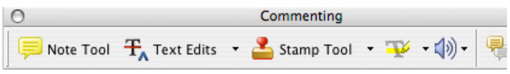
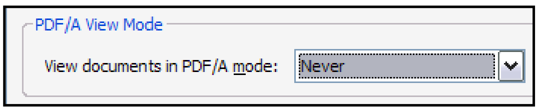
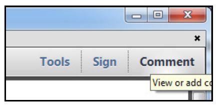
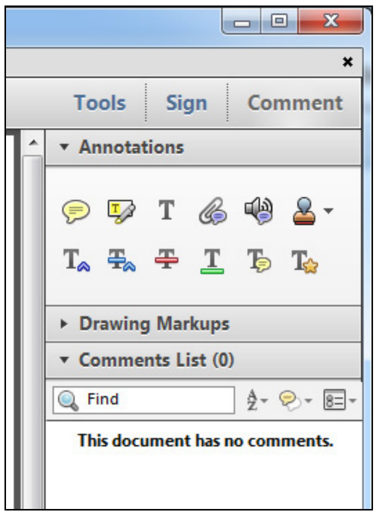
ELSEVIER

INSTRUCTIONS ON THE ANNOTATION OF PDF FILES

To view, print and annotate your content you will need Adobe Reader version 9 (or higher). This program is freely available for a whole series of platforms that include PC, Mac, and UNIX and can be downloaded from http://get.adobe.com/reader/. The exact system requirements are given at the Adobe site: http://www.adobe.com/products/reader/tech-specs.html.

Note: ***Please do NOT make direct edits to the PDF using the editing tools as doing so could lead us to overlook your desired changes.*** *Rather, please request corrections by using the tools in the Comment pane to annotate the PDF and call out the changes you are requesting. If you opt to annotate the file with software other than Adobe Reader then please also highlight the appropriate place in the PDF file.*

PDF ANNOTATIONS	
Adobe Reader version 9	**Adobe Reader version X and XI**
When you open the PDF file using Adobe Reader, the Commenting tool bar should be displayed automatically; if not, click on 'Tools', select 'Comment & Markup', then click on 'Show Comment & Markup tool bar' (or 'Show Commenting bar' on the Mac). If these options are not available in your Adobe Reader menus then it is possible that your Adobe Acrobat version is lower than 9 or the PDF has not been prepared properly.  (Mac) **PDF ANNOTATIONS (Adobe Reader version 9)** The default for the Commenting tool bar is set to 'off' in version 9. To change this setting select 'Edit | Preferences', then 'Documents' (at left under 'Categories'), then select the option 'Never' for 'PDF/A View Mode'.  (Changing the default setting, Adobe version 9)	To make annotations in the PDF file, open the PDF file using Adobe Reader XI, click on 'Comment'. If this option is not available in your Adobe Reader menus then it is possible that your Adobe Acrobat version is lower than XI or the PDF has not been prepared properly.  This opens a task pane and, below that, a list of all Comments in the text. These comments initially show all the changes made by our copyeditor to your file. 

HOW TO...		
Action	**Adobe Reader version 9**	**Adobe Reader version X and XI**
Insert text	Click the 'Text Edits' button on the Commenting tool bar. Click to set the cursor location in the text and simply start typing. The text will appear in a commenting box. You may also cut-and-paste text from another file into the commenting box. Close the box by clicking on 'x' in the top right-hand corner.	Click the 'Insert Text' icon on the Comment tool bar. Click to set the cursor location in the text and simply start typing. The text will appear in a commenting box. You may also cut-and-paste text from another file into the commenting box. Close the box by clicking on '_' in the top right-hand corner.
Replace text	Click the 'Text Edits' button on the Commenting tool bar. To highlight the text to be replaced, click and drag the cursor over the text. Then simply type in the replacement text. The replacement text will appear in a commenting box. You may also cut-and-paste text from another file into this box. To replace formatted text (an equation for example) please <u>Attach a file</u> (see below).	Click the 'Replace (Ins)' icon on the Comment tool bar. To highlight the text to be replaced, click and drag the cursor over the text. Then simply type in the replacement text. The replacement text will appear in a commenting box. You may also cut-and-paste text from another file into this box. To replace formatted text (an equation for example) please <u>Attach a file</u> (see below).
Remove text	Click the 'Text Edits' button on the Commenting tool bar. Click and drag over the text to be deleted. Then press the delete button on your keyboard. The text to be deleted will then be struck through.	Click the 'Strikethrough (Del)' icon on the Comment tool bar. Click and drag over the text to be deleted. Then press the delete button on your keyboard. The text to be deleted will then be struck through.
Highlight text/ make a comment	Click on the 'Highlight' button on the Commenting tool bar. Click and drag over the text. To make a comment, double click on the highlighted text and simply start typing.	Click on the 'Highlight Text' icon on the Comment tool bar. Click and drag over the text. To make a comment, double click on the highlighted text and simply start typing.
Attach a file	Click on the 'Attach a File' button on the Commenting tool bar. Click on the figure, table or formatted text to be replaced. A window will automatically open allowing you to attach the file. To make a comment, go to 'General' in the 'Properties' window, and then 'Description'. A graphic will appear in the PDF file indicating the insertion of a file.	Click on the 'Attach File' icon on the Comment tool bar. Click on the figure, table or formatted text to be replaced. A window will automatically open allowing you to attach the file. A graphic will appear indicating the insertion of a file.
Leave a note/ comment	Click on the 'Note Tool' button on the Commenting tool bar. Click to set the location of the note on the document and simply start typing. <u>Do not use this feature to make text edits</u>.	Click on the 'Add Sticky Note' icon on the Comment tool bar. Click to set the location of the note on the document and simply start typing. <u>Do not use this feature to make text edits</u>.

HOW TO...		
Action	**Adobe Reader version 9**	**Adobe Reader version X and XI**
Review	To review your changes, click on the 'Show' button  on the Commenting tool bar. Choose 'Show Comments List'. Navigate by clicking on a correction in the list. Alternatively, double click on any mark-up to open the commenting box.	Your changes will appear automatically in a list below the Comment tool bar. Navigate by clicking on a correction in the list. Alternatively, double click on any mark-up to open the commenting box.
Undo/delete change	To undo any changes made, use the right click button on your mouse (for PCs, Ctrl-Click for the Mac). Alternatively click on 'Edit' in the main Adobe menu and then 'Undo'. You can also delete edits using the right click (Ctrl-click on the Mac) and selecting 'Delete'.	To undo any changes made, use the right click button on your mouse (for PCs, Ctrl-Click for the Mac). Alternatively click on 'Edit' in the main Adobe menu and then 'Undo'. You can also delete edits using the right click (Ctrl-click on the Mac) and selecting 'Delete'.

SEND YOUR ANNOTATED PDF FILE BACK TO ELSEVIER

Save the annotations to your file and return as instructed by Elsevier. Before returning, please ensure you have answered any questions raised on the Query Form and that you have inserted all corrections: later inclusion of any subsequent corrections cannot be guaranteed.

FURTHER POINTS

- Any (grey) halftones (photographs, micrographs, etc.) are best viewed on screen, for which they are optimized, and your local printer may not be able to output the greys correctly.
- If the PDF files contain colour images, and if you do have a local colour printer available, then it will be likely that you will not be able to correctly reproduce the colours on it, as local variations can occur.
- If you print the PDF file attached, and notice some 'non-standard' output, please check if the problem is also present on screen. If the correct printer driver for your printer is not installed on your PC, the printed output will be distorted.

