Comparative Analysis of Cataract Refractive Outcomes Based on Varied Axial Length and Keratometry Measurements from Diverse Diagnostic Devices

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ABSTRACT

Objective: To compare the refractive absolute error when axial length (AL), anterior chamber depth (ACD) and keratometry (K) are sourced from different measuring devices (IOL Master vs a combination of automated keratometer and A-scan) and inputted into the Barrett Universal II or SRK/T formula.

Methods: This was a retrospective study. Medical charts of eyes that underwent uncomplicated phacoemulsification with in-the-bag implantation of Envista or multifocal FineVision IOL were reviewed. The results of manifest refraction at 1 month after surgery were collected. The predicted refraction corresponding to the IOL power implanted was collected from 4 IOL sheets: using the SRK/T with AL, ACD, and K from IOL Master (Group A); SRK/T formula with AL and ACD from A-scan and K from the automated keratometer (Group B); Barrett formula with AL, ACD and K from IOL Master (Group C); and Barrett formula using with AL, ACD from A-scan and K from automated keratometer. For each group, the absolute error, prediction error, and variances of prediction error were computed.

Results: A total of 132 eyes were included in the study: 56 in the monofocal group and 76 in the multifocal group. The means of manifest refraction spherical equivalent (MRSE) were 0.06 ± 0.38 D and -0.08 ± 0.31 D in the monofocal and multifocal groups, respectively. When AL and K were obtained from various sources and entered into the Barrett formula, the mean absolute error difference in both the monofocal ($p = 0.70$) and multifocal ($p = 0.10$) groups did not reach statistical significance. If the SRK/T formula was used, similar outcomes were observed (monofocal $p = 0.97$; multifocal $p = 0.37$). When compared to A-scan groups, the prediction error variances are significantly smaller in the groups that used the IOL Master as their data source. Among the four groups, the Barrett group using IOL Master as the data source showed the lowest overall variation of prediction error (monofocal $F = 0.04$; multifocal $F = 0.03$).

Conclusion: Though the refractive outcomes may not be statistically different, using the IOL Master as the source of AL and K makes the refractive outcomes more consistent and predictable. Combining the AL and K from the IOL Master with the Barrett Universal II formula further increases the predictability of refractive outcomes.

Keywords: optical biometry, ultrasound biometry, refractive outcomes, Barrett universal II formula, prediction error, axial length keratometry

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Reliable biometry or optical parameter measurements are essential for accurate intraocular lens (IOL) power calculation. These parameters include keratometry (K), axial length (AL), and anterior chamber depth (ACD), which can be obtained using different devices.

Keratometry (K) is the measurement of the corneal curvature which determines the power of the cornea. In the past, keratometers were manual devices. Nowadays, automated keratometers are preferred because of speed and ease of use.

On the other hand, axial length measurement is found to be the most important parameter for IOL power calculation.[1] Axial length (AL) and anterior chamber depth (ACD) can be measured using either A-scan ultrasound devices or optical biometry machines. While A-scan ultrasound devices (or A-scans) are relatively inexpensive, they can be prone to errors due to corneal indentation. Immersion A-scans are preferred over direct contact A-scans because underestimation of the AL ranging from 0.1 to 0.3 mm are avoided in the former.[2]

Since its launch in 1999, the IOL Master has become the gold standard of biometry.[3] It uses partial coherence interferometry technology that allows non-contact, rapid, and accurate measurements of all the required parameters for IOL power calculation: AL, K, and ACD.[3]

One of the most popular and successful formulas for IOL power calculation is the SRK formula.[6,7] It is most accurate for eyes with AL between 22.0 to 24.5 mm. For long and short eyeballs, the SRK II formula was developed. The evolution of IOL power calculation formulas continued on until the 21st century with the conception of the SRK/T formula. The SRK/T formula represents a combination of linear regression in a theoretical eye model that incorporates ACD based on AL combined with K that results in greater accuracy, especially in long eyeballs.[8]

Another popular IOL calculation formula is the Barrett Universal 2 Formula. The formula is based on a theoretical eye model in which ACD is related to AL and K, and uses the relationship between the A-constant and a "lens factor" to determine ACD.[9] Two major studies tested the Barrett Universal 2 formula and proved its accuracy across all axial lengths.[4,5]

Although the IOL Master is the gold standard in biometry, the cost is prohibitive compared to an A-scan and keratometer, thereby hindering the former's universal adoption. The purpose of our investigation was to ascertain which AL and K readings—derived from the A-scan/keratometer or the IOL Master—will most closely approximate the actual refractive result following surgery in terms of predicted refraction. Moreover, our research also aimed to ascertain the application of distinct formulas (Barrett and SRK/T) that can mitigate the impact of AL and K sources on the precision of the anticipated refractive result.

