي ارتباطاً ممتازاً لطول المحور والأنداد القرني ($R^2 > 0.9$); كان الارتباط جيداً لعمق الحجرة الأمامية ($R^2 = 0.885$). لوحظت فروق كبيرة بين طول المحور، والانحدار القرني الأشد، ومتوسط الانحدار القرني، وعمق الحجرة الأمامية. في معظم المرضى، كان الانكسار الفعلي بعد العملية أكثر قصر النظر. أعطت معادلة SRK/T باستخدام IOLMaster انحرافاً نحو قصر النظر أكثر من LenStar، بينما أعطت معادلة Holladay1 باستخدام IOLMaster انحرافاً نحو طول النظر أكثر من LenStar. كانت معادلة Barrett الأكثر انحرافاً نحو قصر النظر مقارنةً بباقي المعادلات. أظهر توقع باريت تحولاً أكثر قصر النظر من البقية. **الاستنتاجات:** تم العثور على فروق ذات دلالة إحصائية بين الجهازين في بعض المعايير، ومع ذلك يمكن أن تكون ضئيلة في التطبيق ويمكن استخدامها بالتبادل. جميع المعادلات أظهرت انحرافاً نحو قصر النظر أكثر من المتوقع لدى معظم المرضى، مع أداء متقارب بينها.

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Article citation: Al-Mudhafar ZA, Al Hashemy AB. The Accuracy of Optical Biometric Measurements in Predicting the Refractive Outcome After Phacoemulsification in Ibn AL-Haitham Teaching Eye Hospital, Baghdad. *Al-Rafidain J Med Sci.* 2025;9(2):333-340. doi: <https://doi.org/10.54133/ajms.v9i2.2496>

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INTRODUCTION

Cataract is the leading cause of blindness and the second most common cause of visual impairment worldwide, preceded only by refractive errors [1-3]. Cataract surgery, being one of the most common surgical operations done around the globe, is mostly

indicated for visual rehabilitation but nowadays is also concerned with the refractive outcome, as crystal clear vision is one of the demands of the modern era [2]. For the best visual outcome postoperatively, intraocular lens (IOL) power calculation should be as optimum as possible. Biometry determines the intraocular lens

power. Ocular biometers are devices that measure multiple ocular parameters by different concepts and mechanisms in order to use these given parameters in different formulas to estimate the postoperative refraction for a specific implanted lens, so for a successful postoperative outcome, precise preoperative biometric measurements and accurate intraocular lens calculations are needed [2]. In 1967 Fyodorov and co-workers first estimated the optical power of IOL using theoretic formulas, in the next decade, various theoretical vergence formulas were developed, and since then these formulas have been evolving, and most likely they will continue to do so [4]. Till 1999, ultrasound biometry was considered the gold standard concept for ocular biometric measurements, then optical biometry was introduced and used clinically, though the concept dates to the 1980s [5]. From that year till now, different modalities and upgrades have ensued. Two of the most commonly used devices are IOLMaster 500 (Carl Zeiss, Jena, Germany) and Lenstar 900 (Haag-Streit AG, Koeniz, Switzerland). [6]. These optical biometers use infrared light by a non-contact method to obtain the various parameters as the axial length (AL—defined as the distance between corneal epithelium and retinal pigmented epithelium), corneal curvature (the flattest meridian known as K1, the steepest meridian known as K2, and the average K), lens thickness (LT), anterior chamber depth (ACD—from corneal epithelium to the anterior surface of the crystalline lens), aqueous depth (AD—from corneal endothelium to the anterior surface of the crystalline lens), and white-to-white distance (WTW—horizontal distance between the borders of the corneal limbus). These devices require the patient to fixate on a target, so they measure the axial length along the visual axis. The advantage of these optical biometers is that they are fast, accurate, and no-contact with the cornea, but they cannot be used in patients with dense cataracts or anything that affects fixation, and they are rather expensive compared to ultrasonic biometry. Most of the optical biometers are based on the principle of the Michelson interferometer. Essentially, a beam of light is directed via a beam splitter to form two paths. One path is directed into the eye and reflects off the various perpendicular surfaces, such as the anterior corneal surface and the retina. The other path is directed into a reference arm of known dimensions (represented by the scanning mirror). The beam splitters then recombine both paths, and the point designated as the detector analyzes the interference pattern of these paths. The parameters obtained from this analysis are proportional to the physical separation of the surfaces in the eye under investigation [6]. IOLMaster 500 (Carl Zeiss, Jena, Germany) Advanced Technology V.7.5 uses partial coherence interferometry (PCI) with integrated keratometry. The device emits infrared light waves and measures the echo delay and intensity of the reflected light from the tissue interface. Since the velocity of light is high, echo delay times

