Comparison of ocular biometry and intraocular lens power using a new biometer and a standard biometer

Sabong Srivannaboon, MD, Chareenun Chirapapaisan, MD, Pratuangsri Chonpimai, BS, Sunisa Koodkaew, BS

PURPOSE: To compare the repeatability and reproducibility of ocular biometry and intraocular lens (IOL) power obtained with a new optical biometer (AL-Scan) and a standard optical biometer (IOLMaster 500).

SETTING: Siriraj Hospital, Mahidol University, Bangkok, Thailand.

DESIGN: Prospective comparative study.

METHODS: Two independent operators measured eyes with cataract using both biometers. The keratometry values, axial length, anterior chamber depth, white-to-white (WTW) corneal diameter, and IOL power calculated using the Holladay 1 formula obtained with each device were recorded. Intraoperator repeatability and interoperator reproducibility of both devices were analyzed using the intraclass correlation coefficient (ICC). The agreement in ocular biometry and IOL power between the 2 devices was evaluated by the Bland-Altman method.

RESULTS: The study recruited 137 eyes of 81 patients. The repeatability and reproducibility of both devices were high for all ocular biometry measurements (ICC, 0.87-1.00). Except for the WTW corneal diameter (ICC, 0.44), the agreement between the biometers was also high (ICC, 0.98-0.99). The IOL powers calculated by the Holladay 1 formula were similar between the 2 biometers.

CONCLUSION: The new optical biometer provided excellent repeatability and reproducibility for all ocular biometry. Agreement with the standard optical biometer was good except for the WTW corneal diameter.

Financial Disclosure: No author has a financial or proprietary interest in any material or method mentioned.

J Cataract Refract Surg 2014; 40:709–715 © *2014 ASCRS and ESCRS*

Ocular biometry is essential for intraocular lens (IOL) power calculation in cataract surgery. The biometric variables that are used for IOL calculation depend on the chosen IOL formula. Current third-generation and fourth-generation IOL formulas require the basic variables of keratometry (K) values and axial length (AL).[1,2] Some formulas may require additional variables, such as anterior chamber depth (ACD) or horizontal white-to-white (WTW) corneal diameter.[3] However, the accurate measurement of variables is crucial.

Unlike ultrasound (US) biometry, modern optical biometry devices measure several variables. Moreover, the built-in software in these devices provides more accurate IOL power calculation and multiple choices of IOL formulas.[4,5] The IOLMaster (Carl Zeiss Meditec AG) is considered to be one of the first standard modern optical biometry devices.[6] It uses the principle of partial coherence interferometry (PCI) to obtain the AL with high precision.[7–9] The device also measures the K values, ACD, and WTW diameter.[10] Several reports have shown the accuracy of the the newest version of IOLMaster (IOLMaster 500) for IOL calculation in routine and complicated cataract cases.[8,11–13]

Several new optical biometry devices can also perform ocular biometry and IOL power calculation.[14] Among them, the AL-Scan (Nidek Co., Ltd.) is one of the most recently released on the market. The device measures 6 variables, including the K value, AL,

0886-3350/$ - see front matter
http://dx.doi.org/10.1016/j.jcrs.2013.09.020

ACD, WTW diameter, pupil size, and central corneal thickness (CCT). The IOL power is generated by several formulas built into the device. To our knowledge, no study has evaluated the repeatability, reproducibility, and accuracy of this device.

The purpose of this study was to evaluate the repeatability, reproducibility of variables (eg, K, AL, ACD, horizontal WTW corneal diameter), and IOL power measured using the AL-Scan device and compare the results with those obtained with the IOLMaster 500 device.

PATIENTS AND METHODS

This prospective comparative study recruited cataract patients from Siriraj Eye Clinic, Bangkok, Thailand. Institutional ethic committee approval and patient informed consent were obtained. Eyes with ocular disease other than cataract were excluded.

The AL-Scan optical biometer (new biometer) measures K values using double-mire rings projected onto the cornea at the 2.4 mm zone and 3.3 mm zone. The Scheimpflug imaging technique is applied for CCT and ACD measurements. The AL is acquired by PCI.

The IOLMaster 500 optical biometer (standard biometer) measures K values using 6 spots of light projected onto the cornea at the central 2.5 mm zone. The ACD is measured by lateral slit illumination, and the AL is acquired by the PCI method.