METHODS

Patients and Methods

This retrospective cohort study reviewed medical records of patients who underwent phacoemulsification with in-the-bag IOL implantation from November 2013 up to June 2017 performed by a single surgeon at the Asian Eye Institute. This study was approved by a local Institutional Review Board and was conducted in accordance with the tenets of the Declaration of Helsinki.

Eyes were included if the following inclusion criteria were met: uneventful phacoemulsification with in-the-bag lens implantation, implantation with monofocal non-toric IOL (Envista, Bausch and Lomb, USA) or multifocal non-toric IOL (FineVision, Physiol, Belgium), and presence of pre-operative ACD, K, and AL measurements using the IOL Master (Carl Zeiss Meditec, Jena, Germany), automated keratometer (HRK-9000A, Huvitz, South Korea), and manual A-scan ultrasound biometry (Axis Nano, Quantel Medical, France). Eyes with the following characteristics were excluded: corneal astigmatism >1.0 D, corneal pathology that may affect manifest refraction, history of refractive surgery or ocular surgery that may alter AL (i.e., scleral buckling), complicated cataract surgery, additional procedures during cataract surgery, and presence of postoperative complications such as infection, inflammation, and lens dislocation. Patients with incomplete medical records were also excluded.

The following data were collected: age, gender, eye laterality, implanted IOL power, and manifest refraction at 1 month post-surgery expressed in spherical equivalent (actual refraction). In addition, for each eye, the following pre-operative measurements were collected: K from the automated keratometer; AL and ACD from A-scan; and K, AL, and ACD from the IOL Master. The mean values for each parameter were obtained by averaging three individual measurements, and the resulting average values were subsequently recorded for analysis. In all subjects, the surgeon used the basic IOL Master printout for IOL selection in cataract surgeries, without specifically relying on the Barrett formula or any other formula for all cases.

Eyes were divided into two major groups based on the type of implanted IOL: monofocal (eyes implanted with non-toric Envista IOL) and multifocal (eyes implanted with non-toric FineVision). Each major group was further subdivided into 3 subgroups based on AL: long >25mm; medium 22-25 mm; and short <22mm.

Four distinct IOL power calculation sheets were gathered for each eye: (1) IOL Master printout with 119.0 A-constant and SRK/T formula; (2) A-scan printout with 119.0 A-constant and SRK/T formula; (3) printout of the Barrett calculator with the IOL Master AL, K values, and A-constant of 119.0; and (4) printout of the Barrett calculator with A-scan AL and keratometer K reading at A-constant of 119.0. A projected refraction for each implanted monofocal and multifocal IOL power was included in the calculation sheet. With the use of four calculation sheets, the actual emmetropic refraction after one month following surgery was compared to the expected emmetropic refractions in order to generate four refractive prediction errors (PE) and four absolute errors (AE) for each eye based on different combinations of source of parameter (IOL Master and A-scan with keratometer) and IOL calculation formula.

For each eye included in the study, the absolute error and refractive prediction error were computed. The *absolute error* (AE) is the absolute difference between the actual and predicted refractions (absolute value of actual refraction minus predicted refraction). The *refractive prediction error* (prediction error or PE) is the numerical difference of predicted refraction from the actual refraction outcome (actual refraction minus predicted refraction). A PE of 0 means the actual refraction exactly matched the predicted refraction. A negative PE value indicates a myopic outcome wherein the actual refraction is off-target towards more myopia, compared to the predicted refraction. On the other hand, a positive PE value represents a hyperopic outcome wherein the actual refractive result is off-target towards more hyperopia compared to the predicted refraction.[10]

Scatterplot graphs of the PE for each group were created to show how far each eye's actual refractive result was from the targeted predicted refractive outcome and the distribution of PE towards myopia or hyperopia. The *variance* of the mean PEs per group was calculated to derive the standard deviation and range of error.

