ARTICLE

Scheimpflug–Placido topographer and optical low-coherence reflectometry biometer: Repeatability and agreement

Wuhe Chen, MD, Colm McAlinden, PhD, Konrad Pesudovs, PhD, Qinmei Wang, MD, Fan Lu, MD, OD, Yifan Feng, MD, MS, Jie Chen, MD, MS, Jinhai Huang, MD, MS

PURPOSE: To assess the repeatability of common measurements with the Sirius Scheimpflug–Placido topographer and Lenstar LS900 optical low-coherence reflectometry (OLCR) biometer and the limits of agreement (LoA) between the devices.

SETTING: Eye Hospital of Wenzhou Medical College, Wenzhou, China.

DESIGN: Comparative evaluation of a diagnostic test or technology.

METHODS: One randomly healthy eye of subjects was scanned 3 times with both devices. The parameters assessed were central corneal thickness (CCT), anterior chamber depth (ACD) from the corneal epithelium and from the endothelium, mean keratometry (K), and white-to-white (WTW) corneal diameter. The repeatability of scans was calculated using the within-subject standard deviation after 1-way analysis of variance was performed. The agreement between devices was assessed using the Bland-Altman LoA method, which equals the mean difference between devices $\pm$ 1.96 $\times$ standard deviation of the differences. The mean of 3 scans of each device was used to assess the LoA.

RESULTS: Forty subjects were evaluated. The repeatability of the Scheimpflug–Placido topographer and OLCR biometer was 3.10 μm and 3.32 μm for CCT, 0.04 mm and 0.05 mm for WTW corneal diameter, and 0.17 D and 0.10 D for mean K, respectively. The repeatability for both devices was 0.02 mm for the ACD from the corneal epithelium and the ACD from the corneal endothelium. On Bland-Altman LoA analysis, all parameters were within clinically acceptable limits.

CONCLUSION: Both devices had excellent repeatability for all parameters assessed. Good LoAs were found between the 2 devices, indicating they can be used interchangeably for the parameters assessed.

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

J Cataract Refract Surg 2012; 38:1626–1632 © 2012 ASCRS and ESCRS

The precision of ocular biometric measurements of the eye has become increasingly relevant in ophthalmic practice. This is particularly true in the field of cataract and refractive surgery because of the reliance on such devices as diagnostic and management tools.[1–3]

The Sirius (Costruzione Strumenti Oftalmici) is a combined Scheimpflug camera and Placido-disk topography device that measures a range of anterior segment parameters, such as central corneal thickness (CCT), anterior chamber depth (ACD), lens thickness, keratometry (K), and white-to-white (WTW) corneal diameter. Recent studies[4,5] have found this device to be repeatable for corneal power, asphericity, lens thickness, spherical aberration, ACD, and anterior chamber volume (ACV).

The Lenstar LS900 (Haag-Streit AG) is a new optical low-coherence reflectometry (OLCR) ocular biometry device. A single noncontact measurement simultaneously provides up to 9 biometric assessments, including CCT, ACD, lens thickness, axial length (AL), retinal thickness, K values, WTW, pupillometry, and eccentricity of the visual axis relative to the optical axis. This device has also been found to provide repeatable and reproducible measurements.[6,7]

However, it is not known whether the values obtained with these 2 devices are comparable and

Published by Elsevier Inc.

0886-3350/$ - see front matter
doi:10.1016/j.jcrs.2012.04.031

can be used interchangeably. The purpose of this study was to assess the repeatability of common measurements of the 2 devices and to assess the limits of agreement (LoA) between devices to ascertain whether they can be used interchangeably.

SUBJECTS AND METHODS

Healthy subjects were invited to take part in this prospective study. Exclusion criteria were a history of corneal pathology, contact lens use, previous ocular surgery, and other anterior segment abnormalities. The Review Board of Wenzhou Medical College approved the study, which was performed according to the tenets of the Declaration of Helsinki for research involving human subjects. All subjects were informed about the study and signed an informed consent document.

Measurement Technique

One eye of each subject was randomly chosen (fair coin toss) and measured sequentially, first with the Sirius Scheimpflug–Placido topographer and then with the Lenstar LS900 OLCR biometer. Three consecutive scans were performed with each device by the same experienced examiner. All measurements were performed without pupil dilation. Subjects were positioned with a headrest and instructed to fixate on an internal fixation device with the temporal lid canthus of the right eye and left eye aligned to the markers on the holding bars of the headrest. Subjects were asked to blink just before measurements were acquired to spread an optically smooth tear film over the cornea. Scans that were substandard because of blinking or eye movements were discarded and repeated.