AUTHOR QUERY FORM

ELSEVIER	**Journal:** JCRS **Article Number:** 9867	**Please e-mail your responses and any corrections to:** **E-mail:** k.powers@elsevier.com

Dear Author,

Please check your proof carefully and mark all corrections at the appropriate place in the proof (e.g., by using on-screen annotation in the PDF file) or compile them in a separate list. **It is crucial that you NOT make direct edits to the PDF using the editing tools as doing so could lead us to overlook your desired changes.** Note: if you opt to annotate the file with software other than Adobe Reader then please also highlight the appropriate place in the PDF file. To ensure fast publication of your paper please return your corrections within 48 hours.

For correction or revision of any artwork, please consult http://www.elsevier.com/artworkinstructions.

Any queries or remarks that have arisen during the processing of your manuscript are listed below and highlighted by flags in the proof.

Location in article	Query / Remark: Click on the Q link to find the query's location in text Please insert your reply or correction at the corresponding line in the proof
	If there are any drug dosages in your article, please verify them and indicate that you have done so by initialing this query
Synopsis	The new anterior segment optical coherence tomographer combined with Placido topography provided repeatable measurements in healthy unoperated eyes and eyes that had previous excimer laser surgery.
Q1	JCRS attempts to manage the perception of bias by limiting the unnecessary repetitive use of trade and brand names, and your paper has already been edited according to this policy and thus you need not make changes in terms of the policy. For a copy of the policy, please contact Genie Bailey at gbailey@ascrs.org.
Q2	JCRS style is to boldface vectors. Please make sure we did this in a correct manner.
Q3	Per JCRS style, data given in the tables were removed from the text.
Q4	The references "42 and 44 "were cited in the Table 1, but not provided in the reference list. Kindly check and provide.
Q5	We defined "S_w" as within subject. If that is not correct, please provide a definition.
Q6	Please confirm that given names and surnames have been identified correctly and are presented in the desired order and please carefully verify the spelling of all authors' names.

(*continued on next page*)

	Please check this box or indicate your approval if you have no corrections to make to the PDF file ☐

Thank you for your assistance.

ARTICLE

Repeatability of automatic measurements by a new anterior segment optical coherence tomographer combined with Placido topography and agreement with 2 Scheimpflug cameras

Giacomo Savini, MD, Domenico Schiano-Lomoriello, MD, Kenneth J. Hoffer, MD, FACS

Purpose: To evaluate the repeatability of automatic measurements by a new anterior segment optical coherence tomographer (AS-OCT) combined with Placido topography and their agreement with those provided by 2 rotating Scheimpflug cameras.

Setting: G.B. Bietti Foundation IRCCS, Rome, Italy.

Design: Evaluation of a diagnostic test instrument.

Methods: Unoperated eyes and eyes with previous myopic excimer laser surgery were analyzed. Three consecutive scans were acquired with an AS-OCT device (MS-39) and 1 with 2 rotating Scheimpflug cameras (Pentacam HR and Sirius). The following parameters were evaluated: simulated keratometry, posterior and total corneal power, total corneal astigmatism, corneal asphericity, thinnest corneal thickness, central epithelial thickness, corneal diameter, and aqueous depth. Repeatability was assessed using test–retest variability, the coefficient of variation (CoV), and the intraclass correlation coefficient; agreement was assessed by the 95% limits of agreement.

Results: The study comprised 96 unoperated eyes and eyes 43 with previous myopic excimer laser surgery. High repeatability was achieved in both groups, as shown by a CoV less than 1.0% for most parameters. The repeatability of epithelial thickness was slightly lower than that of the whole corneal thickness, although the CoV was still good (1.87% in unoperated eyes; 3.28% in post-refractive surgery eyes). Moderate repeatability was found for total corneal astigmatism measurements, with a CoV greater than 20.0%. Agreement with Scheimpflug cameras was high for aqueous depth and thinnest corneal thickness and moderate for most other parameters.

Conclusion: The high repeatability of automatic measurements by the new AS-OCT device supports its use in clinical practice.

Imaging of the anterior segment of the eye has undergone an impressive evolution over the past 15 years. The introduction of scanning-slit topography first and Scheimpflug technology later has allowed clinicians to obtain new information about their patients. They can measure posterior and total corneal astigmatism to plan toric intraocular lens (IOL) implantation,[1–10] use elevation maps of the anterior and posterior corneal surface, and pachymetric maps to detect keratoconus and ectasia,[11–14] calculate total corneal power (TCP) by ray tracing to calculate IOL power after corneal refractive surgery,[15] and apply corneal densitometry in the follow-up of eyes after refractive surgery.[16]

On the other hand, one of the main limitations of Scheimpflug imaging is the low resolution and poor quality of anterior segment scans. In this regard, anterior segment optical coherence tomography (AS-OCT) is known to produce better images with higher definition (Figure 1). The first commercially available AS-OCT device was a time-domain instrument, the Visante (Carl Zeiss Meditec AG), which uses a 1310 nm infrared light wavelength and could obtain no more than 4 simultaneous radial cross-sectional

Submitted: November 26, 2017 | Final revision submitted: February 3, 2018 | Accepted: February 5, 2018

From G.B. Bietti Eye Foundation IRCCS (Savini, Scjoamp-Lomoriello), Rome, Italy; Stein Eye Institute (Hoffer), University of California, Los Angeles, and St. Mary's Eye Center (Hoffer), Santa Monica, California, USA.

The Italian Ministry of Health and Fondazione Roma, Rome, Italy, supported G.B. Bietti Foundation IRCCS.

Corresponding author: Giacomo Savini, MD, Fondazione G.B. Bietti IRCCS, Via Livenza, 3, Rome, Italy. E-mail: giacomo.savini@alice.it.

scans of the anterior segment.[17] To generate corneal maps, it was later combined with Placido corneal topography (Visante Omni).[18–21] Subsequently, the RTVue-100 (Optovue, Inc.), which relied on spectral-domain OCT (SD-OCT) and a shorter wavelength centered at 830 nm, was introduced.[22] The current version (Cornea Advance) is able to acquire 8 evenly spaced 6.0 mm radial cross-sections of the anterior segment and provide users with corneal and pachymetric maps. Until now, a greater number of radial scans could be acquired only by the Casia SS-1000 and subsequently by the Casia 2 (Tomey Corp.), both of which use SD-OCT and a 1310 nm light source. These 2 devices acquire 16 radial B-scans centered on the corneal vertex, each of them 10.0 mm long and 6.0 mm deep, to generate corneal curvature and thickness maps.[23]

The purpose of this study was to evaluate the repeatability of automatic measurements provided by a new AS-OCT device combined with Placido corneal topography (MS-39, Costruzione Strumenti Oftalmici) and assess their agreement with those of the corresponding measurements taken with a rotating Scheimpflug camera (Pentacam HR, Oculus Optikgeräte GmbH) and a rotating Scheimpflug camera combined with Placido disk topography (Sirius, Costruzione Strumenti Oftalmici).