The first operator took 3 consecutive measurements with each device (intraoperator repeatability). The patients were asked to close their eyes between each measurement. Then, the second operator took another measurement (interoperator reproducibility). Four major parameters (K value, AL, ACD, WTW) were recorded. The IOL power by the Holladay 1 formula from both devices was calculated using the IOL constant provided by the User Group for Laser Interference Biometry (ULIB) web site.[A]

Statistical analysis was performed using SPSS software (version 19.0, SPSS, Inc.). The data normality was checked with the Shapiro-Wilk test. The intraoperator repeatability was calculated using the 3 sets of the measurements taken by the first operator. For interoperator reproducibility, the first measurement of the first operator was selected and compared with the measurement of the second operator. The agreement between the 2 devices was also evaluated using the first measurement of the first operator for each device. An intraclass correlation coefficient (ICC) of more than 0.8 was acceptable as a high value.[15] The Pearson correlation was used to determine the relationship between all parameters. A statistically significant difference was defined as $P < .05$. Bland-Altman plots were used to assess the agreement of measurements between the 2 devices.

RESULTS

The study recruited 137 eyes of 81 patients. The mean age of patients was 65.28 years $\pm$ 10.56 (SD). Table 1 shows the values of 4 ocular parameters (K, AL, ACD, WTW) and the calculated IOL power obtained with the new biometer and the standard biometer. The mean value of all measurements, except the WTW distance, and the calculated IOL power showed a good correlation between the 2 devices.

Repeatability

The intraoperator repeatability of both devices was very good. The ICC of the new biometer and the standard biometer ranged from 0.94 to 1.00 (Table 2). For ACD, the new biometer produced a much lower mean difference with a small standard deviation (SD) than the standard biometer. In contrast, the WTW measurement of the new biometer had a slightly lower ICC and wider SD of the mean difference than the standard biometer.

Reproducibility

The interoperator reproducibility of both devices was good, which yielded a high ICC value for all parameters (Table 3). The new biometer produced slightly higher ICC values than the standard biometer for most parameters, especially for the ACD measurement. Moreover, the mean difference and SD of the ACD measurement by the new biometer was much smaller than by the standard biometer. However, the new biometer provided a lower ICC value than the standard biometer for WTW.

Agreement

The agreement of the ocular parameters derived from both biometry devices was high except for the WTW distance (Table 4). The mean difference and SD of the WTW parameter had the highest values of all parameters. However, the Bland-Altman plots showed that the limits of agreement (LoA) between the 2 biometers remained narrow over all parameters (Figures 1 to 5).

DISCUSSION

This study found that the AL-Scan biometer (new biometer) and the IOLMaster 500 biometer (standard biometer) had high repeatability and reproducibility for all tested parameters. The agreement between them was also very high except for the WTW parameter. The WTW diameter measured with the new

Submitted: May 6, 2013.
Final revision submitted: September 30, 2013.
Accepted: September 30, 2013.

From the Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand.

Corresponding author: Chareenun Chirapapaisan, MD, Department of Ophthalmology, Siriraj Hospital, Mahidol University, 2 Prannok Road, Bangkoknoi, Bangkok 10700, Thailand. E-mail: chareenun@gmail.com.

Table 1. Parameters obtained by the 2 optical biometers.

Parameter	New Biometer	Standard Biometer	*P* Value*	*r* Value
K 2.4 mm (D)				
Mean ± SD	44.31 ± 1.63	44.22 ± 1.60	<.05	0.994
Range	40.42, 47.31	40.52, 47.67		
K 3.3 mm (D)				
Mean ± SD	44.30 ± 1.64	NA	<.05	0.993
Range	40.26, 47.12			
AL (mm)				
Mean ± SD	23.51 ± 1.02	23.50 ± 1.02	.09	0.999
Range	21.18, 25.97	21.17, 25.94		
ACD (mm)				
Mean ± SD	3.11 ± 0.44	3.14 ± 0.43	<.05	0.970
Range	2.18, 4.06	2.35, 3.94		
WTW (mm)				
Mean ± SD	11.51 ± 0.75	12.03 ± 0.44	<.05	0.445
Range	8.70, 12.60	10.90, 12.90		
IOL power (D)				
Mean ± SD	20.33 ± 2.57	20.60 ± 2.60	<.05	0.995
Range	12.73, 25.51	13.15, 26.25		

ACD = anterior chamber depth; AL = axial length; IOL = intraocular lens; K = keratometry; NA = not applicable; *r* Value = Pearson correlation coefficient; WTW = white-to-white corneal diameter
*Statistically significant when $P < .05$

Table 2. Repeatability.