cannot be measured directly, and interferometric techniques have to be employed [7]. It uses the PCI technique to measure axial length and photographic technique to obtain measurements of anterior chamber depth, corneal curvature, and white-to-white distance [1,8]. LenStar 900 (Haag-Streit AG, Koeniz, Switzerland) with EyeSuite™ IOL, V4.6.0 is based on optical low coherence reflectometry (OLCR). It detects the reflected light wave from the surface of the anterior cornea to the retinal pigmented epithelium; it can obtain multiple parameters in a single measurement without the need for realignment [9]. The IOL formulas are categorized either according to their generation or according to their derivation, the latter categorization is being used more recently. According to generations, they are classified into four, but according to derivation, they are classified into historical/refraction-based, regression, vergence, ray tracing, and artificial intelligence [4]. Historical and regression formulas (first- and second-generation IOL formulas like Sanders, Retzlaff, Kraff (SRK), Binkhorst, Hoffer, and SRKII), with rare exceptions, are mostly considered out of date. The first generation of IOL formulas relied on a single, fixed constant for ACD based on the IOL type. Second-generation formulas, such as the SRK II and Hoffer, introduced changes to the ACD constant as a function of AL. Third- and fourth-generation formulas attempt to determine the effective lens position (ELP—denoting the position of the IOL in the eye, the distance separating the principle image plane of the cornea from the principle object plane of the IOL) by taking more biometry factors into account [4]. SRK/T and Holladay 1 are both third-generation formulas, developed from a series of modifications and updates as more knowledge was gained about how IOL power changes with the varying ALs and corneal curvature of the eye. As larger numbers of cataract refractive results were systematically collected and analyzed, third-generation lens equations evolved with more complex theoretical mathematical derivations to incorporate biometry data into predicting the IOL power. The SRK/T equation combined a theoretical mathematical model with empirical regression to optimize the ACD and to change the retinal thickness and the corneal refractive index [4]. SRK/T and Holladay 1 depend on the Fyodorov method of using axial length and keratometry to predict the corneal height, which is the distance from the corneal endothelium to the iris plane. The SRK/T formula uses the A constant as a value to be added to the corneal height of Fyodorov to produce ACD. While in Holladay 1 ACD was the sum of the corneal height, corneal thickness, and the distance from the iris plane to the IOL's principal plane. The last value is termed as the surgeon factor (SF), and because it could not be known before surgery, it was necessary to calculate it from a series of postoperative eyes of one IOL style using the formula and the average for that lens style [10]. The Barrett II universal formula uses a theoretical model eye

in which the anterior chamber depth is related to the axial length and keratometry; it uses axial length, corneal power, anterior chamber depth, lens thickness, and white-to-white distance, the latter three being optional. This formula differs from others in that the location of the principal plane of refraction of the IOL is retained as a relevant variable in the formula, which contributes to the accuracy of the Barrett formula, although the actual derivation of the formula has not been published yet [4,11]. The primary aim of the study is to compare the predicted refractive outcome by the five formulae [SRK/T and Holladay 1 in IOLMaster, SRK/T, Holladay 1, and Barrett in LenStar] and the real postoperative refractive outcome. The secondary aim is to compare the concordance and accuracy in ocular biometric measurements using optical low coherence reflectometry [LenStar 900 (Haag-Streit AG, Koeniz, Switzerland) with EyeSuite™ IOL, V4.6.0] and partial coherence interferometer [IOLMaster 500 (Carl Zeiss, Jena, Germany) Advanced Technology V.7.5].

METHODS

Study design and setting

Longitudinal prospective comparative study was conducted during the period from February till September 2021 in Ibn AL-Haitham Teaching Eye Hospital, Baghdad, Iraq.

Patient selection

Patients with cataracts attending Ibn Al-Haitham Teaching Eye Hospital during the data collection period who met the inclusion criteria. A convenient sample of the patient attending the hospital who met the inclusion criteria was included in the study.