PARTICIPANTS AND METHODS

This prospective comparative study enrolled patients with healthy unoperated corneas and those who had corneal refractive surgery performed using an excimer laser. The study was performed in accordance with the ethical standards stated in the 1964 Declaration of Helsinki and approved by the G.B. Bietti Foundation IRCCS Clinical Research Ethics Committee. All patients provided informed consent.

Exclusion criteria were the presence of keratoconus or suspect keratoconus as shown by 1 or both Scheimpflug cameras,[11,12] a previous diagnosis of dry eye, a history of corneal disease or trauma, any kind of ocular surgery, and contact lens use in the past month. One eye of each patient was randomly selected.

Instruments

The MS-39 (software version 3.6) uses SD-OCT and Placido-disk corneal topography to obtain measurements of the anterior segment of the eye. After autocalibration, the scanning process acquires (in approximately 1 second) 1 Placido top-view image and a series of 25 SD-OCT radial scans at a wavelength of 840 nm, with an axial resolution of 3.5 nm, a transverse resolution of 35 nm, and a maximum depth of 7.5 mm. Each scan is 16.0 mm long and includes 1024 A-scans. The ring edges are detected on the Placido image so that height, slope, and curvature data can be calculated using the arc-step method with conic curves. Profiles of the anterior cornea, posterior cornea, anterior lens, and iris are derived from the SD-OCT scans. Data for the anterior surface from the Placido image and SD-OCT scans are merged using a proprietary method. All other measurements for internal structures (posterior cornea, anterior lens, and iris) are derived solely from SD-OCT data.

The Pentacam HR (software version 1.20r10) is a rotating Scheimpflug camera. Scans were taken in the automatic release mode, and the 25-picture scan was used.

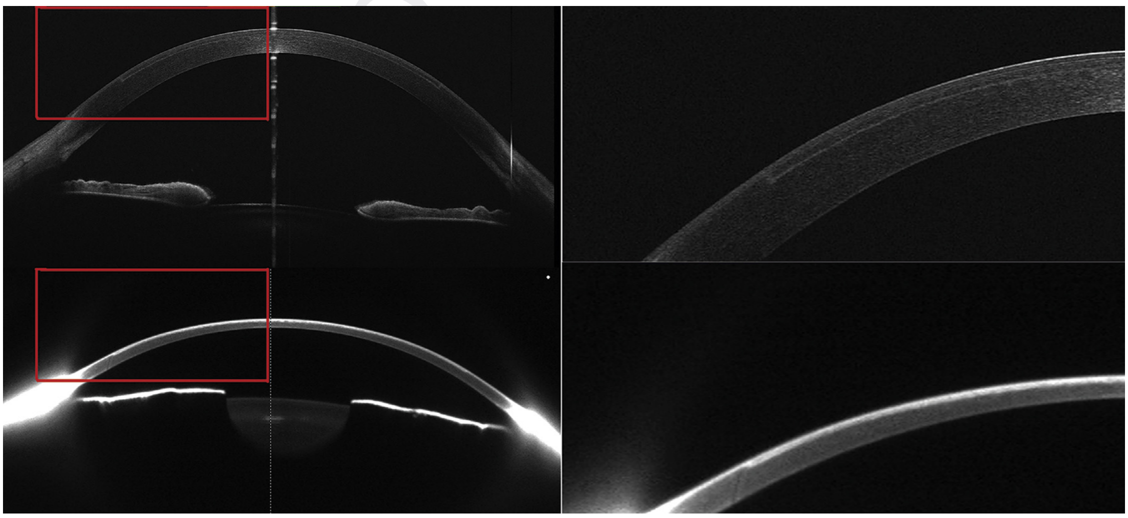
The Sirius (software version 3.2) combines a single rotating Scheimpflug camera and a Placido disk corneal topographer. The scanning process acquires a series of 25 Scheimpflug images (meridians) and 1 Placido top-view image. Technical details have been described.[24]

Measurement Procedures

The 3 instruments were used according to the manufacturers' guidelines in a random order. Each device was brought into focus, and the patient's eye was aligned along the visual axis with a central fixation light. The patients were instructed to blink completely just before each measurement, and no eyedrops were applied before testing.

With the AS-OCT device, 3 repeated consecutive measurements were taken by the same experienced examiner (G.S.) to assess repeatability. The patients were asked to sit back after each measurement, and the device was realigned before the subsequent measurement. All measurements were taken between 10 AM and 4 PM to minimize diurnal change and had to display good quality according to the instrument software or be repeated.

With the rotating Scheimpflug camera and the Scheimpflug camera–Placido topographer, only 1 measurement was acquired if the quality specification was OK; otherwise, the measurement



print & web 4C/FPO

Figure 1. Horizontal section of a cornea with previous femtosecond laser in situ keratomileusis. *Top*: Anterior segment optical coherence tomography allows visualization of the flap edge and interface (*left*: whole-eye section; *right*: section of the cornea inside the *red box*). *Bottom*: With the Scheimpflug camera, the flap cannot be visualized.

FLA 5.5.0 DTD ■ JCRS9867_proof ■ 10 April 2018 ■ 7:08 pm

was repeated until a good quality scan, as indicated by the instrument, was available. The starting sequence of the devices was drawn at random.

Measured Parameters

The following automatic measurements by the AS-OCT device were evaluated in this study:

- *Simulated keratometry (K)*. This value is obtained from the arithmetic mean of the curvature radii (in mm) of the flattest and steepest anterior corneal meridians. For each meridian, the radii are calculated by averaging the axial curvature from the fourth to the eighth Placido rings, which correspond to a diameter between 2.5 mm and 4.0 mm in the average eye. (The diameter is slightly larger in flat corneas and smaller in steep corneas.) The curvature is converted in keratometric diopters (D) using the standard keratometric index of 1.3375.
- *Posterior corneal curvature*. This value is the arithmetic mean of the corneal radii of the pair of meridians 90 degrees apart with the greatest and least curvature in the 3.0 mm zone of the posterior corneal surface. The conversion from the curvature (mm) into power (diopters [D]) is performed by using the refractive indices of the cornea (1.376) and the aqueous humor (1.336.)
- *Total corneal power*. This value (defined as the mean pupil power) is the total power of the cornea obtained by ray tracing through its anterior and posterior surfaces and a 3.0 mm diameter entrance pupil. The angle of refraction of incoming parallel rays is calculated using Snell's law and the following indices of refraction: 1.000 for air, 1.376 for cornea, and 1.336 for aqueous.
- *Total corneal astigmatism (TCA)*. This value, obtained over a 3.0 mm diameter area centered on the pupil, was analyzed with and without vector analysis. With the former approach, the polar value along the zero-degree meridian, defined as the **KP(0)** vector, and the polar value along the 45-degree meridian, defined as the **KP(45)** vector, were calculated.[25] When vector analysis was not performed, only magnitude was evaluated.
- *Corneal asphericity*. This measurement is expressed as the asphericity (Q) values of the anterior and posterior corneal surfaces in the 8.0 mm zone. The Q value is zero when the curve is a circle, lies between −1 and zero when the curve is a prolate ellipse, and is higher than zero when the curve is an oblate ellipse.
- *Corneal diameter and thinnest corneal thickness*.
- *Epithelial thickness*. The instrument automatically calculates the epithelial thickness in the 8.0 mm zone and provides measurements over 25 sectors. The present study evaluated the central reading over an area of 3.0 mm and the 4 paracentral measurements (nasal, temporal, superior, and inferior), with a diameter between 3.0 mm and 6.0 mm.
- *Aqueous depth*. This is the axial distance between the corneal endothelium and the anterior surface of the lens.