	Intraoperator Reproducibility					
		LoA			CL	
Parameter	Mean Difference* ± SD	Lower	Upper	ICC	Lower	Upper
K 2.4 mm (D)						
New biometer	0.000 ± 0.136	−0.271	0.271	0.999	0.998	0.999
Standard biometer	0.009 ± 0.091	−0.174	0.191	0.999	0.999	0.999
K 3.3 mm (D)						
New biometer	0.022 ± 0.180	−0.338	0.382	0.998	0.998	0.999
Standard biometer	NA	NA	NA	NA	NA	NA
AL (mm)						
New biometer	0.005 ± 0.017	−0.040	0.030	1.000	0.999	1.000
Standard biometer	0.005 ± 0.016	−0.037	0.026	1.000	0.999	1.000
ACD (mm)						
New biometer	0.003 ± 0.014	−0.025	0.032	0.999	0.999	0.999
Standard biometer	0.029 ± 0.106	−0.240	0.182	0.993	0.988	0.995
WTW (mm)						
New biometer	0.042 ± 0.584	−1.125	1.209	0.945	0.914	0.967
Standard biometer	0.087 ± 0.179	−0.272	0.445	0.974	0.959	0.984
IOL power (D)						
New biometer	0.020 ± 0.190	−0.361	0.400	0.999	0.999	0.999
Standard biometer	0.001 ± 0.108	−0.214	0.216	0.999	0.999	0.999

ACD = anterior chamber depth; AL = axial length; CL = confidence limit; ICC = intraclass correlation coefficient; IOL = intraocular lens; K = keratometry; LoA = 95% limits of agreement; NA = not applicable; WTW = white-to-white corneal diameter
*Mean difference between 2 measurements for each subject by same operator

Table 3. Reproducibility.

	Interoperator Reproducibility					
		LoA			CL	
Parameter	Mean Difference* ± SD	Lower	Upper	ICC	Lower	Upper
K 2.4 mm (D)						
New biometer	0.02 ± 0.13	−0.24	0.29	0.998	0.997	0.998
Standard biometer	0.00 ± 0.13	−0.25	0.26	0.998	0.997	0.999
K 3.3 mm (D)						
New biometer	0.04 ± 0.16	−0.27	0.35	0.997	0.996	0.998
Standard biometer	NA	NA	NA	NA	NA	NA
AL (mm)						
New biometer	−0.001 ± 0.05	−0.10	0.10	0.999	0.999	0.999
Standard biometer	−0.006 ± 0.05	−0.10	0.11	0.996	0.994	0.997
ACD (mm)						
New biometer	0.004 ± 0.01	−0.03	0.03	0.999	0.999	0.999
Standard biometer	−0.022 ± 0.10	−0.21	0.17	0.987	0.980	0.991
WTW (mm)						
New biometer	0.06 ± 0.50	−0.94	1.06	0.873	0.804	0.918
Standard biometer	−0.03 ± 0.20	−0.44	0.37	0.946	0.917	0.965
IOL power (D)						
New biometer	−0.04 ± 0.19	−0.42	0.34	0.998	0.997	0.999
Standard biometer	−0.003 ± 0.15	−0.31	0.30	0.991	0.998	0.999

ACD = anterior chamber depth; AL = axial length; CL = confidence limit; ICC = intraclass correlation coefficient; IOL = intraocular lens; K = keratometry; LoA = 95% limits of agreement; NA = not applicable; WTW = white-to-white corneal diameter
*Mean difference between 2 measurements for each subject by 2 operators

biometer was significantly smaller than that measured with the standard biometer, and there was low correlation between the measurements.

Today, ophthalmologists are gaining more accessibility to optical biometry devices. In a study of cataract surgery practice patterns in the United States Veterans Health Administration,[16] 83% of the respondents said they used PCI devices for preoperative biometry. At present, several optical biometry devices are used in clinical practice. However, different types of optical biometry devices may yield different IOL power results. Most IOL power calculations based on PCI technology use the IOL constant provided by the ULIB web site.[A] The web site currently provides the optimized IOL constant for 2 optical biometers only; that is, the IOLMaster and the Lenstar (Haag-Streit AG). A new device that uses the ULIB constant must be verified against the standard biometer. Therefore, we

Table 4. Agreement of each parameter between the new biometer and standard biometer.