The variance and means of AE and PE were computed for each group (SRK/T formula using IOL Master data vs SRK/T formula using A-scan/keratometer data vs Barrett formula using IOL Master data vs Barrett formula using A-scan/keratometer data). The means of AE between the two groups that used the same IOL formula but utilized data sourced from different machines were compared and analyzed (i.e., SRK/T formula using IOL Master data vs. SRK/T formula using A-scan/keratometer; Barrett formula using IOL Master data vs. Barrett formula using A-scan/keratometer). In the same manner, the means of AE between the two groups that had the same source of ocular data inputted into different IOL formulas were compared and analyzed (i.e., IOL Master data inputted into SRK/T formula vs IOL Master data inputted into Barrett formula; A-scan/keratometer data inputted into SRK/T printout vs A-scan/keratometer data inputted into Barrett formula). Paired *t*-test was used and a *p*-value of less than 0.05 was considered statistically significant. Fisher's *F*-test was used to analyze the variances of each group and an *F*-value of less than 0.05 was considered statistically significant. The short AL subgroups for both the monofocal and multifocal groups were not statistically analyzed since the samples were small (monofocal $n = 1$; multifocal $n = 3$).

RESULTS

This study included 132 eyes that underwent uneventful phacoemulsification with in-the-bag IOL implantation. There were 56 eyes that were implanted with the monofocal IOL, while 76 eyes were implanted with the multifocal IOL. The mean age of patients was 70.46 years in the monofocal group and 70.51 years in the multifocal group (Table 1). Table 2 shows the pre-operative AL, K, and ACD values measured using different machines and grouped according to eyeball length. In the monofocal group, the mean AL using the IOL Master was 23.77 ± 0.91 mm, while it was 23.76 ± 0.90 mm on the A-scan. On the other hand, the mean AL in the multifocal group was 23.98 ± 1.3 and 23.93 ± 1.32 mm using the IOL Master and A-scan, respectively. The mean average Ks (ave K) in the monofocal group were 43.98 ± 1.44 D and 43.92 ± 1.51 D on the IOL Master and automated keratometer, respectively. For the multifocal group, the ave Ks were 44.1 ± 1.44 and 44.13 ± 1.47 D on the IOL Master and automated keratometer, respectively.

Table 1. Characteristics of patients and eyes

	Monofocal *n* = 56	Multifocal *n* = 76
Mean Patient Age (in years)	70.46	70.51
Patient Sex, *n* (%)		
Male	27 (48.2%)	25 (32.9%)
Female	29 (51.8%)	51 (67.1%)
Laterality, *n* (%)		
OD	23 (41.1%)	40 (52.6%)
OS	33 (58.9%)	36 (47.4%)
Number of eyes based on AL, *n* (%)		
Long eyeballs (>25 mm)	7 (12.5%)	18 (23.7%)
Medium eyeballs (22-25 mm)	48 (85.7%)	55 (72.4%)
Short eyeballs (<22 mm)	1 (1.8%)	3 (3.9%)
IOL Master Measurements		
AL	23.77 ± 0.91	23.98 ± 1.35
ACD	3.11 ± 0.46	3.13 ± 0.45
Average K	43.98 ± 1.44	44.1 ± 1.44
A-Scan Measurements		
AL	23.76 ± 0.90	23.93 ± 1.32
ACD	2.93 ± 0.37	2.99 ± 0.49
Keratometer (Average K)	43.92 ± 1.51	44.13 ± 1.47

Table 2. Pre-operative parameter measurements using different machines and eyeball length categories.

Long Eyes (>25mm)		Monofocal (*n* = 7)		Multifocal (*n* = 18)	
	Parameters	IOL Master	A-scan	IOL Master	A-scan
	AL	25.23 ± 0.03	25.23 ± 0.03	25.80 ± 0.89	25.76 ± 0.82
	ACD	3.5 ± 0.34	3.19 ± 0.27	3.43 ± 0.47	3.39 ± 0.47
	Ave K	44.15 ± 0.31	44.13 ± 0.70	43.15 ± 0.83	43.03 ± 0.75
Medium Eyes (22-25mm)		Monofocal (*n* = 48)		Multifocal (*n* = 55)	
	Parameters	IOL Master	A-Scan	IOL Master	A-Scan
	AL	23.63 ± 0.75	23.61 ± 0.74	23.48 ± 0.69	23.45 ± 0.69
	ACD	3.07 ± 0.46	2.91 ± 0.36	3.03 ± 0.41	2.85 ± 0.42
	Ave K	43.95 ± 1.54	43.88 ± 1.61	44.38 ± 1.34	44.38 ± 1.36
Short Eyes (<22mm)		Monofocal (*n* = 1)		Multifocal (*n* = 3)	
	Parameters	IOL Master	A-Scan	IOL Master	A-Scan
	AL	21.82	21.82	21.49 ± 0.49	21.59 ± 0.57
	ACD	2.65	2.46	2.65 ± 0.17	2.52 ± 0.10
	Ave K	44.62	44.88	47.03 ± 0.08	47.0 ± 0.87