The Lenstar biometer uses an OLCR technique with coherent superposition of light waves to measure distances within the eye in a technique similar to that used with optical coherence tomography (OCT). It uses 820 μm superluminescent diodes for measurements of AL, CCT, ACD, lens thickness, and retinal thickness. The optical-path-length measurements are aligned on the subject's visual axis. The device uses a 950 nm light-emitting diode (LED) for K and WTW distance measurements. Corneal radius of curvature measurements are produced based on image analysis of a mire of constant size reflected from the anterior surface of the cornea. Corneal radius measurements in the flat meridian and steep meridian are acquired by analyzing a pattern of 32 projected lights that are arranged on 2 rings of 1.65 mm and 2.30 mm diameter with 16 measuring points each. For each measurement, the corneal curvatures are measured in 2 meridia and the 2 readings are averaged. The WTW is obtained by fitting the best circle with the lowest error square to the detected edge. The instrument takes 16 consecutive scans per measurement without the need for realignment in a single shot.

The Sirius system is a new topography device that combines a monochromatic 360-degree rotating Scheimpflug camera and a Placido disk to analyze the anterior segment by obtaining 25 radial sections of the cornea and anterior chamber. In a single scan, it provides tangential and axial curvature data of the anterior and posterior corneal surfaces, the global refractive power of the cornea, a biometric estimation of various structures, complete corneal pachymetry, and wavefront analysis. A 475 nm blue LED light is used to measure 35 632 points for the anterior corneal surface and 30 000 for the posterior cornea. A pachymetric map is then reconstructed using the point-by-point anterior and posterior corneal surface data. In this study, CCT, ACD, mean K, and WTW were used for analysis. The system provides K values along the flattest meridian as well as the K value in the steepest meridian. The mean K is calculated from the flattest and steepest meridian keratometry readings. Each measurement consists of 25 consecutive scans in a single shot.

For calculating ACD, both devices can measure the distance from the corneal endothelium to the anterior lens capsule, which was defined for this study as the ACD from the corneal endothelium, and the distance from the corneal epithelium to the anterior lens capsule (traditional ACD), which was defined as the ACD from the corneal epithelium.[6]

Statistical Analysis

The measurements derived from both methods were entered and analyzed using SPSS software (version 13.0, SPSS, Inc.). The normality of all anatomic data distributions was confirmed with the Kolmogorov-Smirnov test, and parametric statistical tests were used for data analyses.

Repeatability of the 3 repeated measurements for each device was assessed using the within-subject standard deviation (S_w), derived after a 1-way analysis of variance was performed. The repeatability limit is reported as $1.96\sqrt{2} \times S_w$, which gives the likely limits within which 95% of measurements should occur.[8]

The mean data of 3 scans of each device was used to evaluate the agreement between the 2 systems. The agreement between the two systems was assessed using the Bland-Altman LoA method. Using this method, graphs were created showing the differences between the 2 devices plotted against the mean values of the 2 devices. The difference between the 2 methods was displayed on the y-axis, with the mean value of the methods displayed on the x-axis. The 95% LoA were calculated as the mean difference in measurements from the 2 devices $\pm$ 1.96 $\times$ standard deviation (SD) of the differences.[9]

RESULTS

Forty eyes of 40 subjects were included in the study. The mean age of the 24 men and 16 women was

Submitted: January 16, 2012.
Final revision submitted: March 22, 2012.
Accepted: April 16, 2012.

From the School of Optometry and Ophthalmology and Eye Hospital (W. Chen, Wang, Lu, Feng, J. Chen, Huang), Wenzhou Medical College, Wenzhou, Zhejiang, China; NH&MRC Centre for Clinical Eye Research (McAlinden, Pesudovs), Department of Optometry and Vision Science, Flinders Medical Centre and Flinders University of South Australia, Adelaide, South Australia, Australia.

Supported in part by the Foundation of Wenzhou City Science & Technology Bureau (Y20110045; Dr. Huang); innovative project of School of Optometry and Ophthalmology and Eye Hospital, Wenzhou Medical College (YNCX201101, YNKT201101; Dr. Huang); and the Health Bureau of Zhejiang Provence (2012KYB135; Dr. Huang).

Corresponding author: Jinhai Huang, MD, MS, Eye Hospital of Wenzhou Medical College, 270 West Xueyuan Road, Wenzhou, Zhejiang 325027, China. E-mail: viphjh@hotmail.com.