	Agreement					
		LoA			CL	
Parameter	Mean Difference* ± SD	Lower	Upper	ICC	Lower	Upper
K 2.4 mm (D)	0.09 ± 0.18	−0.26	0.44	0.996	0.991	0.998
K 3.3 mm (D)	0.08 ± 0.20	−0.32	0.48	0.995	0.991	0.997
AL (mm)	0.01 ± 0.02	−0.04	0.05	0.999	0.998	0.999
ACD (mm)	−0.02 ± 0.11	−0.24	0.19	0.983	0.974	0.989
WTW (mm)	−0.51 ± 0.68	−1.87	0.84	0.448	−0.106	0.701
IOL power (D)	−0.26 ± 0.26	−0.74	0.22	0.994	0.947	0.998

ACD = anterior chamber depth; AL = axial length; CL = confidence limit; ICC = intraclass correlation coefficient; IOL = intraocular lens; K = keratometry; LoA = 95% limits of agreement; WTW = white-to-white corneal diameter
*Mean difference in each parameter measurement between new biometer and standard biometer

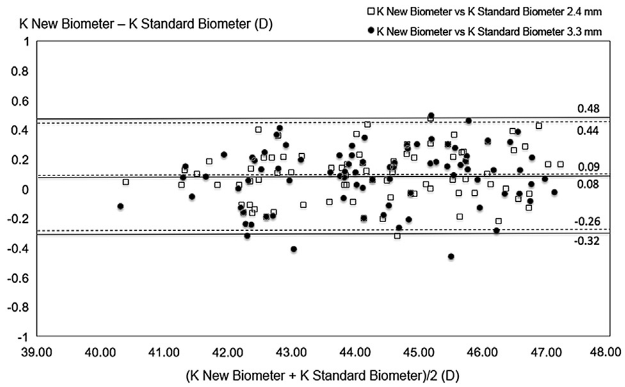

Figure 1. Agreement of K measurements between biometers. The *solid lines* show the mean difference and 95% LoA for K at the 2.4 mm zone. The *dashed lines* show the mean difference and 95% LoA for K at the 3.3 mm zone (K = keratometry).

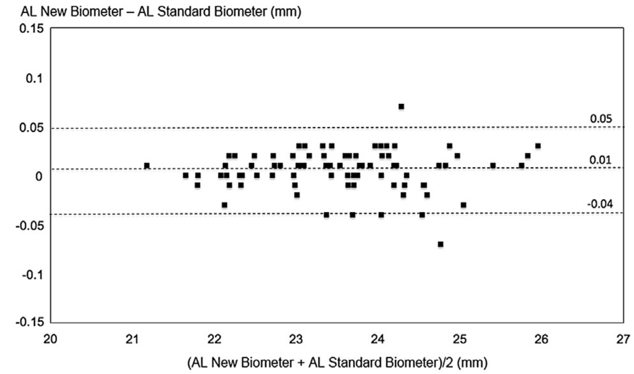

Figure 2. Agreement of AL measurements between biometers. The lines show the mean difference and 95% LoA (AL = axial length).

chose to validate the AL-Scan biometer using the IOLMaster 500 biometer. The parameters in this study (K, AL, ACD, WTW) were chosen for comparison because they are required by current third-generation and fourth-generation IOL formulas.[2,3,17] The new biometer measures the K value at 2 zone diameters (2.4 mm and 3.3 mm), while the standard biometer measures it at 2.5 mm only. The other parameters are measured similarly by the 2 devices.

In this study, all parameter measurements, except the WTW, were comparable between devices. The WTW from the IOLMaster device has been shown to be precise.[18,19] There had been no study of the WTW diameter measured by the AL-Scan device. The mean difference in the WTW measured by the 2 devices was 0.51 mm. The agreement and correlation between them was also low (ICC = 0.448 and r = 0.445, respectively). The explanation for this finding could be the difference in the algorithm for edge detection around iris image between the 2 devices. Furthermore, the dissimilarity in the light source for image acquisition between the devices could have a role. The AL-Scan device uses a green light source (wavelength 525 nm) to measure the WTW, whereas the IOLMaster device uses an infrared light source (wavelength 880 nm).[B,C] The infrared light source has been used in ophthalmic devices for eye tracking with high accuracy for decades.[20–22] The infrared light might be a better choice for the WTW measurement. Even though the repeatability and reproducibility of the WTW measured from the AL-Scan device were quite high (ICC 0.945 and ICC 0.873, respectively), they were lower than those with the IOLMaster 500 device (ICC 0.974 and ICC 0.946, respectively). Moreover, the SDs of the measurement difference in repeatability and reproducibility of the WTW measurement were higher for the AL-Scan device (0.58 and 0.50, respectively) than for the IOLMaster 500 device (0.17 and