With the exception of central epithelial thickness, the corresponding values provided by the rotating Scheimpflug camera and the Scheimpflug camera–Placido topographer were analyzed to assess agreement. With the Scheimpflug camera–Placido topographer, the "adjusted corneal diameter" setting was selected.

STATISTICAL ANALYSIS

In the present study, the term *repeatability* was used according to the definition of the International Organization for Standardization,[26] which considers it a part of accuracy. Accuracy includes trueness and precision. Trueness is the inverse of bias and is obtained by comparing the measurement result with the accepted reference (conventional true) value. Precision is the inverse of statistical uncertainty and is normally expressed in terms of the standard deviation (SD). The factors involved include (1) the operator, (2) the equipment used, (3) the equipment calibration, (4) the environment, and (5) the elapsed time between measurements. Precision has 2 conditions: (1) repeatability and (2) reproducibility. Under repeatability conditions, factors such as 1 to 5 are considered constant and do not contribute to the variability of the measurement result. Under reproducibility conditions, those factors can vary. Repeatability and reproducibility are the 2 extremes of precision.

Repeatability was assessed on the basis of intrasession test–retest variability, the coefficient of variation (CoV), and the intraclass correlation coefficient (ICC). The following methods were used:

- *Intrasession test–retest variability*. Also known as repeatability or limits of repeatability, this was calculated by multiplying the pooled within-participant SD by 2.77.[27] On the basis of repeatability, it can be expected that the difference between 2 measurements for the same participant will be less than 2.77 within-participant for 95% of pairs of observations.
- *Coefficient of variation*. This was calculated as the within-participant divided by the mean of the measurements and expressed as a percentage. The CoV was not calculated for parameters with both positive values and negative values; for example, **KP(0)** and **KP(45)**.[28]
- *Intraclass correlation coefficient*. This is defined as the ratio of the between-subjects variance to the sum of the pooled within-subject variance and the between-subjects variance. The ICC, which approaches 1.0 when there is no variance between repeated measurements, was automatically calculated using SPSS software (version 22, IBM Corp.) with the 2-way mixed model and absolute agreement. Intraclass correlation coefficients ranging from 0 to 1 are commonly classified as follows: ICC less than 0.75 = poor agreement; ICC 0.75 to less than 0.90 = moderate agreement; ICC 0.90 and more = high agreement.[29]

The level of agreement between the 3 instruments was evaluated according to the method described by Bland and Altman,[30] who suggested plotting the differences between measurements (y-axis) against their mean (x-axis). Bland and Altman plots allowed an assessment of the existence of any systematic difference between measurements (ie, fixed bias). The mean difference is the estimated bias, and the SD of the differences measures the random fluctuations around this mean. The 95% limits of agreement (LoA) were defined as means ±1.96 SD of the differences between the 2 measurement techniques. In addition, repeated-measures analysis of variance with a Bonferroni multiple comparison post test was used to compare the mean values measured by the 3 devices; with the AS-OCT-Placido topographer, only the first scan was used for this purpose. Finally, the tolerance index was calculated as described by Bergin et al.[31] This index was developed to assess whether the 95% LoA (interdevice noise) are wider than the limits of repeatability (intradevice noise). The tolerance index is computed as the log of the ratio between the LoA and the limits of repeatability. Two devices can be

FLA 5.5.0 DTD ■ JCRS9867_proof ■ 10 April 2018 ■ 7:08 pm

considered interchangeable if the tolerance index is smaller than the cutoff values shown in Table 1 in the paper by Bergin et al.[31] (ie, 0.27 for a sample of 40 eyes and 0.18 for a sample of 100 eyes).

The sample size was calculated to yield a minimum 15% confidence in the estimate. According to McAlinden et al.,[32] this means that at least 43 eyes had to be enrolled in each group.

RESULTS

The study enrolled 96 participants (mean age 46.5 years ± 16.5 [SD], range 18 to 83 years; 50 women) in the unoperated group and 43 patients (mean age 40.2 ± 10.1 years, range 24 to 69 years; 24 men) in the post-refractive surgery group. In the latter group, 37 eyes had myopic photorefractive keratectomy or laser in situ keratomileusis (LASIK) and 6 eyes had hyperopic LASIK.

Table 1 shows the test–retest repeatability, CoV, and ICC for the parameters measured by the AS-OCT device as well as by the Scheimpflug cameras. A CoV of less than 1.0% was obtained for most parameters in both groups of eyes and the ICC was more than 0.90 with all parameters, indicating excellent repeatability. The repeatability of central epithelial thickness measurements was slightly lower than that of whole corneal thickness measurements, although the CoV was still good. The repeatability of the 4 paracentral measurements was similar, with CoVs ranging between 1.95%

Table 1. Repeatability analysis of the measurements provided by anterior segment optical coherence tomography combined with Placido corneal topography and comparison to the corresponding values given by different Scheimpflug cameras.

	Test–Retest Repeatability ($2.77\ S_w$)		Coefficient of Variation (%)		Intraclass Correlation Coefficient	
Parameter	Unoperated	P-RS	Unoperated	P-RS	Unoperated	P-RS
Simulated K (D)	0.20	0.25	0.16	0.22	0.999	1.000
Dual Scheimpflug analyzer (G2 version)[35]	0.27	—	0.23	—	0.991	—
Dual Scheimpflug analyzer (G4 version)[37]	—	—	0.16	0.19	0.998	—
Rotating Scheimpflug camera[35,36]	0.17	—	0.14	—	0.996	—
Scheimpflug camera–Placido topographer[26]	0.29	0.34	0.24	0.32	0.994	0.993
Posterior K (D)	0.07	0.05	0.39	0.28	0.997	0.999
Dual Scheimpflug analyzer (G2 version)[35]	0.07	—	0.35, 0.40	—	0.989, 0.998	—
Dual Scheimpflug analyzer (G4 version)[37]		—	0.40	0.32	0.992	0.990
Rotating Scheimpflug camera[35]	0.06	—	0.34	—	0.992	—
Scheimpflug camera–Placido topographer[26]	0.05	0.05	0.30	0.31	0.993	0.993
Total corneal power (D)	0.27	0.26	0.22	0.24	0.999	1.000
Dual Scheimpflug analyzer (G2 version)[35]	0.34	—	0.30	—	0.985	—
Dual Scheimpflug analyzer (G4 version)[37,44]		—	0.20, 0.21	0.21	0.996, 0.997	0.998
Rotating Scheimpflug camera[35]	0.14	—	0.11	—	0.998	—
Scheimpflug camera–Placido topographer[26]	0.34	0.45	0.28	0.43	0.992	0.991
TCA magnitude (D)	0.52	0.43	22.08	20.20	0.961	0.949
Dual Scheimpflug analyzer (G2 version)[35]	0.12	—	17.27	—	0.913	—
Dual Scheimpflug analyzer (G4 version)[37,44]	—	—	18.77, 28.16	24.18	0.811, 0.910	0.898
KP(0) vector	0.62	0.24	NA	NA	0.975	0.963
KP(45) vector	0.48	0.27	NA	NA	0.950	0.914
Corneal asphericity (Q value)	0.07	0.16	8.49	NA	0.978	0.932
Scheimpflug camera–Placido topographer[26]	0.11	0.10	—	—	0.904	0.995
Corneal diameter (mm)	0.12	0.34	0.37	1.02	0.997	0.967
Dual Scheimpflug analyzer (G1 version)[42]	0.14	—	0.41		0.995	
Thinnest corneal thickness (μm)	4.77	5.52	0.32	0.40	0.999	0.999
Dual Scheimpflug analyzer (G2 version)[35]	4.82	—	0.31	—	0.996	—
Dual Scheimpflug analyzer (G4 version)[44]		—	0.65	—	0.977	—
Rotating Scheimpflug camera[35]	9.84, 11.88	—	0.66, 0.76	—	0.981, 0.982	—
Scheimpflug camera–Placido topographer[26]	7.37	5.96	0.48	0.46	0.992	0.998
Central epithelial thickness (μm)	2.73	5.10	1.87	3.28	0.964	0.957
SD-OCT[41]		—	1.07	1.05	0.985	0.995
Nasal epithelial thickness (μm)	2.96	4.16	1.95	2.60	0.961	0.959
Temporal epithelial thickness (μm)	3.15	5.81	2.12	3.58	0.960	0.957
Superior epithelial thickness (μm)	4.36	5.79	2.95	3.70	0.958	0.958
Inferior epithelial thickness (μm)	3.10	4.73	2.02	2.89	0.960	0.961
Aqueous depth (mm)	0.04	0.04	0.45	0.51	1.000	0.999
Dual Scheimpflug analyzer (G2 version)[35]	0.06	—	0.71	—	0.995	—
Rotating Scheimpflug camera[35]	0.05	—	0.62	—	0.997	—
Scheimpflug camera–Placido topographer[26]	0.04	0.03	0.49	0.39	0.999	0.997