24.58 years ± 3.67 (SD) (range 18 to 37 years). The mean spherical equivalent refraction was −5.05 ± 2.32 diopters (D) (range −0.50 to −9.875 D).

Repeatability

Table 1 shows the repeatability and repeatability limits for both devices. The repeatability of the CCT, ACD from the corneal endothelium, ACD from the corneal epithelium, WTW, and mean K for the 2 devices were excellent.

Agreement

Table 2 shows the mean difference, SD, and 95% LoA between the 2 devices. The CCT, ACD from the corneal endothelium, ACD from the corneal epithelium, and K measurements taken with the Scheimpflug–Placido topographer were statistically significantly higher than those taken with the OLCR biometer ($P<.01$). However, the Scheimpflug–Placido topographer significantly underestimated the WTW value compared with the OLCR biometer ($P<.001$). Bland-Altman plots (Figures 1 to 5) showed that the mean differences between the 2 devices were not significantly different from zero for the comparison of all parameters. All measurements showed a narrow 95% LoA, which implies good agreement.

DISCUSSION

At present, contact ultrasound (US) is the most widely used for measuring axial intraocular distances such as CCT and ACD, and it is regarded as the standard. However, US is a contact technique and requires the use of topical anesthesia, which leads to patient discomfort and a small risk for corneal infection.[10] Furthermore, this clinical procedure is highly dependent on the examiner's experience or skill and the patient's cooperation. These disadvantages have led to the development of noninvasive, noncontact devices. Currently available ocular anterior segment topography systems have been developed rapidly because of the increasing interest in corneal refractive surgery and refractive phakic intraocular lens (IOL) implantation techniques. For a new instrument to gain widespread use, it must provide measurements that have high repeatability and are in agreement with other currently established methods. The aim of the present study was to evaluate the repeatability of anterior segment measurements with a topography system (Sirius) that combines Scheimpflug photography and Placido-disk technologies as well as the agreement with those obtained with the Lenstar LS900 OLCR biometer. This study found that all measurements assessed, including the CCT, ACD from the corneal endothelium, ACD from the corneal epithelium, mean K value, and WTW corneal diameter, were very repeatable for both devices. Regarding the agreement between devices, all parameters were within acceptable limits, indicating that the devices could be used interchangeably for the parameters assessed.

Savini et al.[4] assessed the repeatability of the Sirius Scheimpflug–Placido device in 3 groups of patients: healthy eyes (n = 64), eyes after myopic refractive surgery (n = 17), and eyes with keratoconus (n = 13). They found the device provided repeatable measures of anterior and posterior corneal power, corneal thickness, ACD, ACV, corneal asphericity, and to a lesser extent, spherical aberration. These findings are in agreement with those in the present study for the common parameters assessed. Milla et al.[5] assessed the repeatability of pachymetric measurements obtained with a Scheimpflug–Placido device (Sirius) in 18 healthy subjects and found excellent repeatability of CCT measurements, which is in line with the results in the present study.

Table 1. The repeatability and repeatability limits for measurements obtained with the Scheimpflug–Placido topographer and the OLCR biometer.

	Repeatability (Repeatability Limit)	
Parameter	Scheimpflug–Placido Topographer	OLCR Biometer
CCT (μm)	3.10 (8.59)	3.32 (9.18)
ACDendo (mm)	0.02 (0.07)	0.02 (0.05)
ACDepi (mm)	0.02 (0.07)	0.02 (0.05)
WTW (mm)	0.04 (0.10)	0.05 (0.15)
Km (D)	0.17 (0.46)	0.10 (0.26)

ACDendo = anterior chamber depth from the corneal endothelium; ACDepi = anterior chamber depth from the corneal epithelium; CCT = central corneal thickness; Km = mean keratometry; OLCR = optical low-coherence reflectometry; WTW = white to white

Table 2. The mean difference, LOA, paired *t* test for the differences, and their significance between the Scheimpflug–Placido topographer and the OLCR biometer.