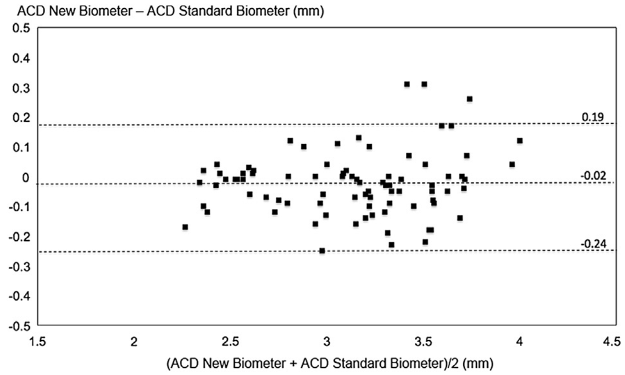

Figure 3. Agreement of ACD measurements between biometers. The lines show the mean difference and 95% LoA (ACD = anterior chamber depth).

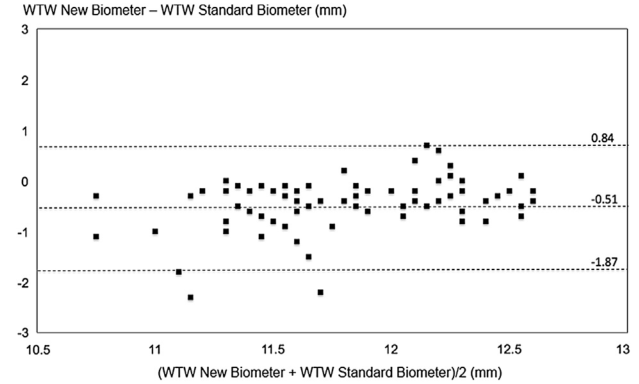

Figure 4. Agreement of WTW corneal diameter measurements between biometers. The lines show the mean difference and 95% LoA (WTW = white-to-white corneal diameter).

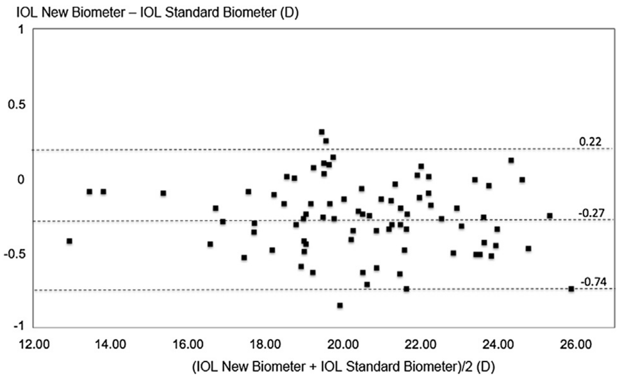

Figure 5. Agreement of IOL power measurements between biometers. The lines show the mean difference and 95% LoA (IOL = intraocular lens).

0.20, respectively). Therefore, the WTW measurement from the AL-Scan device should be used with caution.

The ACD measurement by both devices in this study was similar. However, the new biometer had slightly better repeatability and reproducibility. The mean difference and its SD were lower for the new biometer than for the standard biometer (repeatability 0.003 $\pm$ 0.014 versus 0.029 $\pm$ 0.106; reproducibility 0.004 $\pm$ 0.01 versus -0.022 ± 0.10). The LoA range was also lower for the new biometer. This finding could be the result of the Scheimpflug image principle used for the ACD measurement by the new biometer; the standard biometer uses a scanning-slit image. The measurement from the Scheimpflug image has been shown to have better repeatability than slit imaging, US biomicroscopy, and magnetic resonance imaging.[23,24] However, the ACD measured using a different method was considerably below a clinically significant level.