K = keratometry; **KP(0)** = polar value along zero-degree meridian; **KP(45)** = polar value along the 45-degree meridian; P-RS = Post-refractive surgery; NA = not applicable; SD-OCT = spectral domain optical coherence tomography; S_w = within subject; TCA = total corneal astigmatism

FLA 5.5.0 DTD ■ JCRS9867_proof ■ 10 April 2018 ■ 7:08 pm

and 2.95% in unoperated eyes and between 2.60% and 3.70% in post-refractive surgery eyes. The repeatability was only moderate for TCA measurements, with a CoV of more than 20%.

The tolerance index was more than 1 for all parameters when the measurements of the AS-OCT device were compared with those of the 2 Scheimpflug cameras. Being higher than the cutoff for the sample size of unoperated and post-refractive surgery eyes, the tolerance index showed that the measurements given by the new AS-OCT Placido topographer cannot be considered interchangeable with those provided by the other 2 devices.

Table 2 shows the mean values for each parameter measured by all 3 devices in the unoperated group. Compared with the 2 Scheimpflug cameras, the AS-OCT Placido topographer provided slightly higher simulated K and TCP values. For these parameters, the mean difference was statistically, but not clinically, significant, ranging between 0.06 D and 0.11 D for simulated K and between 0.13 D and 0.26 D for TCP. Accordingly, the agreement was high. Statistically, but not clinically, significant differences were also found for posterior corneal power, corneal diameter (slightly smaller than measured with the rotating Scheimpflug camera), and anterior Q value (higher than the value given by the rotating Scheimpflug camera). Among these parameters, relatively poor agreement (ie, wide 95% LoA) was found for the Q value. In contrast, the agreement for aqueous depth was excellent between the 3 devices (notwithstanding a statistically, but not clinically, significant difference) and thinnest corneal thickness (whose mean values did not show a statistically significant difference). Regarding corneal astigmatism, no statistically significant differences were detected for the mean TCA power. However, vectorial analysis showed statistically significant differences for the vectors **KP(0)** and **KP(45)**. Further vectorial analysis of the 50 eyes with a TCA power of 0.50 D or more as measured by all 3 devices showed that most of these eyes (n = 35) had with-the-rule astigmatism. In this subsample, no statistically significant difference was observed for the mean **KP(0)** values provided by the AS-OCT device (−1.15 ± 0.58), the rotating Scheimpflug camera (−1.14 ± 0.67), and the Scheimpflug camera–Placido topographer (−1.11 ± 0.65). However, a significantly more negative **KP(45)** vector was measured by the AS-OCT device (−0.15 ± 0.41) than by the rotating Scheimpflug camera (−0.01 ± 0.36) and the Scheimpflug camera–Placido topographer (0.03 ± 0.39) ($P = .0003$). This led to a small difference in the mean astigmatism, which was 1.17 @ 94 with the AS-OCT device, 1.14 @ 90 with the rotating Scheimpflug camera, and 1.11 @ 89 with the Scheimpflug camera–Placido topographer.

In the post-excimer laser group, no statistically significant differences were detected and good agreement was found for simulated K, posterior K, and TCA power (Table 3). Regarding astigmatism, there were alao no statistically significant differences for the **KP(0)** and **KP(45)** vectors, although in this case agreement was only moderate. However, statistically significant differences were observed for TCP. The mean value provided by the AS-OCT device was higher than those provided by the rotating Scheimpflug camera (by 0.17 D) and the Scheimpflug camera–Placido topographer (by 0.18 D); the TCP measurements also had a slightly wider 95% LoA for the simulated K. Results similar to those obtained in unoperated eyes were observed for aqueous depth (ie, excellent agreement and a statistically, but not clinically

Table 2. Mean values from the 3 devices in the unoperated group.

Parameter	AS-OCT–Placido Topographer	Rotating Scheimpflug Camera		Scheimpflug Camera–Placido Topographer		
	Mean ± SD	Mean ± SD	95% LoA*	Mean ± SD	95% LoA[†]	*P* Value[‡]
Simulated K (D)	43.83 ± 1.51	43.72 ± 1.50	−0.28, +0.49	43.77 ± 1.52	−0.26, +0.38	<.0001[§,¶]
Posterior K (D)	−6.22 ± 0.27	−6.28 ± 0.27	−0.05, +0.16	−6.21 ± 0.27	−0.16, +0.12	<.0001[§,¶]
Total corneal power (D)	43.32 ± 1.50	43.06 ± 1.46	−0.23, +0.75	43.19 ± 1.52	−0.31, +0.56	<.0001[§,¶]
TCA power (D)	0.82 ± 0.56	0.79 ± 0.58	−0.57, +0.64	0.87 ± 0.56	0.00, +0.11	NS
KP(0) vector	−0.38 ± 0.80	−0.43 ± 0.78	−0.63, +0.72	−0.31 ± 0.87	−0.78, +0.63	.0083[§]
KP(45) vector	−0.11 ± 0.44	−0.02 ± 0.42	−0.59, +0.42	0.01 ± 0.46	−0.64, +0.41	.0002[§,¶]
Q value	−0.28 ± 0.09	−0.34 ± 0.12	−0.10, +0.22	−0.27 ± 0.11	−0.16, +0.13	<.0001[§]
Thinnest corneal thickness (μm)	539.42 ± 33.71	538.72 ± 34.23	−18.18, +19.58	538.29 ± 35.37	−19.22, +21.47	NS
Central epithelial thickness (μm)	52.79 ± 3.20	—	—	—	—	—
CD (mm)	11.71 ± 0.49	11.84 ± 0.44	−0.46, +0.19	11.74 ± 0.48	−0.54, +0.47	<.0001[§]
Aqueous depth (mm)	2.94 ± 0.41	2.88 ± 0.42	0.01, +0.12	2.89 ± 0.41	0.00, +0.11	<.0001[§,¶]
TCA (D @ axis)	0.40 @ 95	0.43 @ 91	NA	0.31 @ 90	NA	NA