Parameter	Mean Difference ± SD	*P* Value*	95% LoA
CCT (μm)	−4.29 ± 5.69	<.001	−15.43. 6.85
ACDendo (mm)	−0.09 ± 0.06	<.001	−0.21. 0.03
ACDepi (mm)	−0.10 ± 0.06	<.001	−0.22. 0.02
Km (D)	−0.06 ± 0.12	.004	−0.29. 0.18
WTW(mm)	0.11 ± 0.15	<.001	−0.19. 0.41

ACDendo = anterior chamber depth from the corneal endothelium; ACDepi = anterior chamber depth from the corneal epithelium; CCT = central corneal thickness; Km = mean keratometry; LoA = limits of agreement; WTW = corneal diameter (white to white)
*Two tailed

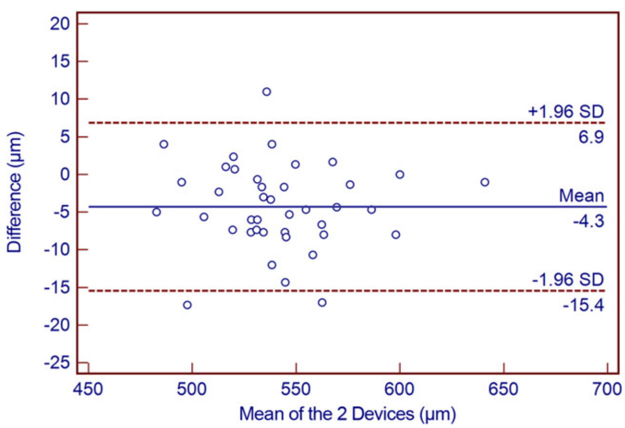

Figure 1. Comparison of the CCT readings between the Scheimpflug−Placido topograper and the optical biometer (Bland-Altman plot). The solid line represents the mean difference. The dotted lines represent the upper and lower 95% confidence interval LoA (Difference = optical low-coherence reflectometry biometer − Scheimpflug−Placido topographer).

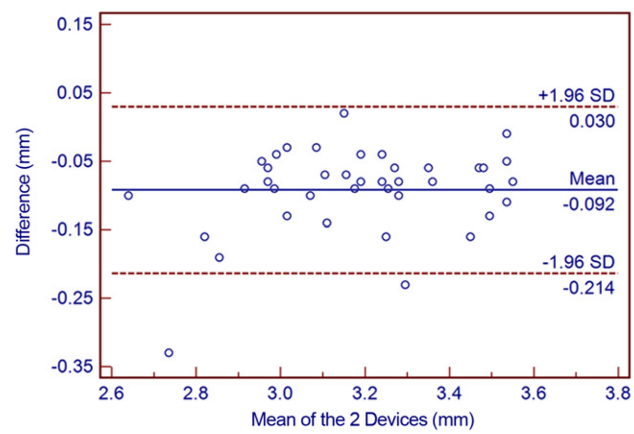

Figure 2. Comparison of the ACD from the corneal epithelium readings between the Scheimpflug−Placido topographer and the optical biometer (Bland-Altman plot). The solid line represents the mean difference. The dotted lines represent the upper and lower 95% confidence interval LoA (Difference = optical low-coherence reflectometry biometer − Scheimpflug−Placido topographer).

Regarding the repeatability of anterior segment measures with the Lenstar OLCR biometer, Cruysberg et al.[11] assessed the repeatability of 3 repeated measures in 76 healthy eyes; they report excellent repeatability for CCT, ACD, and WTW corneal diameter. Buckhurst et al.[12] studied the repeatability and reproducibility (change in time) of the Lenstar OLCR biometer. Five repeated measures were acquired to assess repeatability in 112 subjects awaiting cataract surgery. Similar to the present study, the CCT, ACD, and WTW corneal diameter parameters were very repeatable. Şahin et al.[13] also report good repeatability and reproducibility with the Lenstar OLCR biometer for CCT and ACD measurements in a group of children. These findings are consistent with those in the present study.

In addition, several studies have compared this technology with US, scanning-slit, or partial coherence interferometry (PCI)–based devices, with results showing an excellent correlation. Gursoy et al.[14] assessed the agreement in CCT and ACD measurements between the Lenstar OLCR biometer and A-scan contact US in the right eyes of 565 children. They found good agreement for both parameters, indicating the

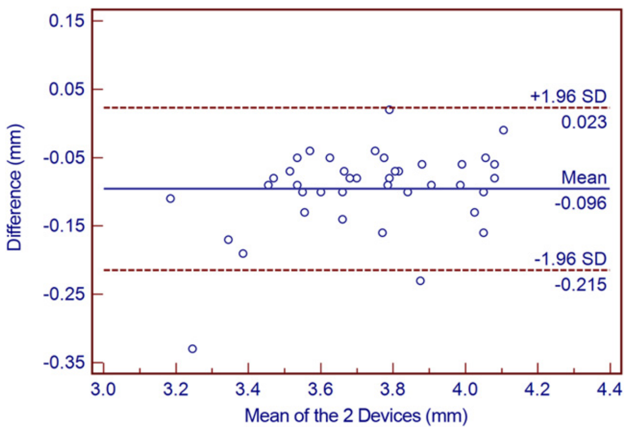

Figure 3. Comparison of the ACD from the corneal endothelium between the Scheimpflug−Placido topographer and the optical biometer (Bland-Altman plot). The solid line represents the mean difference. The dotted lines represent the upper and lower 95% confidence interval LoA (Difference = optical low-coherence reflectometry biometer − Scheimpflug−Placido topographer).