Inclusion criteria

Patient with cataract, which is indicated for surgery and fit for phacoemulsification. Both the [LenStar 900 (Haag-Streit AG, Koeniz, Switzerland) with EyeSuite™ IOL, V4.6.0] and the [IOLMaster 500 (Carl Zeiss, Jena, Germany) Advanced Technology V.7.5] could obtain optical automated biometry. Undergone uncomplicated phacoemulsification with foldable in-the-bag implanted IOL (Rayner C-flex Aspheric model 970C, United Kingdom), with full follow-up schedule at day 1, day 7, and 4 weeks after surgery.

Exclusion criteria

Poor fixation, corneal disease, previous intraocular or refractive surgery on the same eye, dense cataract (dense PSC or mature) precluding optical biometry, and complicated surgery or failure to commit to the follow-up schedule.

Preoperative assessment and surgery

All candidates went through these preparations before scheduled phacoemulsification surgery: visual acuity by Snellen chart, IOP by air puff tonometry, Nidek NT-530 (Japan), autorefraction by Nidek autorefractor, ARK-1 (Japan), slit lamp examination to assess the anterior segment, fundus examination with a +90 diopter condensing lens, optical biometry by LenStar 900 (Haag-Streit AG, Koeniz, Switzerland), and IOLMaster 500 (Carl Zeiss, Jena, Germany). The measurements were done by three well-trained optometrists. IOL power was estimated using SRK/T and Holladay 1 in IOLMaster, SRK/T, Holladay 1 and Barrett in LenStar using the pre-installed manufacturers' constant for each equation, and the IOL power was chosen to best fit the individual patient's need and other eye status and refraction. Each one of the included patients underwent uncomplicated phacoemulsification surgery under retrobulbar anesthesia with in-the-bag implantation of foldable IOL (Rayner C-flex Aspheric model 970C, United Kingdom), which is the foldable IOL brand available in the hospital.

Postoperative assessment

Each patient was seen on post op day 1 and day 7 to exclude any complication such as wound leak or endophthalmitis. The follow-up assessment was done for each patient 4 weeks postoperatively and included visual acuity by Snellen chart, IOP measurement using air puff tonometry, autorefraction measurements by Nidek autorefractor, ARK-1, slit lamp examination, and fundus examination with a +90 diopter condensing lens.

Calculations for comparison

For each patient, the following calculations were done: the postoperative spherical equivalent (SE, which is the actual spherical equivalent) was calculated depending on the objective autorefraction, and according equation 1.

$$SE = \text{sphere power} + \frac{1}{2} \text{cylinder power} \quad \text{-- Eq. 1}$$

Then for each formula, the mean numerical error (MNE) was calculated according to equation 2.

$$MNE = \text{postoperative spherical equivalent} - \text{predicted spherical equivalent} \quad \text{-- Eq. 2}$$

Then the mean absolute error was calculated as the absolute value of the MNE. These values were used to compare between the five equations by the two devices according to the recommendations of how to study and report the efficacy and accuracy of IOL formulas [12-15].

Ethical considerations

This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki, 2013. Approval was obtained from the administration of Ibn AL-Haitham Teaching Eye Hospital and the Arab Board

for Health Specialization Ethical and Scientific Committee. Informed consent was obtained from all the patients.

Statistical analysis

The data analysis and presentation were done using Microsoft^(C) Office Excel 2016 and Statistical Package for the Social Sciences IBM 20. Paired t-test was used to study the significance of mean differences between the multiple values, and Pearson's correlation was used to study the significance of correlation between continuous variables. A p -value < 0.05 was considered for significant differences.

RESULTS

During the study period, biometry was done for 94 patients (94 eyes), who were eligible for the study, using IOLMaster 500 (CarlZeiss, Germany) and repeated using Lenstar 900 (Haag-Streit, Switzerland). The age ranged from 26 to 78 years, with a mean of 57.8 ± 12.01 years. Males (52; 55.3%) were slightly more than females (42; 44.7%) with a male-to-female ratio of 1.2:1. Chronic medical illnesses such as diabetes and hypertension were reported by 52 patients (55.3%),