The IOL power (Holladay 1 formula) derived by both devices was quite similar, with good agreement and correlation. The mean difference was only 0.26 diopter (D), less than the increment in the IOL power step (0.50 D). Although both devices did not have a clinically significant impact on IOL power, the chosen IOL formula should be considered. If the WTW measurement is required in a formula, such as in the Holladay 2, the result might be different.

In the Bland-Altman plots, a few cases were not within the LoA. But in most cases, the difference between the 2 devices was considered not clinically significant. The maximum difference in K value was 0.48 D, in AL was 0.07 mm, in ACD was 0.3 mm, in WTW was 2.3 mm, and in IOL power was 0.78 D. In cases in which the difference in IOL power was more than 0.50 D, it was mainly the result of the difference in the K value.

This study was not intended to compare penetration through a dense cataract between the 2 devices. However, the 2 devices performed very similarly. In eyes in which the AL cannot be obtained by the IOLMaster 500 device, it cannot be obtained by the AL-Scan device either.

A limitation of this study might be both eyes of the some patients were enrolled. In this study, we recruited both eyes of 56 patients (112 eyes) and 1 eye of 25 patients. A previous study[25] discussed the bias effects of collecting the data from both eyes and comparing them with data from 1 eye. However, the aim of our study was to compare the performance of the 2 devices; thus, the data obtained from 1 eye or 2 eyes should not significantly affect the accuracy of either biometer.

In conclusion, the AL-Scan biometer performed very similarly to the IOLMaster 500 biometer. They both showed very high repeatability and reproducibility and were in good agreement with each other. The WTW measurement from the AL-Scan biometer should be further verified.

WHAT WAS KNOWN

- The standard device in the study is one of the most accurate PCI optical biometers and had high repeatability and reproducibility.

WHAT THIS PAPER ADDS

- The repeatability and reproducibility of the new PCI optical biometer was high.
- The accuracy of the new biometer was comparable to that of the standard biometer. In most cases, the mean ocular parameter values, repeatability, and reproducibility were similar between the 2 biometers.
- The WTW measurements were different between the 2 biometers. The results have to be verified. Therefore, the WTW distance derived from the new biometer should be used with caution.

REFERENCES

1. Lee AC, Qazi MA, Pepose JS. Biometry and intraocular lens power calculation. Curr Opin Ophthalmol 2008; 19:13–17
2. Joo J, Whang W-J, Oh T-H, Kang K-D, Kim H-S, Moon J-I. Accuracy of intraocular lens power calculation formulas in primary angle closure glaucoma. Korean J Ophthalmol 2011; 25:375–379. Available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3223703/pdf/kjo-25-375.pdf. Accessed November 28, 2013
3. Terzi E, Wang L, Kohnen T. Accuracy of modern intraocular lens power calculation formulas in refractive lens exchange for high