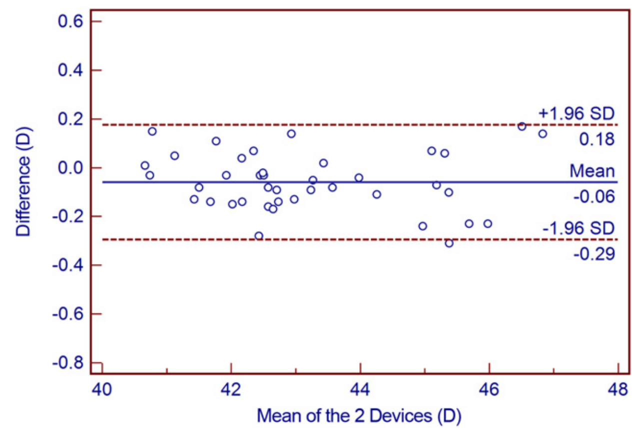

Figure 4. Comparison of the WTW corneal diameter reading readings between the Scheimpflug−Placido topographer and the optical biometer (Bland-Altman plot). The solid line represents the mean difference. The dotted lines represent the upper and lower 95% confidence interval LoA (Difference = optical low-coherence reflectometry biometer − Scheimpflug−Placido topographer).

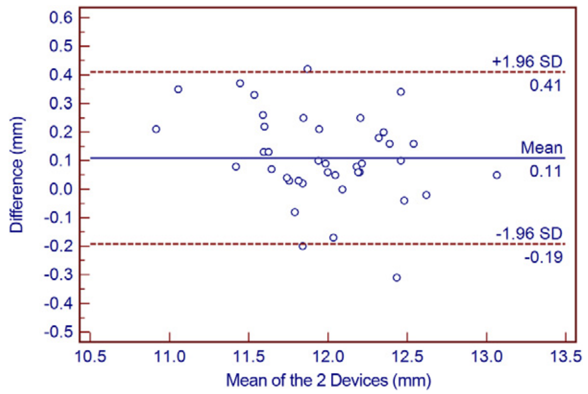

Figure 5. Comparison of the mean K readings between the Scheimpflug−Placido topographer and the optical biometer (Bland-Altman plot). The solid line represents the mean difference. The dotted lines represent the upper and lower 95% confidence interval LoA (Difference = optical low-coherence reflectometry biometer − Scheimpflug−Placido topographer).

devices can be used interchangeably. Huang et al.[6] compared the Pentacam Scheimpflug scanning-slit topographer (Oculus, Inc.) and Lenstar OLCR biometer pachymetry measurements and found good concordance between the 2 devices, with a mean difference of 3.7 μm. Chen et al.[15] compared the Lenstar OLCR biometer and the IOLMaster PCI device (Carl Zeiss Meditec) in 336 eyes with cataract. They found the mean K reading was significantly flatter with the Lenstar device. Mylonas et al.[16] found significantly greater ACD measurements with the Visante anterior segment OCT (AS-OCT) device (Carl Zeiss Meditec AG) than with the Lenstar biometer in 51 eyes. Salouti et al.[17] found an acceptable level of agreement in K and ACD measurements between the Lenstar device, IOLMaster device, and A-scan contact US. Tappeiner et al.[18] also report good agreement between CCT and ACD measurements with the Lenstar device and contact US.