Refractive outcomes for monofocal group

For the long AL group, the refractive outcomes were generally myopic for all groups (negative PE) and the IOL master printout with the SRK/T formula had the lowest mean absolute error (0.17 ± 0.08). For both the medium and short AL groups, the refractive outcomes were generally hyperopic. The combination A-scan/keratometer printout with the SRK/T formula had the lowest mean absolute error for the medium AL group (0.39 ± 0.27), while the IOL Master printout with SRK/T formula had the lowest mean AE in the short AL group (0.25). Overall, the refractive outcomes were hyperopic for all groups, and AL, ACD, and K values derived from IOL Master using either IOL formula (SRK/T formula - IOL Master data) had the lowest mean absolute error (0.40 ± 0.27) (Table 3).

Table 3. Actual refraction (AR), predicted refraction (PR), absolute error (AE), and prediction error (PE) in the monofocal and multifocal groups

Axial Length (Monofocal)	**Means ± SD**	**Means ± SD of PR, AE and PE**						*p**	*p***
		SRK/T formula - IOL Master data			**SRK/T formula - A-scan/automated keratometer data**				
	AR	PR	AE	PE	PR	AE	PE		
Total (56)	0.06 ± 0.37	–0.24 ± 0.21	0.40 ± 0.27	0.30 ± 0.39	–0.13 ± 0.31	0.40 ± 0.30	0.19 ± 0.47		
Long (7)	–0.43 ± 0.38	–0.33 ± 0.24	0.17 ± .08	–0.09 ± 0.17	–0.10 ± 0.52	0.50 ± 0.52	–0.33 ± 0.66	0.12	0.14
Medium (48)	0.13 ± 0.33	–0.23 ± 0.20	0.44 ± 0.27	0.36 ± 0.38	–0.13 ± 0.27	0.39 ± 0.27	0.26 ± 0.40	0.15	0.51
Short (1)	0.25	0	0.25	0.25	–0.30	0.55	0.55	0.97	0.31
Axial Length (Monofocal)	**Means ± SD**	**Barrett printout - IOL Master data**			**Barrett printout - A-scan/automated keratometer data**			*p**	*p***
	AR	PR	AE	PE	PR	AE	PE		
Total (56)	0.06 ± 0.37	–0.28 ± 0.26	0.43 ± 0.24	0.34 ± 0.36	–0.28 ± 0.36	0.45 ± 0.33	0.34 ± 0.44		
Long (7)	–0.43 ± 0.38	–0.40 ± 0.23	0.22 ± 0.10	–0.03 ± 0.26	–0.29 ± 0.44	0.37 ± 0.40	–0.14 ± 0.55	0.29	0.56
Medium (48)	0.13 ± 0.33	–0.27 ± 0.26	0.46 ± 0.24	0.40 ± 0.34	–0.28 ± 0.35	0.46 ± 0.32	0.41 ± 0.38	0.87	0.05
Short (1)	0.25	–0.12	0.37	0.37	–0.37	0.62	0.62	0.70	0.26
Axial Length (Multifocal)	**Means ± SD**	**SRK/T formula - IOL Master Data**			**SRK/T A-scan/ automated keratometer data**			*p**	*p***
	AR	PR	AE	PE	PR	AE	PE		
Total (76)	–0.07 ± 0.31	–0.00 ± 0.25	0.16 ± 0.37	–0.07 ± 0.38	0.07 ± 0.32	0.20 ± 0.40	–0.14 ± 0.43		
Long (18)	–0.06 ± 0.33	–0.14 ±0.20	0.11 ± 0.32	0.07 ± 0.36	0.08 ± 0.34	0.17 ± 0.38	–0.13 ± 0.40	0.76	0.06
Medium (55)	–0.07 ± 0.30	0.05 ± 0.24	0.15 ± .36	–0.12 ± 0.36	0.09 ± 0.29	0.20 ± 0.40	–0.16 ± 0.42	0.48	0.10
Short (3)	–0.17 ± 0.52	–0.14 ± 0.47	0.67 ± .58	–0.03 ± 0.72	–0.43 ± 0.57	0.33 ± 0.58	0.26 ± 0.83	0.37	0.10
Axial Length (Multifocal)	**Means ± SD**	**Barrett printout - IOL Master Data**			**Barrett printout A-scan/automated keratometer data**			*p**	*p***
	AR	PR	AE	PE	PR	AE	PE		
Total (76)	–0.07 ± 0.31	–0.03 ± 0.22	0.17 ± 0.38	–0.04 ± 0.35	–0.00 ± 0.34	0.24 ± 0.43	–0.07 ± 0.45		
Long (18)	–0.06 ± 0.33	–0.06 ±0.16	0.17 ± 0.38	–0.00 ± 0.32	0.10 ± 0.25	0.22 ± 0.43	–0.16 ± 0.41	0.06	0.76
Medium (55)	–0.07 ± 0.30	–0.01 ± 0.21	0.16 ± 0.37	–0.07 ± 0.33	–0.01 ± 0.36	0.24 ± 0.43	–0.06 ± 0.44	0.10	0.48
Short (3)	–0.17 ± 0.52	–0.35 ± 0.41	0.33 ± 0.58	0.19 ± 0.76	–0.38 ± 0.41	0.33 ± 0.58	0.21 ± 0.80	0.10	0.37