myopia and high hyperopia. J Cataract Refract Surg 2009; 35:1181–1189
4. Wang J-K, Chang S-W. Optical biometry intraocular lens power calculation using different formulas in patients with different axial lengths. Int J Ophthalmol 2013; 6:150–154. Available at http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3633751/pdf/ijo-06-02-150.pdf. Accessed November 28, 2013
5. Rabsilber TM, Jepsen C, Auffarth GU, Holzer MP. Intraocular lens power calculation: clinical comparison of 2 optical biometry devices. J Cataract Refract Surg 2010; 36:230–234
6. Sheng H, Bottjer CA, Bullimore MA. Ocular component measurement using the Zeiss IOLMaster. Optom Vis Sci 2004; 81:27–34. Available at http://journals.lww.com/optvissci/Fulltext/2004/01000/The_Contact_Lens_and_Myopia_Progression__CLAMP_.7.aspx. Accessed November 28, 2013
7. Vogel A, Dick HB, Krummenauer F. Reproducibility of optical biometry using partial coherence interferometry: intraobserver and interobserver reliability. J Cataract Refract Surg 2001; 27:1961–1968
8. Kunavisarut P, Poopattanakul P, Intarated C, Pathanapitoon K. Accuracy and reliability of IOL master and A-scan immersion biometry in silicone oil-filled eyes. Eye 2012; 26:1344–1348. Available at http://www.nature.com/eye/journal/v26/n10/pdf/eye2012163a.pdf. Accessed November 28, 2013
9. Fontes BM, Fontes BM, Castro E. Intraocular lens power calculation by measuring axial length with partial optical coherence and ultrasonic biometry. Arq Bras Oftalmol 2011; 74:166–170. Available at http://www.scielo.br/pdf/abo/v74n3/04.pdf. Accessed November 28, 2013
10. Fotedar R, Wang JJ, Burlutsky G, Morgan IG, Rose K, Wong TY, Mitchell P. Distribution of axial length and ocular biometry measured using partial coherence laser interferometry (IOL Master) in an older white population. Ophthalmology 2010; 117:417–423
11. Hsieh Y-T, Wang I-J. Intraocular lens power measured by partial coherence interferometry. Optom Vis Sci 2012; 89:1697–1701
12. Roessler GF, Dietlein TS, Plange N, Roepke A-K, Dinslage S, Walter P, Mazinani BA. Accuracy of intraocular lens power calculation using partial coherence interferometry in patients with high myopia. Ophthalmic Physiol Opt 2012; 32:228–233
13. Olsen T. Improved accuracy of intraocular lens power calculation with the Zeiss IOLMaster. Acta Ophthalmol Scand 2007; 85:84–87. Available at http://onlinelibrary.wiley.com/doi/10.1111/j.1600-0420.2006.00774.x/pdf. Accessed November 28, 2013
14. Chen Y-A, Hirnschall N, Findl O. Evaluation of 2 new optical biometry devices and comparison with the current gold standard biometer. J Cataract Refract Surg 2011; 37:513–517
15. Rosner B. Fundamentals of Biostatistics, 5th ed. Pacific Grove, CA, Duxbury Press, 2000; 562–563
16. Greenberg PB, Havnaer A, Oetting TA, Garcia-Ferrer FJ. Cataract surgery practice patterns in the United States Veterans Health Administration. J Cataract Refract Surg 2012; 38:705–709
17. Hoffer KJ. Clinical results using the Holladay 2 intraocular lens power formula. J Cataract Refract Surg 2000; 26:1233–1237
18. Baumeister M, Terzi E, Ekici Y, Kohnen T. Comparison of manual and automated methods to determine horizontal corneal diameter. J Cataract Refract Surg 2004; 30:374–380
19. Kiraly L, Duncker G. Biometrie des vorderen Augensegmentes zur Implantation phaker Vorderkammerlinsen. Ein Vergleich aktueller Messgeräte [Biometry of the anterior eye segment for implantation of phakic anterior chamber lenses. A comparison of current measurement devices]. Ophthalmologe 2012; 109:242–249
20. Okuyama F, Tokoro T, Fujieda M. Eye-tracking infra-red optometer. Ophthalmic Physiol Opt 1990; 10:291–299
21. Pruehsner W, Enderle JD. Eye tracker. Biomed Sci Instrum 1999; 35:235–240
22. Fassi A, Riboldi M, Forlani CF, Baroni G. Optical eye tracking system for noninvasive and automatic monitoring of eye position and movements in radiotherapy treatments of ocular tumors. Appl Opt 2012; 51:2441–2450
23. Wolffsohn JS, Davies LN. Advances in anterior segment imaging. Curr Opin Ophthalmol 2007; 18:32–38
24. Koretz JF, Strenk SA, Strenk LM, Semmlow JL. Scheimpflug and high-resolution magnetic resonance imaging of the anterior segment: a comparative study. J Opt Soc Am A Opt Image Sci Vis 2004; 21:346–354
25. Armstrong RA. Statistical guidelines for the analysis of data obtained from one or both eyes. Ophthalmic Physiol Opt 2013; 33:7–14. Available at http://onlinelibrary.wiley.com/doi/10.1111/opo.12009/pdf. Accessed November 28, 2013

OTHER CITED MATERIAL

A. User Group for Laser Interference Biometry. Available at: http://www.augenklinik.uni-wuerzburg.de/ulib/. Accessed November 28, 2013
B. Carl Zeiss Meditec AG. IOLMaster with Advanced Technology, User Manual, 2009; 135. Available at: http://www.doctor-hill.com/physicians/docs/iolmaster_5-4.pdf. Accessed November 28, 2013
C. Nidek Co., Ltd. Optical Biometer AL-Scan, operator's manual, 2012; 220

First author:
Sabong Srivannaboon, MD

Faculty of Medicine, Siriraj Hospital, Mahidol University, Bangkok, Thailand