Comparison of the predictive refractive error and refractive outcomes using the IOLMaster 500 and Pentacam-AXL Wave

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Abstract

Cataracts are a major cause of morbidity worldwide. More so than ever, clinicians rely on the accuracy of their instruments in predicting refractive error (pred. RE) to ensure optimal post-operative outcomes. Here, we compare the pred. RE accuracy of the IOLMaster 500 against the Pentacam-AXL wave in 92 eyes receiving CNA0T0 + lenses. Our data demonstrates nil significant difference between the two instruments with the IOLMaster 500 pred. REs falling within 0.40D ± 0.31 (SD) of the objective refractive error (obj. RE), compared to 0.42 ± 0.29D (SD) when using the Pentacam-AXL wave (p-value 0.35). Nonetheless, there is a trend of the IOLMaster 500 performing marginally better than the Pentacam-AXL wave, with 71.6% vs. 66.3% and 97.8% vs. 95.7% of pred. REs falling within ± 0.50D and ± 1.00D of their obj. RE respectively. Lastly, the Pentacam-AXL wave frequently calculates more hyperopic pred. RE for a given IOL (> 92%). This results in the Pentacam-AXL wave selecting more a powerful IOLs in most cases (90%), thereby avoiding hyperopic post-operative outcomes. In conclusion, the IOLMaster 500 and Pentacam-AXL wave are comparable in terms of pred. RE accuracy. Nonetheless, clinicians wishing to avoid leaving patients hyperopic may benefit from relying on the pred. RE's suggested by the Pentacam-AXL wave.

Introduction

More than 10 million cataract surgeries are performed worldwide each year[1]. Improving technology has resulted in increasingly high post-operative expectations for both the clinician and patient. Several instruments have recently been developed claiming to offer superior estimates of predictive residual refraction [2–7]. One such instrument, the Pentacam-AXL wave, reports to being the new gold standard[8], thus claiming the title from more established devices such as the IOLMaster 500.

The Pentacam-AXL wave enables the user to take three-dimensional scans of the anterior eye using the Scheimpflug camera, thus providing measurements of both the anterior and posterior corneal curvatures. In addition, the Pentacam-AXL wave also uses total wavefront aberrometry to measure refractive power and an additional partial coherence interferometry (PCI) module to calculate axial length[6,9,10]. This combined with other measures of anterior segment biometry enable the Pentacam-AXL wave to provide accurate estimates of pred. RE [6,11,12]. By comparison, the IOLMaster 500 cannot perform total wavefront aberrometry and lacks a Scheimpflug camera, and thus has no such means of taking three-dimensional scans of the anterior eye or calculating posterior corneal curvature. Instead, The IOLMaster 500 relies on the anterior corneal curvature alone to calculate corneal power, and uses these keratometry values to calculate pred. RE. Previous studies have demonstrated that posterior astigmatism can influence calculations of corneal power[13]. Hence, the inability of the IOLMaster 500 to measure posterior corneal curvature may result in an inaccurate pred RE. calculation. Furthermore, it has been suggested that the K-values calculated by the IOLMaster 500 may be less accurate than those obtained using a Scheimpflug camera[14]. Despite this, the IOLMaster 500 continues to be the most widespread device in use, at least partly due to the Pentacam-AXL wave remaining cost prohibitive for many practices.

Several manuscripts have been published detailing the efficacy of the Pentacam-AXL and IOLMaster 500 [2,3,5,6,12,14,15]. However, to date, no studies directly compared the newer Pentacam-AXL wave to the IOLMaster 500. Furthermore, literature that directly compares the Pentacam-AXL series to the IOLMaster 500 in terms of their ability to accurately calculate pred. RE's is scant. Such work would help facilitate informed decision making when choosing to invest in devices that enable anterior segment biometry. It would also aid in ensuring optimal patient outcomes post cataract removal and intraocular lens (IOL) insertion. Here, we use a retrospective approach to compare the differences in pred. RE calculations between the IOLMaster 500 and Pentacam-AXL wave against both objective refractive error (obj. RE) and, in a subset of patients, subjective refractive error (sub. RE).

Methods

Selection criteria and study design

This retrospective study included 92 eyes across 76 patients undergoing cataract surgery between December 2020 and June 2021 at Bloomfield medical centre, Orange, NSW, Australia. This study was approved by the Greater Western Human Research Ethics Committee and followed the tenets stated within the Declaration of Helsinki.