and a history of previous intraocular surgery in the other eye was reported in 38 patients (40.4%). The right eye was operated upon in 53 patients (56.4%), in 62 patients (66.0%) Preoperative Best Corrected Visual Acuity (BCVA) was 6/60 or better, 53 patients (51.0%) had myopia, 37 patients (39.4%) had no reflex, 4 patients (4.2%) were hypermetropic, and Axial Length (AL) was medium ($>22 - <26$) in 90 (95.7%) of patients, long (≥ 26) in three (3.2%), and short (≤ 22) in only one patient (1.1%). The type of IOL implanted was the Rayner C-flex Aspheric model 970C in all patients (100%). LT ranged from 3.1 to 5.43 mm with a mean of 4.2 ± 0.48 mm SD, WTW ranged from 10.7 to 13.1 mm with a mean of 12.02 ± 0.45 mm SD. CCT ranged from 401 to 596 μm with a mean of 525.6 ± 34.9 μm , and AD ranged from 1.89 to 3.67 mm with a mean of 2.9 ± 0.4 mm. Comparing the measurement of axial length, keratometry, and anterior chamber depth by the two devices revealed that their mean differences were statistically significant regarding AL, Steepest Keratometry (K2), Mean Keratometry, and Anterior Chamber Depth (ACD), whereas the mean differences were statistically not significant regarding Flattest Keratometry (Table 1).

Table 1: Biometric measurements of the eyes studied by the two devices

Measurements	IOLMaster	LenStar	Difference IOLMaster- LenStar	p -value
AL (mm)	(21.95 – 26.98) 23.8 \pm 0.98	(21.94 – 27.07) 23.8 \pm 0.997	(-0.3 – 0.09) -0.03 \pm 0.05	<0.001
Flattest Keratometry (K1, R1)	(40.37 – 47.27) 43.396 \pm 1.5	(39.89 – 47.63) 43.42 \pm 1.5	(-0.79 – 1.23) -0.03 \pm 0.3	0.3
Steepest Keratometry (K2, R2)	(40.86 – 48.28) 44.38 \pm 1.6	(40.76 – 48.45) 44.28 \pm 1.6	(0.73 – 1.28) 0.1 \pm 0.3	<0.001
Mean Keratometry	(40.61 – 47.78) 43.9 \pm 1.5	(40.43 – 48) 43.8 \pm 1.5	(-0.49 – 1.25) 0.05 \pm 0.3	0.044
Anterior Chamber Depth (ACD)	(2.42 – 4.19) 3.27 \pm 0.4	(2.43 – 4.19) 3.37 \pm 0.4	(-0.96 – 0.19) -0.095 \pm 0.15	<0.001

Values are presented as range and mean \pm SD. Paired t-test was used at $p < 0.05$.

IOLMaster gave nearly the same measurement as LenStar for axial length and flat keratometry, a slightly higher measurement for steep keratometry and mean keratometry, and a lower measurement for anterior chamber depth. Figure 1 (A-E) shows the correlations of AL, K1, K2, mean keratometry, and ACD measurements between IOLMaster and LenStar. Linear regression showed an excellent correlation for AL, K1, K2, and mean keratometry ($R^2 > 0.9$), whereas the correlation was very good for ACD ($R^2 = 0.885$). Table 2 showed the mean difference of MNE and MAE of the SRK/T and Holladay formulas of the eyes studied by the two devices. It was found that the mean difference was statistically significant only for the MNE of the SRK/T formula of the two devices ($p=0.02$), whereas the mean differences were statistically not significant between the MNE of Barrett (LenStar) and that of SRK/T from both devices (Table 3). The mean difference of MNE between the Holladay formula from

IOLMaster and Barrett by LenStar was statistically significant (Table 3). All of the five formulas resulted in more myopic shift than expected; SRK/T by IOLMaster gave more myopic shift than SRK/T by LenStar, while Holladay 1 by IOLMaster resulted in more hyperopic shift than Holladay 1 by LenStar. Barrett gave more myopic shift than the rest of the formulas. Among all the five formulas, the Barrett and Holladay 1 by LenStar showed the highest percentage of patients within 0.5 D of the predicted refraction; Barrett showed the least percentage with predicted refraction higher than 2 D, while the SRK/T by IOLMaster showed the lowest percentage within 0.5 D and the highest above 2 D (Table 4). The Best Corrected Visual Acuity (BCVA) outcome among the studied patients was $\leq 6/12$ in 86 patients (91.5%) and worse than 6/12 in 8 patients (8.5%).

DISCUSSION

In this study, linear regression showed an excellent correlation for AL, K1, K2, and mean Keratometry ($R^2 >$

0.9), whereas the correlation was good for ACD ($R^2 = 0.885$), which is similar to what was described by Holzer *et al.* and Tanja *et al.* [16,17].