We also evaluated the agreement of the biometric measurements between the Sirius Scheimpflug–Placido topographer and the Lenstar LS900 OLCR biometer and found all parameters to be clinically interchangeable. To our knowledge, this is the first study to compare the 2 devices. Milla et al.[5] compared the agreement in pachymetry measures between the Sirius topographer and the Visante AS-OCT system in 18 eyes. Corneal thickness was measured at 6 locations on the cornea with both devices. Poor agreement was found, indicating that the 2 devices cannot be used interchangeably. The authors speculate that the tear film might have played a role in the discrepancies between Scheimpflug and OCT techniques. In the present study, there was good agreement between Sirius Scheimpflug–Placido photography and Lenstar OLCR biometer in CCT values, with narrow 95% LoA (range 6.85 to −15.43 μm). For CCT measurements, the 95% LoA using a single Scheimpflug imaging system, noncontact specular microscope (EM-3000, Tomey Corp.), and combined scanning-slit and Placido-disk topographer (Orbscan II, Bausch & Lomb) were reported to be −9.2 to 9.5 μm, −25.13 to 18.06 μm, and −32.1 to 26.4 μm, respectively.[19–21] In addition, Alió and Piñero[22] found a significant corneal flap thickness variation after laser in situ keratomileusis of −9 μm to 37 μm, −12 μm to 31 μm, −9 μm to 23 μm using the M2 microkeratome (Moria), the Carriazo-Pendular microkeratome (Schwind Eye-Tech-Solutions GmbH & Co. KG), and the Intralase femtosecond laser (Abbott Medical Optics, Inc.), respectively. A meta-analysis showed the SD of the CCT in normal eyes is 31 μm.[23] The discrepancy in CCT measurement between the Lenstar OLCR biometer and the Sirius Scheimpflug–Placido topographer was much smaller than these variations and clinically irrelevant, indicating the measurements with the 2 devices can be used interchangeably for most practical purposes.

Savini et al.[4] recently assessed the agreement between 3 Scheimpflug devices (1 of which was the Sirius) and a Placido-disk topographer in 25 healthy eyes. They found the following parameters and devices to be clinically interchangeable: simulated K readings with the Sirius and Pentacam; posterior corneal power with the Sirius, Pentacam, and TMS-5 (Tomey Corp.); ACD with the Sirius and Pentacam; and Q values (corneal asphericity) with the Sirius, Pentacam, and Keratron (Optikon 2000 SpA). In the present study, we evaluated the agreement between the Sirius and Lenstar ACD measurements in both modes (ACD from the corneal endothelium and ACD from the corneal epithelium) separately. The ACD from the corneal endothelium and the ACD from the corneal epithelium values obtained with the Sirius device were slightly, but significantly, deeper than those obtained with Lenstar device. The Lenstar biometer detects the anterior and posterior corneal and anterior crystalline lens peaks in the OLCR waveform, while the Sirius topographer uses image analysis to measure ACD. The use of distinct methodologies in each device might induce this tendency. However, IOL power varies by 0.05 D for each 0.1 mm of ACD; thus, the differences (0.09 mm and 0.10 mm, respectively) were too small to create a noticeable difference in refractive outcome. In addition, Bland-Altman plot analysis showed narrow 95% LoA (range −0.11 to −0.07 mm and −0.12 to −0.08 mm, respectively), which is comparable to the reliability of A-scan US and OLCR biometry, for which the respective 95% LoA were reported to be −0.32 to 0.26 mm and −0.11 to 0.14 mm.[24,25] These findings indicate good agreement in ACD measurements between devices.

Both the Sirius topographer and Lenstar biometer use image analysis to obtain K values by converting the measured radius into diopters using the standard 1.3375 refractive index. The mean K reading from the 3 devices was similar, with a mean difference of 0.06 D. Bland-Altman analysis showed narrow LoA. The Scheimpflug–Placido topographer could be expected to measure as much as 0.29 D above to 0.18 D below the OLCR biometer for K, which is comparable to the reliability of the Pentacam single Scheimpflug imaging system and Keratron corneal topographer (−0.56 to 0.49 D and −0.50 to 0.33 D, respectively).[26] In addition, an error of 0.1 D in K values is equivalent to a refractive error of approximately 0.1 D,[6,27] which is acceptable and means that the 2 instruments can be used interchangeably.

Salouti et al.[28] compared WTW measurements from the Galilei dual Scheimpflug–Placido topographer (Ziemer), Orbscan II scanning-slit topographer, and Eyesys Placido topographer (Eyesys Laboratories, Inc.) in eyes with cataract. They found that the Galilei and Eyesys measurements were larger than those obtained with the Orbscan II device, with a mean difference of 0.38 mm and 0.42 mm, respectively. The authors suggest that the use of different methodologies and the different ways each device "defines" the limbus may be a partial explanation. We evaluated agreement of WTW measurements between these 2 instruments. The discrepancy in WTW readings (0.11 mm) obtained with the 2 devices was small and clinically irrelevant. In addition, Bland-Altman analysis showed narrow 95% LoA (range −0.19 to 0.41 mm), which was better than the reproducibility using the OLCR biometer (−1.13 to 1.05 mm),[25] suggesting the WTW measurements from the 2 devices can be used interchangeably.