CD = corneal diameter; K = keratometry; **KP(0)** = polar value along 0-degree meridian; **KP(45)** = polar value along the 45-degree meridian; LoA = limits of agreement; NA = not applicable; NS = not significant; TCA = total corneal astigmatism

*AS-OCT – rotating Scheimpflug camera

[†]AS-OCT – Scheimpflug camera with Placido topographer

[‡]Analysis of variance

[§]Statistically significant difference between AS-OCT and rotating Scheimpflug camera according to Bonferroni multiple-comparison test

[¶]Statistically significant difference between AS-OCT–Placido topographer and Scheimpflug camera–Placido topographer according to Bonferroni multiple-comparison test

Table 3. Mean values from the 3 devices in the post-excimer laser group.

Parameter	AS-OCT–Placido Topographer	Rotating Scheimpflug Camera		Scheimpflug Camera–Placido Topographer		P Value‡
	Mean ± SD	Mean ± SD	95% LoA*	Mean ± SD	95% LoA†	
Simulated K (D)	40.75 ± 2.98	40.67 ± 2.97	−0.28, +0.44	40.69 ± 2.98	−0.41, +0.54	NS
Posterior K (D)	−6.20 ± 0.26	−6.22 ± 0.27	−0.09, 0.13	−6.23 ± 0.29	−0.15, +0.22	NS
Total corneal power (D)	39.71 ± 3.49	39.54 ± 3.35	−0.51, +0.85	39.53 ± 3.57	−0.42, +0.78	.0044§,¶
TCA power (D)	0.75 ± 0.41	0.66 ± 0.36	−0.06, +0.18	0.75 ± 0.39	−0.06, +0.14	NS
KP(0) vector	−0.55 ± 0.52	−0.44 ± 0.48	−0.86, +0.64	−0.51 ± 0.58	−0.69, +0.63	NS
KP(45) vector	0.07 ± 0.40	0.00 ± 0.37	−0.54, +0.67	0.07 ± 0.36	−0.77, +0.76	NS
Q value	0.21 ± 0.75	0.19 ± 0.67	−0.31, +0.33	0.29 ± 0.79	−0.42, +0.25	.0031¶
Thinnest corneal thickness (μm)	492.02 ± 44.18	493.23 ± 44.85	−16.76, +14.34	489.58 ± 48.09	−20.01, +24.89	NS
Central epithelial thickness (μm)	55.77 ± 4.98	—	—	—	—	—
CD (mm)	11.87 ± 0.36	11.99 ± 0.40	−0.55, +0.32	12.29 ± 0.37	−0.32, −0.28	<.0001§
Aqueous depth (mm)	3.09 ± 0.36	3.03 ± 0.38	−0.06, +0.18	3.05 ± 0.37	−0.06, +0.14	<.0001§,¶
TCA (D @ axis)	0.55 @ 8	0.44 @ 90	NA	0.52 @ 87	NA	NA

CD = corneal diameter; K = keratometry; **KP(0)** = polar value along 0-degree meridian; **KP(45)** = polar value along the 45-degree meridian; LoA = limits of agreement; NA = not applicable; NS = not significant; TCA = total corneal astigmatism
*AS-OCT – rotating Scheimpflug camera
†AS-OCT – Scheimpflug camera with Placido topographer
‡Analysis of variance
§Statistically significant difference between AS-OCT and rotating Scheimpflug camera according to Bonferroni multiple-comparison test
¶Statistically significant difference between AS-OCT–Placido topographer and Scheimpflug camera–Placido topographer according to Bonferroni multiple-comparison test

significant, difference as a result of the slightly higher mean value with AS-OCT), thinnest corneal thickness (excellent agreement and no statistical difference), and corneal diameter (good agreement between the 3 devices and a lower mean value with the AS-OCT device than with the rotating Scheimpflug camera). Anterior Q value measurements, which were negative in the unoperated group and turned into positive values in the post-excimer laser surgery group, showed a statistically, but not clinically significant, difference; agreement between the 3 devices was only moderate for this parameter.

DISCUSSION

The main purpose of this study was to assess the repeatability of the automatic measurements provided by the new AS-OCT Placido topographer. As with any other new diagnostic device, assessing repeatability is mandatory before its measurements can be relied on in clinical practice. In this regard, the results of the repeatability analysis were good in both healthy eyes and post-refractive surgery eyes. The high repeatability of corneal power measurements (simulated K and TCP) was confirmed by a test–retest repeatability ranging between 0.20 D and 0.27 D. This means that the difference between 2 measurements in the same participant is expected to be less than a quarter of a diopter for 95% of pairs of observations. As previously explained,[24] this value has a low clinical impact in IOL power calculation. The repeatability values for corneal power are slightly better than those previously reported for the Sirius Scheimpflug camera–Placido topographer[24] and the Galilei G2 dual Scheimpflug analyzer (Ziemer Ophthalmic Systems AG)[33] and are similar to those reported for the Pentacam HR rotating Scheimpflug camera[33,34] and the Galilei G4 dual Scheimpflug analyzer (Ziemer Ophthalmic Systems AG).[35] Comparison to the repeatability of corneal power measurements provided by another AS-OCT device (RTVue) is difficult because in the only paper addressing this issue the author reported the pooled SD only.[22] However, if we divide the latter by the mean value of each parameter, we obtain a CoV of 0.39% and 0.65% for the anterior corneal curvature in unoperated eyes and post-LASIK eyes, respectively. These values are worse than those obtained in the present study.

Posterior corneal power measurements provided by the AS-OCT Placido topographer were similar to those obtained with Scheimpflug imaging and also showed similar repeatability.[24,33,35]

The repeatability of thinnest corneal thickness measurements was improved compared with that determined for the Sirius Scheimpflug camera–Placido topographer and the Pentacam HR rotating Scheimpflug camera[24,33,36] and was as high as the repeatability observed for the Galilei G2 dual Scheimpflug analyzer.[33] Measurements of the central epithelial thickness produced mean values (52.79 ± 3.20 μm and 55.77 ± 4.98 μm in unoperated eyes and in post-refractive surgery eyes, respectively) close to those previously reported with an AS-OCT device (53.4 ± 3.20 μm and 57.9 ± 6.08 μm, respectively) as well as with very high-frequency digital ultrasound (54.1 ± 2.96 μm and 60.5 ± 6.47 μm, respectively).[37] They showed slightly lower repeatability than measurements of the whole corneal thickness; however, they were still highly repeatable. The CoV were slightly higher than reported for the only other AS-OCT device that measures epithelial thickness, for which a CoV of 1.07% and 1.05% has been reported in unoperated eyes and post-refractive surgery eyes, respectively.[38]