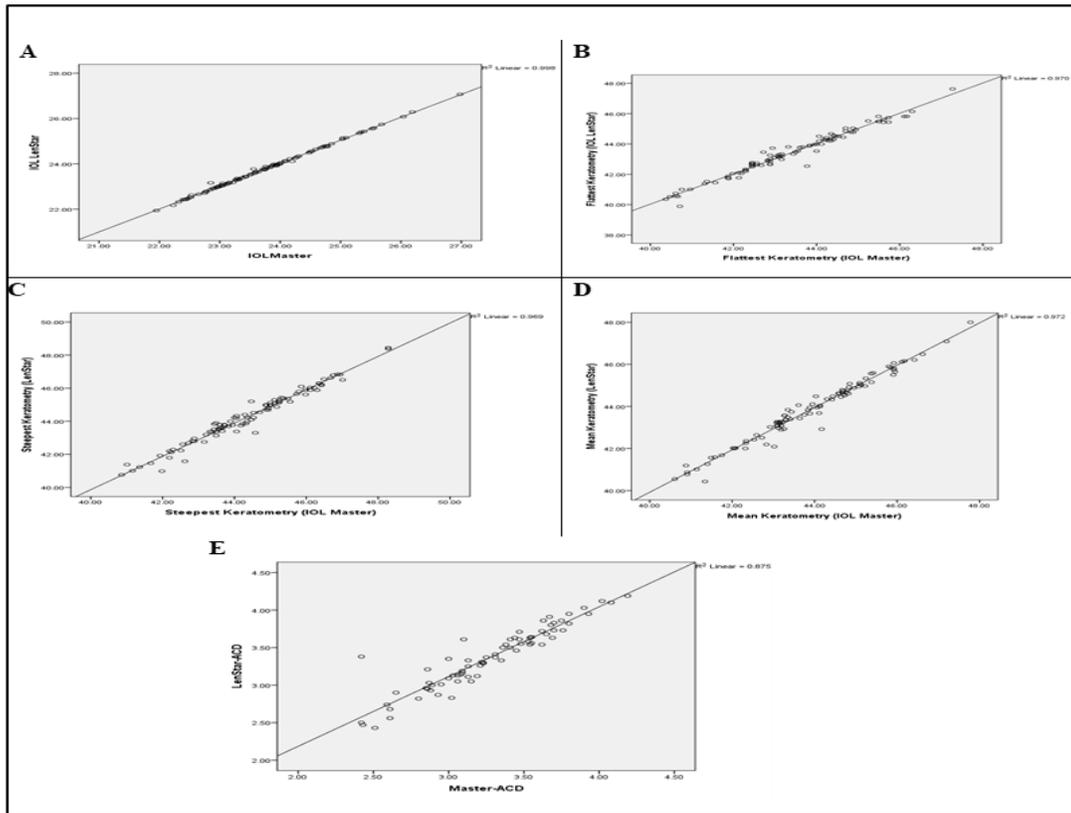


Figure 1: A) Correlation between IOLMaster and LenStar measurements of Axial Length; B) Correlation between IOLMaster and LenStar measurements of Flattest Keratometry; C) Correlation between IOLMaster and LenStar measurements of Steepest Keratometry; D) Correlation between IOLMaster and LenStar measurements of Mean Keratometry; and E) Correlation between IOLMaster and LenStar measurements of Anterior Chamber Depth (All are significant at $p=0.01$ 2-tailed).

Table 2: Mean differences between MNE and MAE of SRK/T and Holladay formulas of the studied eyes by the two devices

Measurements	IOLMaster	LenStar	Difference IOLMaster- LenStar	p-value
MNE-SRK/T	(-2.96 – 1.36) -0.4±0.8	(-2.83 – 1.63) -0.37±0.8	(-0.56 – -0.89) -0.05±0.2	0.02
MNE-Holladay	(-3.05 – 1.57) -0.3±0.8	(-2.92 – 1.44) -0.28±0.78	(-3.94 – 2.71) 0.05±0.996	0.17
MAE-SRK/T	(0.0 – 2.96) 0.66±0.6	(0.01 – 2.83) 0.64±0.6	(0.0 – 0.89) 0.05± 0.2	0.26
MAE-Holladay	(0.01 – 3.05) 0.62±0.59	(0.0 – 2.92) 0.6±0.56	(0.02 – 3.49) 0.7±0.69	0.8

Values are presented as range and mean±SD. Paired t-test was used at $p < 0.05$.