**p value (comparison of mean absolute errors differentiated by source of parameters)*
***p value (comparison of mean absolute errors differentiated by IOL calculator used)*

Figure 1 shows the generated scatterplots for the monofocal IOL group. The use of IOL Master data in the SRK/T and Barrett formulas showed smaller ranges of error and lower variances (range: –0.60 to 0.96 D, variance: 0.15; and range: –0.64 to 0.99 D, variance: 0.13, respectively) compared to using the A-scan data in the SRK/T and its Barrett calculator counterpart (range: –1.55 to 1.29 D, variance: 0.22; and range: –1.22 to 1.19 D, variance: 0.19, respectively).

Refractive outcomes for multifocal group

For the long AL group, the refractive outcomes were slightly myopic for all groups (negative PE) except for the IOL Master printout (PE = 0.07 ± 0.36). The IOL Master printout had the lowest mean absolute error (0.11 ± 0.32). For the medium AL groups, the refractive outcomes were generally myopic (negative PE). The IOL Master printout had the lowest mean absolute error for the medium AL group (0.15 ± 0.27). Overall, the outcomes were slightly myopic for all groups and the IOL Master printout had the lowest mean absolute error (0.16 ± 0.37) (Table 3).

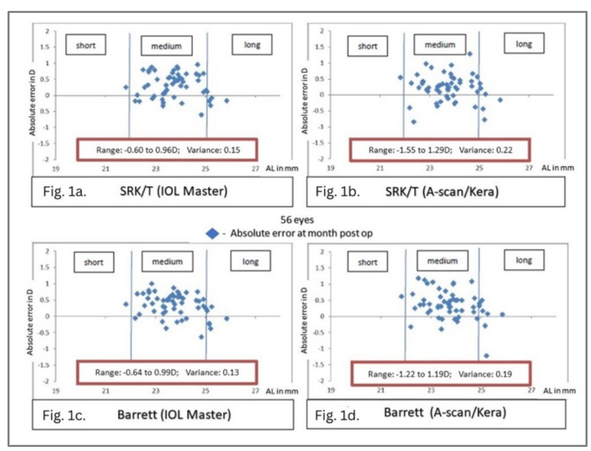

Figure 1. Scatterplot graphs of prediction errors in the monofocal IOL group with corresponding range and variance.

Figure 2 shows the scatter plot for the multifocal IOL group. When the IOL Master data was used in the SRK/T formula (IOL Master printout) and its Barrett calculator counterpart, the results showed smaller ranges of error and lower variances (range: –0.95 to 0.81 D, variance: 0.15; and range: –0.86 to 1.04 D, variance: 0.12, respectively) compared to if the A-scan was the source for the SRK/T formula (A-scan printout) and its Barrett calculator counterpart (range: –1.30 to 1.22 D, variance: 0.19; and range: –1.05 to 1.09 D, variance: 0.21, respectively).