Eligible patients included were those with senile cataracts receiving CNA0T0 IOLs. Patients with traumatic cataracts, additional anterior or posterior segment disease, and/or those requiring toric IOL's were excluded from the study. Additionally, patients who had parameter measurements that were deemed potentially unreliable by either the Pentacam-AXL wave or IOLMaster 500 software were excluded from this study.

Anterior segment biometry was performed using the IOLMaster 500 (Zeiss, Germany) and Pentacam-AXL wave (OCULUS, Germany). Measurements of axial length (AL), anterior chamber depth (ACD) Keratometry (K1, K2), Cylinder (CYL), predicted residual refraction and suggested IOL powers were collected from both devices. Measurements were calculated using the SRK/T formula. IOL selection for each operation was made based off measurements from the IOLMaster 500.

Topcon and Nidek OPD auto refractometers were used to obtain objective refractive error (obj. RE) two to four weeks post cataract surgery. Individual optometrists were contacted to obtain post operative subjective refractive errors (sub. RE) in a subset of 21 patients. Mean predicted refractive error (MPE) was derived based on the difference between either the obj. RE or sub. RE and the pred. RE for the selected IOL, as measured by either the IOLMaster 500 or Pentacam-AXL wave respectively. To ensure optimal comparison between devices, the median absolute refractive error (MedAE) and mean absolute refractive error (MAE) were also calculated. The proportion of eyes with a pred. RE within ±0.00 dioptre (D) to 0.25D, ±0.25D to 0.50D, ±0.50D to 0.75D, and ±0.75D to 1.00D of the objective and subjective refractive errors were also obtained.

Surgical procedure

Wounds were constructed using a clear corneal incision method, with a temporal three-step main wound created using a 2.2mm keratome. The anterior chamber was then filled with viscoat, and side ports were placed superiorly and inferotemporally.

A cystotome was used to breach the anterior capsule, with an Inamura Capsulorrhexis forceps used to complete the continuous curvilinear Capsulorrhexis. Following hydrodissection and hydrodelineation, a divide and conquer method was used to complete phacoemulsification. Cortex was removed with the use of bimanual irrigation / aspiration. The capsular bag was distended with provisc, and the lens was inserted.

At completion, the remaining viscoelastic device was removed with bimanual irrigation / aspiration, and wounds were hydrated with a balanced salt solution to ensure no leak. Intracameral cefazolin 2mg/0.1ml was instilled.

Post operatively, the shield was removed 12 hours later, and the patient commenced Prednefrin forte eye drops four times per day.

Statistical analysis

Normality of the data was validated with a Chi-Squared Goodness-of-Fit test and graphical analysis. Descriptive statistics were calculated, and paired t-tests were used to compare the mean predictive and absolute errors between instruments. P-values <0.05 with 95% confidence intervals were considered significant.

Ethical approval

Ethics for this study was approved by the Greater Western Human Research Ethics Committee.

Results

92 eyes across 76 patients (35 male: 41 female) undergoing uncomplicated cataract extraction and IOL implantation were included in this study. Normality of the subjective and objective predictive error data from both the IOLMaster 500 and Pentacam-AXL wave was guaranteed using Chi-square goodness of fit tests (p-values >0.05).

The IOLMaster 500 performed marginally better than the Pentacam-AXL wave, calculating a pred. RE closer to the obj. RE in 51.1% of eyes tested. By comparison, the Pentacam-AXL wave calculated a more accurate pred. RE in 45.7% of instances (Fig. 1a). Similar results were found when comparing the pred. REs against the sub. RE, with IOLMaster 500 and the Pentacam-AXL wave calculating a more accurate pred. RE in 52.4% vs. 42.9% of eyes respectively (Fig. 1b). The IOLMaster 500 also outperformed the Pentacam-AXL wave when analysing the data in terms of dioptre ranges, with 34.8% vs. 38.0%, 30.4% vs. 32.6%, 20.7% vs. 14.1% and 8.7% vs. 12.0% of pred. RE falling within ±0.00D to 0.25D, ±0.25D to 0.50D, ±0.50D to 0.75D, and ±0.75D to 1.00D respectively (Fig. 1c). As a total, 71.7% and 97.8% of the IOLMaster

500’s pred. RE’s fell within ±0.5D and ±1.0D of the Obj. RE respectively, as compared to 66.3% and 95.7% when using the Pentacam-AXL wave (Fig. 1c). This trend largely persisted when evaluating data against the sub. RE, with 47.5% vs. 42.9%, 14.5% vs. 38.1%, 23.8% vs. 4.8% and 9.5% vs. 9.5% of the Pentacam-AXL wave and IOLMaster 500 calculated pred. REs falling within these same dioptre ranges (Fig. 1d). When evaluated as a total, the 81.0% and 95.3% of the IOLMaster 500 pred. RE’s fell within ±0.5D and ±1.0D of the sub. RE, compared to 66.7% and 95.3% when using the Pentacam-AXL wave.