This relatively lower correlation of ACD compared to other parameters could be explained by the fact that each device uses a different technique for measuring ACD [17]. IOLMaster uses image analysis to measure the distance between the anterior surface of the cornea and the crystalline lens. LenStar detects the anterior and posterior corneal and anterior crystalline lens peaks in the optical low coherence reflectometry waveform to measure the ACD and corneal thickness. ACD measured by LenStar was deeper than that measured by IOL in this study with a mean difference of -0.09 ± 0.14 mm, which is the same result found by Holzer *et al.*,

Tanja *et al.*, and Buckhurst *et al.* [16-18]. The difference in ACD between the 2 devices was statistically significant in this study ($p < 0.001$), which agrees with Tanja *et al.*; however, Holzer *et al.* reported that differences in ACD were not statistically significant [16,17]. Axial length measurements were shorter when measured by IOLMaster, with mean differences of -0.03 ± 0.05 mm, which was statistically significant ($p < 0.001$). While Buckhurst *et al.* agreed with this result, Tanja *et al.* and Holzer *et al.* found no statistically significant difference in AL measurements [16-18]. Although the difference is statistically significant, it can be negligible in clinical practice, as a 1 mm error in AL

measurement results in a refractive error of approximately 2.35 D in a 23.5 mm eye; that error declines to only 1.75 D/mm in a 30 mm eye but rises up to 3.75 D/mm in a 20 mm eye [19]. Regarding keratometry measurements, no statistically significant difference was found in the flattest; however, the steepest keratometry and mean keratometry had statistically significant differences between the two devices, with the LenStar measuring higher values in flat and mean keratometry. Tanja *et al.* found that the steepest and mean keratometry were different and both had higher values in LenStar compared to IOLMaster,

while Holzer *et al.* and Buckhurst *et al.* stated that both devices gave similar results. Holzer *et al.* also mentioned that IOLMaster measured higher keratometric values [16-18]. Haigis *et al.* used immersion biometry data to find that the postoperative refraction could be predicted within ± 1 D 86% of the time and within ± 2 D 99% of the time [5]. A similar result was obtained using optical biometry [4]. Olsen found that the prediction within $\pm 0.5D$, $\pm 1D$, and $\pm 2D$ was 62.5%, 92.4%, and 99%, respectively [20]. Kanclerz *et al.* found that the newer generation formulas predicted more than 80% within $\pm 0.5D$ [21].

Table 3: Mean differences of MNE and MAE between Barrett formula measured by different formulas

Barrett formula (LenStar) vs. SRK/T formula (IOLMaster)	IOLMaster SRK/T	LenStar Barrett	Difference IOLMaster - LenStar	p
Mean Numerical Error (MNE)	(-2.96 – 1.36) -0.4±0.8	(-2.96 – 1.24) -0.41±0.7	(-1.19 – 1.33) 0.01± 0.3	0.74
Mean Absolute Error (MAE)	(0.0 – 2.96) 0.66±0.6	(0.01– 2.96) 0.6±0.57	(0.0 – 1.33) 0.23± 0.22	0.1
Barrett formula (LenStar0) vs. SRK/T formula (LenStar)	LenStar SRK/T	LenStar Barrett	Difference SRK/T (LenStar)- Barrett (LenStar)	p
Mean Numerical Error (MNE)	(-2.83 – 1.63) -0.37±0.8	(-2.96 – 1.24) -0.41±0.7	(-0.97 – 0.53) 0.057± 0.23	0.07
Mean Absolute Error (MAE)	(0.01– 2.38) 0.64±0.6	(0.01– 2.96) 0.6±0.57	(-0.76 – 0.97) 0.03± 0.39	0.17
Barrett formula (LenStar) vs. Holladay formula (IOLMaster)	IOLMaster Holladay1	LenStar Barrett	Difference IOLMaster- LenStar	p
Mean Numerical Error (MNE)	(-3.05 – 1.57) -0.32±0.8	(-2.96 – 1.24) -0.4±0.73	(-1.24 – 1.45) 0.1±0.33	0.014
Mean Absolute Error (MAE)	(0.01 – 3.05) 0.62±0.6	(0.01– 2.96) 0.6±0.57	(-1.45 – 1.24) 0.027± 0.33	0.7
MAE of Barrett formula (LenStar) vs. Holladay1 formula (LenStar)	LenStar Holladay1	LenStar Barrett	Difference Holladay1(LenStar)- Barrett (LenStar)	p
Mean Numerical Error (MNE)	(-2.92 – 1.44) -0.29±0.78	(-2.96 – 1.24) -0.4±0.73	(-1.47 – 1.35) 0.034±0. 93	0.24
Mean Absolute Error (MAE)	(0.0 – 2.92) 0.6±0.56	(0.01– 2.96) 0.6±0.57	(-1.35 – 1.35) 0.02± 0.34	0.9