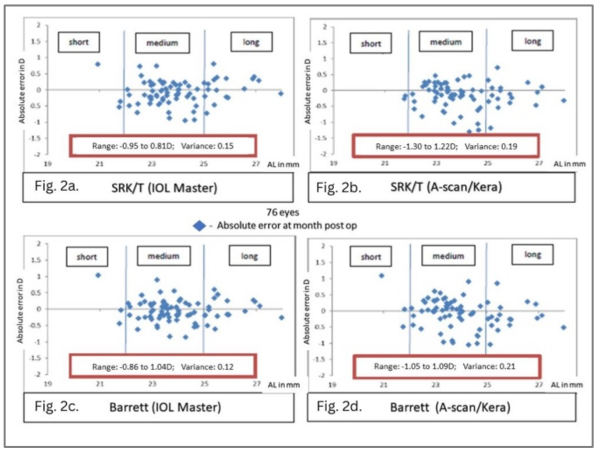

Figure 2. Scatterplot graphs of prediction errors in the multifocal IOL group with corresponding range and variance.

Mean absolute errors: Same formula, different source (IOL Master vs A-scan and keratometer)

When the SRK/T formula was used, there was no statistical difference in the mean absolute errors whether the IOL Master or A-scan/keratometer was used as the source of the AL and K for both monofocal and multifocal groups (monofocal p = 0.97; multifocal p = 0.37). When the Barrett formula was used, there was no statistical difference in the mean absolute errors as well (monofocal p = 0.70; multifocal p = 0.10) (Table 3).

Mean absolute error: Same source, different formula (Barrett vs SRK/T formula)

When the AL and K were obtained from the IOL Master, the mean absolute errors were not statistically different for both monofocal and multifocal groups whether Barrett calculator or SRK/T was used (monofocal p = 0.31; multifocal p = 0.10). When AL and K were obtained from the A-scan and keratometer, the mean predicted errors of Barrett calculator and SRK/T were also not statistically different (monofocal p = 0.26; multifocal p = 0.37) (Table 3).

DISCUSSION

Our study demonstrated that variations in AL and K measurements can significantly impact refractive outcomes following surgery. Different measurement techniques, such as optical biometry, ultrasound biometry, and various keratometry methods, may yield distinct results. This emphasizes how crucial it is to choose a measuring method that is suitable for the unique characteristics of each patient and the needs of the surgery.

Refractive results are largely dependent on the precision and accuracy of measurement tools. Our findings indicate that disparities between measured and real AL or K values might result in inferior surgical outcomes, such as persistent refractive errors and astigmatism. Therefore, continuous improvements in measuring technology are necessary to raise the precision and consistency of preoperative evaluations.

With the growing popularity of advanced intraocular lenses (IOLs) such as toric and multifocal implants, accurate biometry becomes paramount for achieving optimal visual results. By facilitating precise IOL power calculations and alignment, optical biometry enhances the predictability of visual outcomes, especially in patients seeking spectacle independence post-operatively. Many studies have reported the advantages of optical biometry over the ultrasound method in predicting post-operative refraction after cataract surgery.[11,12] Conversely, a few studies have reported similar precision between the two instruments.[13] Several studies have also compared different keratometers and their effects on IOL power calculation but no specific findings point to their effect on refractive outcome.[14] In each of these studies, data from one measurement source are applied into different formulas, or one formula is used to compare different sources of data and their effect on accuracy of outcomes.

Like many developing countries, the Philippines faces obstacles in adopting and making new medical technology like optical biometers available in eye facilities because of the problems of infrastructure, cost, and training. An optical biometer is an advanced instrument that is used to monitor the eye precisely, especially during operations like intraocular lens (IOL) implantation and cataract surgery. Despite these benefits, many eye facilities in the Philippines continue to use a combination of automated keratometers and ultrasonic biometers for a variety of reasons. Therefore, it is crucial to compare refractive outcomes when values are sourced from different machines. In addition, we analyzed two IOL power formulas to determine if using a more advanced formula can help offset the perceived sub-optimal measurements of the ultrasound biometry. Our study is different because it performed a mix-match analysis of same data source with different formulas and same formula with different sources of data. To the best of our knowledge, there has been no published study that comparing a contact and an optical biometer with at least two different IOL power formulas.