FLA 5.5.0 DTD ■ JCRS9867_proof ■ 10 April 2018 ■ 7:08 pm

The excellent repeatability previously reported for aqueous depth measurements with all Scheimpflug cameras[24,33] was confirmed with the new AS-OCT Placido topographer, which also provided highly repeatable measurements of corneal diameter (similar to those given by the Galilei dual Scheimpflug analyzer).[39]

The repeatability of total corneal astigmatism measurements was good, as shown by the ICC of more than 0.9 for magnitude and both vectors, but not as high as that of other parameters, as shown by the higher CoV (∼20%) of total corneal astigmatism magnitude. Several studies[33,35,40,41] have reported similar CoVs for total corneal astigmatism in unoperated eyes (from 17.27% to 28.16%) and post-refractive surgery eyes (24.18%) imaged by a Scheimpflug camera; they related the high CoV to the low mean astigmatism power (0.82 ± 0.56 D) and the consequent small mean value in the denominator. Accordingly, Aramberri et al.[33] found a relatively high CoV for the keratometric astigmatism magnitude measured by the Pentacam HR rotating Scheimpflug camera (10.55%) and the Galilei G dual Scheimpflug analyzer (35.72%). Higher repeatability is expected with higher astigmatism values.

Unfortunately, comparison with the Casia AS-OCT is not possible because to our knowledge, no studies of the repeatability of its measurements in unoperated eyes and post-refractive surgery eyes have been published.

Our study has advantages as well as limitations compared with previous studies. The main advantage is the large sample, with 96 healthy eyes and 43 post-refractive surgery eyes. These numbers are higher than those previously reported by other authors.[33,35,40,41] Also, we measured only 1 eye of each participant, eliminating the compounding of bilateral-eye data. Of the limitations, we must highlight that the present study did not include eyes with pathologic corneas (eg, with keratoconus) and did not assess many parameters that can be automatically measured by the new AS-OCT device, such as those regarding wavefront analysis, pupil size and centration, anterior and posterior corneal elevation, or midperipheral and peripheral corneal thickness. Finally, we did not separately evaluate young eyes and old eyes, which may have different levels of collaboration, thus leading to different repeatability results.

In conclusion, we found that the repeatability of the new MS-39 AS-OCT device combined with a Placido topographer was high for all measured parameters in healthy unoperated eyes and in eyes that had previous excimer laser surgery. Agreement with the measurements of the Pentacam HR rotating Scheimpflug camera and the Sirius Scheimpflug camera–Placido topographer was high for a few parameters, such as aqueous depth and thinnest corneal thickness, and moderate for most parameters. Overall, measurements taken with the new AS-OCT Placido topographer cannot be considered interchangeable with those provided by the 2 Scheimpflug cameras.

WHAT WAS KNOWN

- Imaging devices based on Scheimpflug cameras provide repeatable measurements of the anterior segment of the eye.
- Anterior segment OCT can provide images with higher resolution than Scheimpflug photography but has been less commonly used for measuring corneal power.

WHAT THIS PAPER ADDS

- The new AS-OCT Placido topographer provided repeatable measurements of corneal power, thickness, and diameter as well as aqueous depth.
- Agreement with 2 Scheimpflug cameras was moderate for most parameters, and the new AS-OCT Placido topographer measurements cannot be considered interchangeable with those provided by the 2 Scheimpflug cameras.

REFERENCES

1. Koch DD, Ali SF, Weikert MP, Shirayama M, Jenkins R, Wang L. Contribution of posterior corneal astigmatism to total corneal astigmatism. J Cataract Refract Surg 2012; 38:2080–2087
2. Savini G, Versaci F, Vestri G, Ducoli P, Næser K. Influence of posterior corneal astigmatism on total corneal astigmatism in eyes with moderate to high astigmatism. J Cataract Refract Surg 2014; 40:1645–1653
3. Tonn B, Klaproth OK, Kohnen T. Anterior surface–based keratometry compared with Scheimpflug tomography–based total corneal astigmatism. Invest Ophthalmol Vis Sci 2015; 56:291–298. Available at: http://iovs.arvojournals.org/article.aspx?articleid=2212759. Accessed March 21, 2018
4. Ho J-D, Tsai C-Y, Liou S-W. Accuracy of corneal astigmatism estimation by neglecting the posterior corneal surface measurement. Am J Ophthalmol 2009; 147:788–795
5. Savini G, Næser K. An analysis of the factors influencing the residual refractive astigmatism after cataract surgery with toric intraocular lenses. Invest Ophthalmol Vis Sci 2015; 56:827–835; erratum, 2303. Available at: http://iovs.arvojournals.org/article.aspx?articleid=2212837. Erratum available at: http://iovs.arvojournals.org/article.aspx?articleid=2272564. Accessed March 21, 2018
6. Koch DD, Jenkins RB, Weikert MP, Yeu E, Wang L. Correcting astigmatism with toric intraocular lenses: effect of posterior corneal astigmatism. J Cataract Refract Surg 2013; 39:1803–1809
7. Goggin M, Zamora-Alejo K, Esterman A, van Zyl L. Adjustment of anterior corneal astigmatism values to incorporate the likely effect of posterior corneal curvature for toric intraocular lens calculation. J Refract Surg 2015; 31:98–102
8. Reitblat O, Levy A, Kleinmann G, Abulafia A, Assia EI. Effect of posterior corneal astigmatism on power calculation and alignment of toric intraocular lenses: comparison of methodologies. J Cataract Refract Surg 2016; 42:217–225
9. Goggin M, van Zyl L, Caputo S, Esterman A. Outcome of adjustment for posterior corneal curvature in toric intraocular lens calculation and selection. J Cataract Refract Surg 2016; 42:1441–1448
10. Abulafia A, Koch DD, Wang L, Hill WE, Assia EI, Franchina M, Barrett GD. New regression formula for toric intraocular lens calculations. J Cataract Refract Surg 2016; 42:663–671
11. Arbelaez MC, Versaci F, Vestri G, Barboni P, Savini G. Use of a support vector machine for keratoconus and subclinical keratoconus detection by topographic and tomographic data. Ophthalmology 2012; 119:2231–2238
12. Ambrósio R Jr, Caiado ALC, Guerra FP, Louzada R, Sinha Roy A, Luz A, Dupps WJ, Belin MW. Novel pachymetric parameters based on corneal tomography for diagnosing keratoconus. J Refract Surg 2011; 27:753–758
13. Feng MT, Belin MW, Ambrósio R Jr, Grewal SPS, Yan W, Shaheen MS, Jordon CA, McGhee C, Maeda N, Neuhann TH, Dick HB, Steinmueller A. International values of corneal elevation in normal subjects by rotating Scheimpflug camera. J Cataract Refract Surg 2011; 37:1817–1821

FLA 5.5.0 DTD ■ JCRS9867_proof ■ 10 April 2018 ■ 7:08 pm

14. Ambrósio R Jr, Dawson DG, Salomão M, Guerra FP, Caiado ALC, Belin MW. Corneal ectasia after LASIK despite low preoperative risk: Tomographic and biomechanical findings in the unoperated, stable, fellow eye. J Refract Surg 2010; 26:906–911

15. Savini G, Bedei A, Barboni P, Ducoli P, Hoffer KJ. Intraocular lens power calculation by ray-tracing after myopic excimer laser surgery. Am J Ophthalmol 2014; 157:150–153