Histogram analysis revealed a normal bell curve distribution of data from both the IOLMaster 500 and Pentacam-AXL wave, as confirmed by a Chi-square goodness of fit tests (p-values >0.05) (Figure 2 A-B). Interestingly, this analysis of the Obj. RE’s revealed that the Pentacam-AXL wave pred. RE outliers tend to be more hyperopic, with 2.2% of pred. RE lying +1.00D to +1.25D from the Obj. RE, compared to 0.0% when using the IOLMaster 500 (Fig. 2a). Conversely, the pred. RE outliers calculated by the IOLMaster 500 pred. RE tend to be more myopic, with 0.5% of pred. RE’s falling within both the -1.75D to -1.5D and -1.5D to -1.25D dioptre ranges respectively (Fig. 2a). Comparatively, there were nil instances in which the Pentacam-AXL wave calculated to Pred RE. less than -1.0D of the Obj. RE (Fig. 2a). This trend persisted to a lesser extent when evaluating the data against the Sub. RE, with 4.8% vs. 2.4% and 0.0% vs. 2.4% of the devices pred. RE’s falling within 0.75D to 1.0D and -1.5D to -1.25D of the sub. RE respectively (Fig. 2b).

To better characterize this data, mean absolute refractive errors (MAE) and median absolute refractive errors (MedAE) were also analysed (Table.1). There was nil significant difference between the MAEs of these devices when evaluated against the obj. RE (0.40 ±0.31D vs 0.42±0.30D; p-value 0.77) (Table. 1). This was also seen when evaluated against sub. REs, with the IOLMaster 500 achieving a MAE of 0.37±0.35D, compared to 0.39±0.33D when using the Pentacam-AXL wave (p-value 0.81) (Table.1). Similarly, MedAEs were also comparable between the two instruments. The IOLMaster 500 and Pentacam-AXL wave had MedAEs of 0.37D and 0.40D when compared against obj. RE's, and 0.29D and 0.27D when compared against sub. RE's respectively (Table. 1).

Lastly, pred. RE ranges and mean predictive refractive errors (MPE) were obtained from each device to determine whether a significant difference exists between the specific pred. RE calculated by the two instruments. The IOLMaster 500 and Pentacam-AXL wave’s pred. REs came within a range of -1.60D to 0.97D and -0.99D to 1.25D of the obj. REs respectively (Table. 1). When evaluated against the sub RE, the IOLMaster 500 pred. REs ranged between -1.48D to 0.84D, compared to -1.03D to 0.96D when using the Pentacam-AXL wave (Table. 1). The MPE of the IOLMaster was -0.17±0.48D (Table. 1). By contrast, the Pentacam-AXL wave’s MPE was significantly more hyperopic for the selected IOLs at 0.12±0.50D (p-value <0.001) (Table. 1). This trend was also maintained when evaluated against the sub. RE, with the IOLMaster 500 and Pentacam-AXL wave achieving MPEs of -0.06±0.52D and 0.24±0.45D respectively (p-value <0.05) (Table. 1). This corresponded to the IOLMaster 500 calculating a more myopic pred. RE for the selected IOL in over 92% (85 in 92) of cases. To determine whether this would significantly influence IOL selection, we compared the IOL power recommend by these devices. On average the IOL’s selected by the IOLMaster 500 were 0.62D less powerful than those selected by the Pentacam-AXL wave (20.71±2.74D vs. 21.33+2.71D; p-value<0.001) (Table. 2). This corresponded to the Pentacam-AXL wave selecting a more powerful lens in 90% of instances (Table. 2). Indeed, the IOLMaster 500 selected the more powerful IOL in just 3.3% cases (Table. 2). This suggests that the differences between the calculated pred. RE's of these devices is sufficient to clinically influence IOL selection, and thus has potential to influence post-operative outcomes.