In our study, when using the same sources of AL and K but different IOL formulas, the mean absolute errors were not statistically different across all axial lengths. When using the IOL Master as the source of data, the absolute errors were not statistically different whether the Barrett or SRK/T formula was used. Similarly, when using the A-scan/keratometer as the source of data, there was no statistical difference between the absolute errors of the two formulas. Therefore, we found that the Barrett and SRK/T formulas have no statistically significant effect on absolute errors. Our study is different from a study by Kane et al. (2017), which reported that Barrett formula combined with IOL Master data was superior to SRK/T with IOL Master data in terms of absolute error.[15]

When we compared the IOL Master versus A-scan/keratometer data using the SRK/T formula, no significant difference in absolute error was found in the long and medium axial length eyes. Similarly, when we compared the IOL Master and A-scan/keratometer data using the Barrett formula, there was no statistically significant difference in absolute error. Therefore, the IOL Master seems to have no statistically significant superiority in terms of absolute error over the A-scan/keratometer as a source of data. This is consistent with studies by Aktas S. et al.[16] and Naicker P. et al.[17] which compared refractive outcomes of optical and ultrasound biometers using the same IOL formula. Another study comparing different sources of keratometry and the same IOL formula also found similar refractive outcomes between groups.[14]

An explanation was needed for why the IOL Master was not statistically better over the A-scan in terms of mean absolute error and mean prediction error. Perhaps the low number of eyes was partly the reason why statistical difference was not observed. Another plausible explanation can be seen from the scatterplots. The plots show that more results were off-target in the A-scan groups, but these were on both the myopic and hyperopic sides; therefore, they were cancelling each other out and making it appear like the means were closer to zero, especially in the predicted error analysis. This has led us to put more weight on the range of error and variance because these are measures of consistency or of how close the predicted refractions are to the actual refractive outcomes after a large number of surgeries. In our study, the variance of prediction error was better when IOL Master data were used compared to the A-scan/keratometer data, suggesting that outcomes are more consistent when the IOL Master data are utilized for IOL power calculation. When the IOL Master data were combined with Barrett formula, the scatterplot was the most compact and had the statistically lowest variance of prediction error. This was seen in both the monofocal (F = 0.04) and multifocal (F = 0.03) IOL groups. When the Barrett formula was applied to the A-scan/keratometry data, the predicted outcomes were not better and the variance was not smaller, compared to the outcomes and variance when the SRK/T formula was used on the A-scan data. Therefore, using a more advanced formula like the Barrett did not improve the consistency of outcomes if the source of the data was the A-scan and keratometer. The findings of this study are clinically relevant to surgeons selecting IOLs for cataract surgery because they provide a scientific basis to suggest that using IOL Master data does provide more consistent refractive targeting compared to using A-scan data. Going the extra step and combining the IOL Master data with the Barrett formula can make refractive outcomes even more consistent and therefore more predictable.

Another interesting finding is the prediction error showed a trend towards hyperopia in the monofocal group, whereas the trend was towards myopia in the multifocal group. This can possibly be explained by the selection pattern of the surgeon, who would rather veer towards hyperopia in monofocal IOLs to ensure good distance vision, but avoid a hyperopic outcome in the multifocal group so as not to negate the near vision gain when using a multifocal IOL.

The findings of the study emphasize how important axial length and keratometry measures are in predicting the results of refractive surgeries. By clarifying the effects of various assessment methods, we offer insightful information that can improve patient outcomes in clinical practice. The differences in refractive outcomes were clinically acceptable whether the IOL Master or A-scan/keratometer were used as the sources of axial length (AL), anterior chamber depth (ACD), and keratometry (K) values. However, our study suggests that obtaining the AL and K measurements from the IOL Master can result in better consistency of refractive outcomes. The variance was further decreased when the IOL power was calculated using the Barrett formula. It is therefore our recommendation that the axial length and keratometry data be obtained from the IOL Master data and incorporated into the Barrett formula to calculate IOL power, to achieve more consistent and predictable outcomes. Lastly, further investigations and advancements in measurement precision are warranted to continue refining surgical protocols and improving the efficacy of refractive interventions.

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