One potential limitation of this study is that measurements were acquired from healthy subjects with normal corneas. This population was chosen because the aim of this study was to evaluate and compare anterior ocular segment measurements using Sirius Scheimpflug–Placido photography and the new Lenstar OLCR ocular biometry device in normal subjects with good vision and fixation. Further studies are needed to compare the repeatability and agreement of measurements in patients with conditions such as keratoconus, ocular hypertension, and cataract.

In conclusion, the Sirius Scheimpflug–Placido topographer and Lenstar LS900 OLCR biometer provided excellent repeatable estimates for all measurements assessed, including the CCT, ACD from the corneal endothelium, ACD from the corneal epithelium, mean K, and WTW corneal diameter. Good LoA were found between the 2 devices, indicating they can be used interchangeably for the parameters assessed.

WHAT WAS KNOWN

- High accuracy and precision in the measurements of ocular biometric parameters has become increasingly relevant in ophthalmic practice. Recent studies have found a new combined single Scheimpflug–Placido topographer (Sirius) and a new OLCR biometer (Lenstar) provided reliable anterior segment measurements.

WHAT THIS PAPER ADDS

- This is the first controlled study showing that the 2 devices provide excellent repeatability for CCT, ACD, keratometry, and WTW corneal distance measurements within the same subjects.
- The 2 devices showed good agreement between the noninvasive anterior segment measurements in normal eyes and can be used interchangeably.

REFERENCES

1. Visser N, Berendschot TTJM, Verbakel F, Tan AN, de Brabander J, Nuijts RMMA. Evaluation of the comparability and repeatability of four wavefront aberrometers. Invest Ophthalmol Vis Sci 2011; 52:1302–1311. Available at: http://www.iovs.org/content/52/3/1302.full.pdf. Accessed May 22, 2012
2. McAlinden C, Khadka J, Pesudovs K. A comprehensive evaluation of the precision (repeatability and reproducibility) of the Oculus Pentacam HR. Invest Ophthalmol Vis Sci 2011; 52:7731–7737. Available at: http://www.iovs.org/content/52/10/7731.full.pdf. Accessed May 22, 2012
3. Atchison DA, Mathur A, Read SA, Walker MI, Newman AR, Tanos PP, McLennan RT, Tran AH. Peripheral ocular aberrations in mild and moderate keratoconus. Invest Ophthalmol Vis Sci 2010; 51:6850–6857. Available at: http://www.iovs.org/content/51/12/6850.full.pdf. Accessed May 22, 2012
4. Savini G, Carbonelli M, Sbreglia A, Barboni P, Deluigi G, Hoffer KJ. Comparison of anterior segment measurements by 3 Scheimpflug tomographers and 1 Placido corneal topographer. J Cataract Refract Surg 2011; 37:1679–1685
5. Milla M, Piñero DP, Amparo F, Alió JL. Pachymetric measurements with a new Scheimpflug photography-based system; intraobserver repeatability and agreement with optical coherence tomography pachymetry. J Cataract Refract Surg 2011; 37:310–316
6. Huang J, Pesudovs K, Wen D, Chen S, Wright T, Wang X, Li Y, Wang Q. Comparison of anterior segment measurements with rotating Scheimpflug photography and partial coherence reflectometry. J Cataract Refract Surg 2011; 37:341–348
7. Rohrer K, Frueh BE, Wälti R, Clemetson IA, Tappeiner C, Goldblum D. Comparison and evaluation of ocular biometry using a new noncontact optical low-coherence reflectometer. Ophthalmology 2009; 116:2087–2092
8. McAlinden C, Khadka J, Pesudovs K. Statistical methods for conducting agreement (comparison of clinical tests) and precision (repeatability or reproducibility) studies in optometry and ophthalmology. Ophthalmic Physiol Opt 2011; 31:330–338. Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1475-1313.2011.00851.x/pdf. Accessed May 22, 2012
9. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet

1986; 1:307–310. Available at: http://www-users.york.ac.uk/~mb55/meas/ba.pdf. Accessed May 22, 2012
10. Spadea L, Giammaria D, Di Genova L, Fiasca A. Comparison of optical low coherence reflectometry and ultrasound pachymetry in the measurement of central corneal thickness before and after photorefractive keratectomy. J Refract Surg 2007; 23:661–666
11. Cruysberg LPJ, Doors M, Verbakel F, Berendschot TTJM, De Brabander J, Nuijts RMMA. Evaluation of the Lenstar LS 900 non-contact biometer. Br J Ophthalmol 2010; 94:106–110
12. Buckhurst PJ, Wolffsohn JS, Shah S, Naroo SA, Davies LN, Berrow EJ. A new optical low coherence reflectometry device for ocular biometry in cataract patients. Br J Ophthalmol 2009; 93:949–953
13. Şahin A, Gürsoy H, Başmak H, Yildirim N, Usalp Z, Çolak E. Reproducibility of ocular biometry with a new noncontact optical low-coherence reflectometer in children. Eur J Ophthalmol 2011; 21:194–198
14. Gursoy H, Sahin A, Basmak H, Ozer A, Yıldırım N, Colak E. Lenstar versus ultrasound for ocular biometry in a pediatric population. Optom Vis Sci 2011; 88:912–919
15. 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
16. Mylonas G, Sacu S, Buehl W, Ritter M, Georgopoulos M, Schmidt-Erfurth U. Performance of three biometry devices in patients with different grades of age-related cataract. Acta Ophthalmol 2011; 89:e237–e241
17. Salouti R, Nowroozzadeh MH, Zamani M, Ghoreyshi M, Salouti R. Comparison of the ultrasonographic method with 2 partial coherence interferometry methods for intraocular lens power calculation. Optometry 2011; 82:140–147
18. Tappeiner C, Rohrer K, Frueh BE, Waelti R, Goldblum D. Clinical comparison of biometry using the non-contact optical low coherence reflectometer (Lenstar LS 900) and contact ultrasound biometer (Tomey AL-3000) in cataract eyes [letter]. Br J Ophthalmol 2010; 94:666–667
19. Chen S, Huang J, Wen D, Chen W, Huang D, Wang Q. Measurement of central corneal thickness by high-resolution Scheimpflug imaging, Fourier-domain optical coherence tomography and ultrasound pachymetry. Acta Ophthalmol 2010, Jun 18 [Epub ahead of print]
20. Módis L Jr, Szalai E, Németh G, Berta A. Evaluation of a recently developed noncontact specular microscope in comparison with conventional pachymetry devices. Eur J Ophthalmol 2010; 20:831–838
21. Maldonado MJ, López-Miguel A, Nieto JC, Cano-Parra J, Calvo B, Alió JL. Reliability of noncontact pachymetry after laser in situ keratomileusis. Invest Ophthalmol Vis Sci 2009; 50:4135–4141. Available at: http://www.iovs.org/content/50/9/4135.full.pdf. Accessed May 22, 2012
22. Alió JL, Piñero DP. Very high-frequency digital ultrasound measurement of the LASIK flap thickness profile using the IntraLase femtosecond laser and M2 and Carriazo-Pendular microkeratomes. J Refract Surg 2008; 24:12–23
23. Doughty MJ, Zaman ML. Human corneal thickness and its impact on intraocular pressure measures: a review and meta-analysis approach. Surv Ophthalmol 2000; 44:367–408
24. Tong L, Wong EEH, Chan YH, Balakrishnan V. Agreement between Scheimpflug photography and A-scan ultrasonography in anterior segment ocular measurements in children. Optom Vis Sci 2003; 80:529–534. Available at: http://journals.lww.com/optvissci/Fulltext/2003/07000/Agreement_between_Scheimpflug_Photography_and.14.aspx. Accessed May 22, 2012
25. Bjeloš Rončević M, Bušić M, Čima I, Kuzmanović Elabjer B, Bosnar D, Miletić D. Intraobserver and interobserver repeatability of ocular components measurement in cataract eyes using a new optical low coherence reflectometer. Graefes Arch Clin Exp Ophthalmol 2011; 249:83–87. Available at: http://www.springerlink.com/content/27030l4100k15055/fulltext.pdf. Accessed May 22, 2012
26. Kawamorita T, Nakayama N, Uozato H. Repeatability and reproducibility of corneal curvature measurements using the Pentacam and Keratron topography systems. J Refract Surg 2009; 25:539–544
27. Mehdizadeh M. Effect of axial length and keratometry measurement error on intraocular lens implant power prediction formulas in pediatric patients [letter]. J AAPOS 2008; 12:425; reply by M Eibschitz-Tsimhoni, O Tsimhoni, SM Archer, MA Del Monte 425–426
28. Salouti R, Nowroozzadeh MH, Zamani M, Ghoreyshi M, Salouti R. Comparison of horizontal corneal diameter measurements using Galilei, EyeSys and Orbscan II systems. Clin Exp Optom 2009; 92:429–433. Available at: http://onlinelibrary.wiley.com/doi/10.1111/j.1444-0938.2009.00407.x/pdf. Accessed May 22, 2012

First author:
Wuhe Chen, MD

Eye Hospital of Wenzhou Medical College, Wenzhou, China