Discussion

Collectively, our data suggests that the IOLMaster 500 and Pentacam-AXL wave do not significantly differ in their ability to accurately predict refractive error for cataract extraction and subsequent IOL implantation. This is true when evaluated against both the objective refractive error (as per auto refractometry) and subjective refractive error (as per outpatient optometrist measurement). Nonetheless, differences do exist between these instruments, with the IOLMaster 500 giving a more myopic pred RE. for the selected IOL in over 92% of instances. This in turn results in the Pentacam-AXL wave suggesting a more powerful IOL in 90% of cases. In effect, this may lead to IOLMaster 500 users encountering a greater number of hyperopic post-operative outcomes. Hence, clinicians wishing to avoid leaving their patients hyperopic would benefit from basing their IOL selection on the pred. RE calculated by the Pentacam-AXL wave.

Discrepancies between the calculated pred. REs most likely exists due to the differences by which these devices take measurements. As previously mentioned, the Pentacam-AXL wave uses the Scheimpflug camera to measure the anterior and posterior corneal curvature[6,9], whereas the IOLMaster 500 relies exclusively on the anterior corneal curvature to calculate anterior segment biometry[11,12]. Nonetheless, there is disagreement as to whether the Pentacam-AXL series and IOLMaster 500 significantly differ in terms of their anterior segment biometry measurements. For instance, a study by Shajari et al. (2017) demonstrated nil significant difference between the AL, ACD and keratometry calculated by the Pentacam-AXL and IOLMaster 500[16]. By contrast, Muzyka-Woznaik and colleagues (2019) found that these devices agree regarding ACD measurements but significant differ in both AL and keratometry measurements[15]. Furthermore, data from this study suggest that the Pentacam-AXL selects more powerful IOLs than that of the IOLMaster 500 in 75% of cases when using the Hagis formula, and 62% of cases when using the SRK/T formula[15]. Our findings are consistent with this, with the Pentacam-AXL wave selecting a powerful IOL 90% of cases. Muzyka-Woznaik and colleagues (2019) attributed this to the differences in K-values, as the measured discrepancy in AL and ACD was not sufficient to influence IOL selection[15]. Authors subsequently suggested that the optimization of the Pentacam-AXL would facilitate more accurate predictions of IOL power [15]. Interestingly, our data suggests that this difference persists when using the Pentcam-AXL wave despite recent OCULUS software updates, CNA0T0+ IOL specific a-constants, and the influence of total wavefront aberrometry on pred. RE calculation, a feature absent from the Pentacam-AXL. It may be of interest to determine if clinically significant differences in calculated pred. RE's exist between the devices within the Pentacam series. This would act to determine if extra features such as total wavefront aberrometry significantly influence IOL selection. Ultimately, further studies are required to underpin any such differences between the Pentacam-AXL and Pentacam-AXL wave.

Several groups have also compared the Pentacam-AXL series and IOLMaster 500 to other commercially available devices [2,3,6,16,17]. Srivannaboon et al. (2015) found that the IOLMaster 700 and IOLMaster 500 had good agreement between parameters, including IOL power calculations, with a mean difference of 0.03D and 0.04D when using SRK/T and Hagis formulas respectively[17]. However, the IOLMaster 700 was able to perform AXL measurements on dense cataracts where the IOLMaster 500 failed to do so[17]. Furthermore, the IOLMaster 700 took significantly less time to complete its anterior segment biometry[17]. Both aspects were attributed to by the IOLMaster 700 employing swept-source biometry rather than the standard PCI biometry used by the IOLMaster 500[17]. In context of our findings, this suggests that the IOLMaster 700 may also offer more myopic pred. RE than that of the Pentacam-AXL wave. Other studies have compared the Lenstar LS 900 to the Pentacam-AXL[3,6]. It was determined that while the AXL are comparable between the two devices, the Lenstar LS 900 and Pentacam-AXL give significantly different measurements of ACD, K1 and K2 and central corneal thickness[6]. This resulted in the Lenstar calculating more hyperopic, and ultimately more accurate, pred. REs[6]. As with Muzyka-Woznaik et al. (2019), authors of this study cautioned Pentacam-AXL users to ensure optimization to avoid inaccurate IOL selection[6,15]. The IOLMaster 500 and Lenstar LS 900 also have good agreement in terms on AL, ACD and average keratometry measurements, with nil significant differences between pred. REs[18,19]. Likewise, The OA-2000 is comparable to the IOLMaster 500 in terms of anterior segment biometry and pred. RE calculations[18-22]. However, as with the IOLMaster 700, the OA-2000 had a higher rate of successful AL measurements[19,20]. This is likely due to the OA-2000 also utilizing swept-source rather than PCI biometry[19,20]. Although inferences can be made regarding how the Pentacam-AXL wave compares to these devices, studies that directly compare these instruments are required to underpin the precise differences between measured AL, ACD, keratometry, pred. RE, and ultimately, post operative outcomes.