Values are presented as range and mean±SD. Paired t-test was used at $p < 0.05$.

Table 4: Distribution of patients within 0.5, 1 and 2 diopters of the predictive refraction (n=94)

Diopter	IOLMaster		LenStar		
	SRK/T	Holladay 1	SRK/T	Barrett	Holladay 1
≤ 0.5	46(48.9)	49(52.1)	50(53.2)	52(55.3)	52(55.3)
≤ 1	75(79.8)	76(80.8)	74(78.7)	75(79.8)	75(79.8)
> 2	5(5.3)	4(4.3)	3(3.2)	2(2.1)	3(3.2)

Values are presented as frequency and percentage.

In this study, the Barrett formula gave more myopic results, followed by SRK/T and then Holladay 1; this is consistent with the result obtained by a large-scale study conducted by Kane *et al.* [22]. In this study, Barrett and Holladay 1 by LenStar performance are nearly comparable, as both had the highest percentage of patients within ± 0.5 D of the predicted refraction, but Barrett was slightly better, as it had the least percentage of predicted refraction higher than ± 2 D. The superior accuracy of the Barrett formula over earlier generations' formulas (SRK/T and Holladay 1) was shown by multiple studies, as in Kane *et al.* which showed that Barrett had the highest percentage of eyes with prediction error between ± 0.25 , ± 0.5 , and ± 1 D compared to Haigis, HofferQ, Holladay 1 and 2, and

SRK/T [22]. Cooke *et al.* found that 80.6% and 99.3% were within ± 0.5 D and ± 1 D, respectively, with Barrett [23]. Melles *et al.* also showed the superiority of the Barrett formula compared to Holladay 1 and SRK/T, among other formulas, with approximately 80% and $> 97\%$ within ± 0.5 D and ± 1 D, respectively [23]. While Darcy *et al.* found comparable performance of Barrett, Holladay 1, and SRK/T, although Barrett still surpasses them [25]. In a meta-analysis by Shrivastava *et al.*, the results showed that Holladay 1 had a higher percentage within ± 0.5 D and ± 1 D [26]. However, in the benchmark standards for refractive outcomes after NHS (National Health System) cataract surgery, Gale *et al.* concluded that the refractive outcomes were 85% of patients achieving a final spherical equivalent within 1D of the predicted error and 55% within 0.5D, which should be adopted when using PCI with optimization of

lens constant [27]. This study reached approximately the same result without optimization of the constants but resulted in more myopic shift than was expected, which could be attributed to the lack of optimization. The postoperative BCVA was $\geq 6/12$ in 90.4% of this study's candidates, comparable to the visual outcome (94.3%) mentioned by Laundstorm *et al.* [28].

Limitations of the Study

Most of the patients were of average axial length; future studies directed towards short and long axial lengths are needed. A study for patients who have undergone other ocular surgeries, e.g., refractive surgery or pars plana vitrectomy will be more informative on these special situations. Additionally, the study was conducted in a tertiary center teaching hospital, so it was difficult to choose a single surgeon to perform all or most of the surgeries, hence we could not optimize the constant of any formula.

Conclusions

The differences between the two devices in some parameters can be negligible in clinical practice, as their effect is very small, and they can be used interchangeably. Till the optimization of formula constants, it is advisable to assume a more myopic result than predicted by the IOLMaster (SRK/T, Holladay1) and LenStar (SRK/T, Holladay1, Barrett).

ACKNOWLEDGMENTS

The authors thank the biometry unit in Ibn Al-Haitham Teaching Eye Hospital for their technical support.

Conflict of interests

The authors declared no conflict of interest.

Funding source

The authors did not receive any source of funds.

Data sharing statement

Supplementary data can be shared with the corresponding author upon reasonable request.

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