16. Savini G, Huang J, Lombardo M, Serrao S, Schiano-Lomoriello D. Objective monitoring of corneal backward light scattering after femtosecond laser-assisted LASIK. J Refract Surg 2016; 32:20–25

17. Konstantopoulos A, Hossain P, Anderson DF. Recent advances in ophthalmic anterior segment imaging: a new era for ophthalmic diagnosis? Br J Ophthalmol 2007; 91:551–557. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1994765/pdf/551.pdf. Accessed March 21, 2018

18. Martínez-Albert N, Esteve-Taboada JJ, Montés-Micó R. Repeatability of whole-cornea measurements using an anterior segment imaging device based on OCT and Placido-disk. Expert Rev Med Devices 2017; 14:169–175

19. Shah JM, Han D, Htoon HM, Mehta JS. Intraobserver repeatability and interobserver reproducibility of corneal measurements in normal eyes using an optical coherence tomography-Placido disk device. J Cataract Refract Surg 2015; 41:372–381

20. Viswanathan D, Kumar NL, Males JJ, Graham SL. Comparative analysis of corneal measurements obtained from a Scheimpflug camera and an integrated Placido-optical coherence tomography device in normal and keratoconic eyes. Acta Ophthalmol 2015; 93:e488–e594. Available at: https://onlinelibrary.wiley.com/doi/epdf/10.1111/aos.12622. Accessed March 21, 2018

21. Srivannaboon S, Chotikavanich S, Chirapapaisan C, Kasemson S, Pongam W. Precision analysis of posterior corneal topography measured by Visante Omni: repeatability, reproducibility, and agreement with Orbscan II. J Refract Surg 2012; 28:133–138

22. Tang M, Chen A, Li Y, Huang D. Corneal power measurement with Fourier-domain optical coherence tomography. J Cataract Refract Surg 2010; 36:2115–2122

23. Ueno Y, Hiraoka T, Miyazaki M, Ito M, Oshika T. Corneal thickness profile and posterior corneal astigmatism in normal corneas. Ophthalmology 2015; 122:1072–1078

24. Savini G, Barboni P, Carbonelli M, Hoffer KJ. Repeatability of automatic measurements by a new Scheimpflug camera combined with Placido topography. J Cataract Refract Surg 2011; 37:1809–1816

25. Savini G, Næser K, Schiano-Lomoriello D, Ducoli P. Optimized keratometry and total corneal astigmatism for toric intraocular lens calculation. J Cataract Refract Surg 2017; 43:1140–1148

26. International Organization for Standardization. Accuracy (Trueness and Precision) of Measurement Methods and Results. Part 1. General Principles and Definitions. Geneva, Switzerland, ISO, 1994; (ISO 5725–1:1994)

27. Bland JM, Altman DG. Measurement error [Statistics notes]. BMJ 1996; 313:744. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2352111/pdf/bmj00560-0056b.pdf. Accessed March 21, 2018

28. Budenz DL, Fredette M-J, Feuer WJ, Anderson DR. Reproducibility of peripapillary retinal nerve fiber thickness measurements with Stratus OCT in glaucomatous eyes. Ophthalmology 2008; 115:661–666

29. McGraw KO, Wong SP. Forming inferences about some intraclass correlation coefficients. Psychol Meth 1996; 1:30–46

30. 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 March 21, 2018

31. Bergin C, Guber I, Hashemi K, Majo F. Tolerance and relative utility: two proposed indices for comparing change in clinical measurement noise between different populations (repeatability) or measurement methods (agreement). Invest Ophthalmol Vis Sci 2015; 56:5543–5547. Available at: http://iovs.arvojournals.org/article.aspx?articleid=2429937. Accessed March 21, 2018

32. McAlinden C, Khadka J, Pesudovs K. Precision (repeatability and reproducibility) studies and sample-size calculation [guest editorial]. J Cataract Refract Surg 2015; 41:2598–2604

33. Aramberri J, Araiz L, Garcia A, Illarramendi I, Olmos J, Oyanarte I, Romay A, Vigara I. Dual versus single Scheimpflug camera for anterior segment analysis: precision and agreement. J Cataract Refract Surg 2012; 38:1934–1949

34. Wang Q, Savini G, Hoffer KJ, Wu Z, Feng Y, Wen D, Hua Y, Yang F, Pan C, Huang J. A comprehensive assessment of the precision and agreement of anterior corneal power measurements obtained using 8 different devices. PLoS One 2012; 7 (9):e45607. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3458095/pdf/pone.0045607.pdf. Accessed March 21, 2018

35. Kim EJ, Montes de Oca I, Wang L, Weikert MP, Koch DD, Khandelwal SS. Repeatability of posterior and total corneal curvature measurements with a dual Scheimpflug–Placido tomographer. J Cataract Refract Surg 2015; 41:2731–2738

36. Huang J, Ding X, Savini G, Pan C, Feng Y, Cheng D, Hua Y, Hu X, Wang Q. A comparison between Scheimpflug imaging and optical coherence tomography in measuring corneal thickness. Ophthalmology 2013; 120:1951–1958

37. Reinstein DZ, Yap TE, Archer TJ, Gobbe M, Silverman RH. Comparison of corneal epithelial thickness measurement between Fourier-domain OCT and very high-frequency digital ultrasound. J Refract Surg 2015; 31:438–445. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4596531/pdf/nihms-726292.pdf. Accessed March 21, 2018

38. Ma XJ, Wang L, Koch DD. Repeatability of corneal epithelial thickness measurements using Fourier-domain optical coherence tomography in normal and post-LASIK eyes. Cornea 2013; 32:1544–1548. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4038409/pdf/nihms-586494.pdf. Accessed March 21, 2018

39. Savini G, Carbonelli M, Barboni P, Hoffer KJ. Repeatability of automatic measurements performed by a dual Scheimpflug analyzer in unoperated and post-refractive surgery eyes. J Cataract Refract Surg 2011; 37:302–309

40. Wang L, Shirayama M, Koch DD. Repeatability of corneal power and wavefront aberration measurements with a dual-Scheimpflug Placido corneal topographer. J Cataract Refract Surg 2010; 36:425–430

41. Cerviño A, Dominguez-Vicent A, Ferrer-Blasco T, García-Lázaro S, Albarrán-Diego C. Intrasubject repeatability of corneal power, thickness, and wavefront aberrations with a new version of a dual rotating Scheimpflug-Placido system. J Cataract Refract Surg 2015; 41:186–192

Disclosures: *Dr. Savini is a consultant to SiFi Medtech S.r.l. Dr. Hoffer licenses the registered trademark name "Hoffer" to Carl Zeiss Meditec AG (IOLMasters), Haag-Streit AG (Lenstar), Movu, Inc. (Argos), Nidek, Inc. (AL-Scan), Oculus Optikgeräte GmbH (Pentacam AXL), Tomey Corp. (OA-2000), Topcon Europe Medical B.V./Visia Imaging S.r.l. (Aladdin), Ziemer USA, Inc. (Galilei G6), and all A-scan biometer manufacturers. Dr. Schiano-Lomoriello has no financial or proprietary interest in any material or method mentioned.*

FLA 5.5.0 DTD ■ JCRS9867_proof ■ 10 April 2018 ■ 7:08 pm