In conclusion, this study demonstrates IOLMaster 500 is non-inferior to Pentacam-AXL wave in terms of pred. RE accuracy. Nonetheless, there is as an overall trend of the IOLMaster 500 performing marginally better when comparing individual pred. REs against both obj. RE and, to a lesser degree, sub. RE. Lastly, the Pentacam-AXL wave calculates more hyperopic pred. RE for a given IOL in a majority of instances. This has potential to influence the clinician to select IOLs that will be more likely to avoid hyperopic post-operative outcomes.

Declarations

DATA AVAILIABILITY STATEMENT

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Contributions

RJPS was lead in conceptualized the project, curating the data, preforming data analysis, and writing the manuscript. HB supported the conceptualization of the project, and review and editing of the manuscript. BC led funding acquisition, supervision and support reviewing and editing of the manuscript. All authors read and approved the final manuscript.

ADDITIONAL INFORMATION

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This project was self-funded by eye surgery associates, Orange, NSW, Australia.

Ethical approval and consent to participate

This study was approved by the Greater Western Human Research Ethics Committee and followed the tenets stated within the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors have no competing interests to declare.

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Tables

Table 1. *Comparison of the mean absolute error (MAE), median absolute error (MedAE), range, and mean predictive error (MPE) between the Pentacam-AXL wave and IOLMaster 500 as measured in dioptres (D), ± standard deviation (SD). Measurements evaluated against the objective refractive error (n=92) and subjective refractive error (n=21) are shown. (*p<0.05, ***p<0.001)*

	Objective Refractive Error		**Subjective Refractive Error**	
	IOLMaster 500	*Pentacam-AXL Wave*	*IOLMaster 500*	*Pentacam-AXL Wave*
MAE±SD (D)	0.40±0.31	0.42±0.30	0.37±0.35	0.39±0.33
MedAE (D)	0.37	0.4	0.29	0.27
Range (D)	-1.60 to 0.97	-0.99 to 1.25	-1.48 to 0.84	-1.03 to 0.96
MPE±SD (D)	-0.17±0.48***	0.12±0.50***	-0.06±0.52*	0.25±0.46*

IOLMaster 500 vs. Pentacam AXL wave: Comparison of predicted refractive error accuracy

Table 2. *Comparison between the selected IOL power of the IOLMaster 500 and Pentacam-AXL wave. Also shown is the range of selected IOL powers and frequency (%) in which the respective devices select the more powerful IOL (n=92).*

	IOLMaster 500	**Pentacam-AXL wave**	**P-Value**
Mean IOL Power ± SD (D)	20.71 ± 2.74	21.33 ± 2.71	<0.001
Range (D)	17; 30	16.5; 30	
% More Powerful IOL Selected	3.30%	90%	

IOLMaster 500 vs. Pentacam AXL wave: Comparison of IOL power selection

Figures

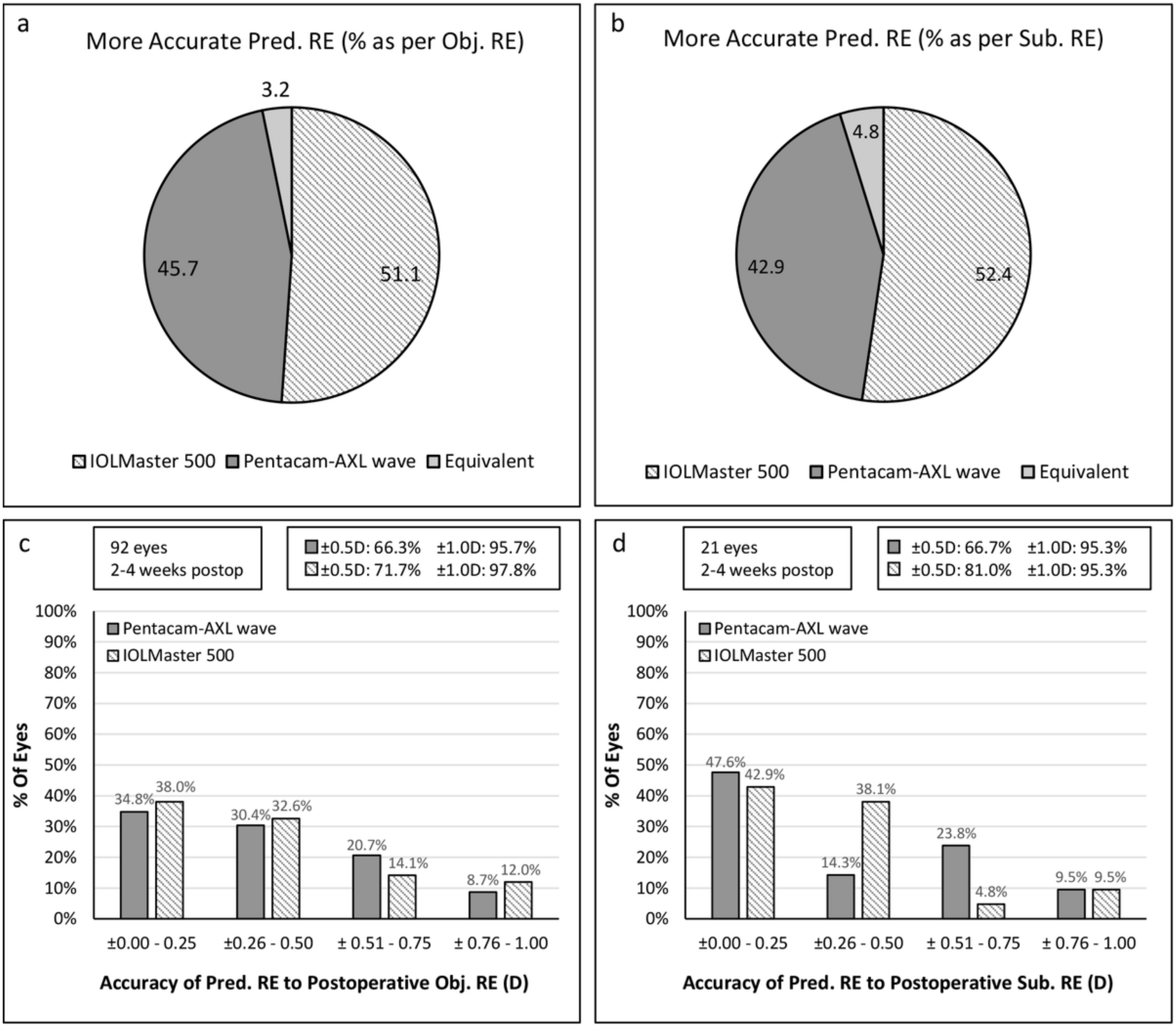

Figure 1

*Predictive refractive error (Pred. RE) accuracy of the Pentacam-AXL wave and IOLMaster 500 against the objective (obj. RE) and subjective refractive error (sub. RE). (**a**) Proportion of Pentacam-AXL wave (solid dark grey) and IOLMaster 500 (line grey) pred. REs that most accurately agree with the Obj. RE. Instances in which the Pred. REs from the IOLMaster 500 and Pentacam-AXL wave are equally accurate is also shown (light grey) (n=92). (**b**) Proportion of Pentacam-AXL wave (solid dark grey) and IOLMaster 500 (line grey) pred. REs that most accurately agree with the sub. RE. Instances in which the Pred. REs from the IOLMaster 500 and Pentacam-AXL wave are equally accurate is also shown (light grey) (n=21). (**c**) Percentage of Pred. REs calculated by the Pentacam-AXL wave (solid grey) and IOLMaster 500 (line grey)* *that fall within ±0.00D to 0.25D, ±0.25D to 0.50D, ±0.50D to 0.75D and ±0.75D to 1.00D of the obj. RE (n=92). (**d**) Percentage of Pred. REs calculated by the Pentacam-AXL wave (solid grey) and IOLMaster 500 (line grey) that fall within ±0.00D to 0.25D, ±0.25D to 0.50D, ±0.50D to 0.75D and ±0.75D to 1.00D of the sub. RE (n=21). Pred. RE = Predictive Refractive Error; obj. RE = Objective Refractive Error; sub. RE = Subjective Refractive Error; D = Dioptre.*

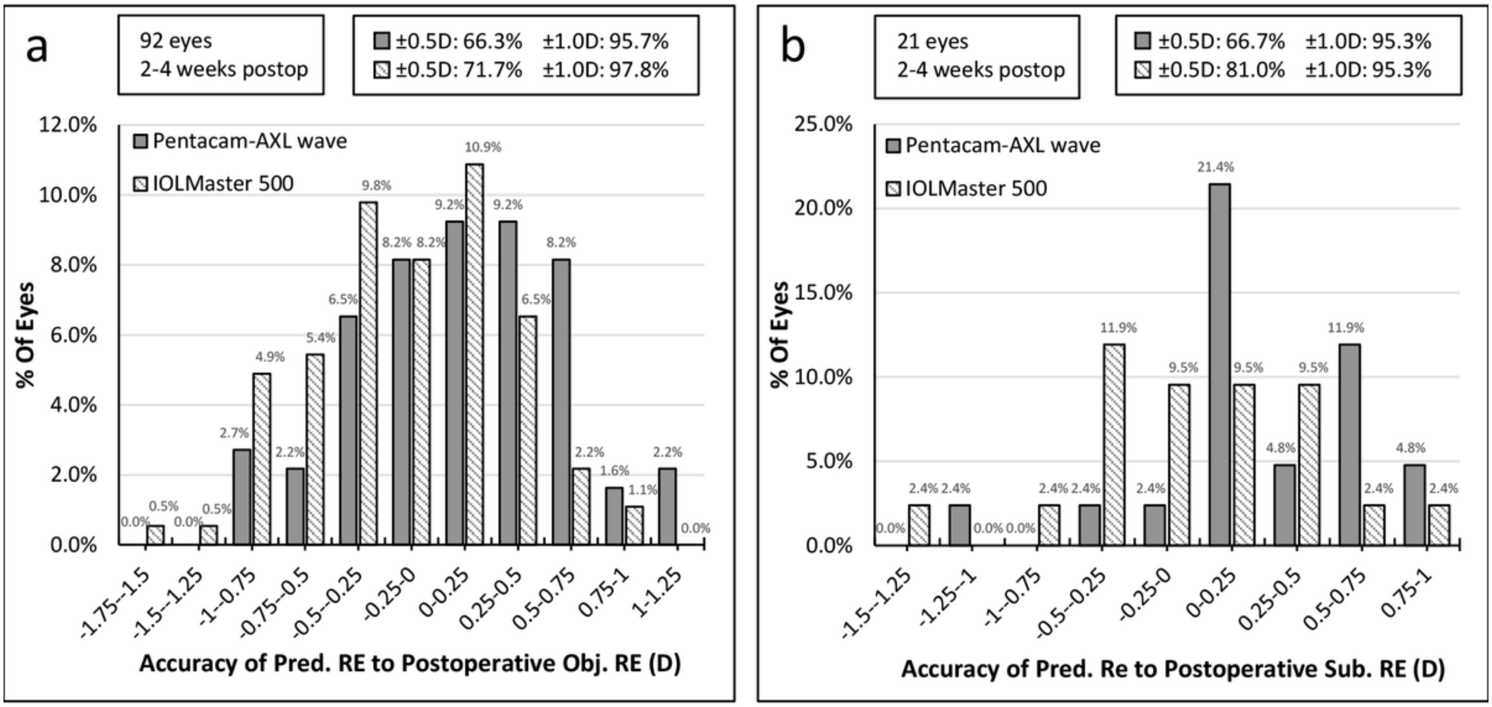

Figure 2

*Histogram analysis of the predictive refractive error (Pred. RE) accuracy of the Pentacam-AXL wave and IOLMaster 500 against the objective (obj. RE) and subjective refractive error (sub. RE). (**a**) Histogram detailing the percentage of eyes falling within the respective dioptre ranges (from -1.75D to 1.25D) of the obj. RE (n = 92). (**b**) Histogram detailing the percentage of eyes falling within the respective dioptre ranges (from -1.50D to 1.00D) of the sub. RE (n = 21). Pred. RE = Predictive Refractive Error; obj. RE = Objective Refractive Error; sub. RE = Subjective Refractive Error; D = Dioptre.*

Supplementary Files

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- SupplementaryDataS1.pdf