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Agreement and Repeatability of Two Biometers to Measure Anterior Segment Components: Refractive Error Effect

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
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Background: To assess the repeatability and agreement between a new high-resolution optical coherence tomographer (OCT) and a Scheimpflug topographer.

Material/Methods: Sixty phakic and healthy participants were measured in this study, and one eye per participant was analyzed. Depending on their refractive error, each participant was allocated into a myopic, hyperopic, or emmetropic group. The Cirrus HD-OCT 5000 (Carl Zeiss Meditec, Jena, Germany), and the Sirius Scheimpflug topographer (Costruzione Strumenti Oftalmici, Florence, Italy) were used to take all measurements.

Results: The repeatability of these instruments to measure the anterior chamber depth, angle-to-angle, thinnest pachymetry, and both nasal and temporal angles was smaller than 0.15 mm, 0.40 mm, 10 µm, and 10 degrees, respectively. However, the repeatability of the Scheimpflug instrument to measure the apex pachymetry was about 15 µm, and for the OCT, it was about 4 µm for all groups. On average, the Sirius Scheimpflug instrument measured shallower anterior chamber depth (about 0.10 mm), shorter angle-to-angle (about 0.5 mm), thinner corneas (approximately 10 µm), and narrower angles (around 5 degrees) for all refractive groups.

Conclusions: The repeatability of the Cirrus OCT and Sirius Scheimpflug instrument was good and independent of the refractive error. Nevertheless, to judge whether these instruments could be used interchangeable, clinical criteria are needed.

MeSH Keywords: Biometry • Refractive Errors • Tomography, Optical Coherence

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3390 4 — 24

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Background

From a clinical point of view, measurements of the anterior segment are important to determine the intraocular lens (IOL) power, compensate the intraocular pressure based on the corneal thickness, or during the preoperative session of a refractive surgery. Nowadays, there are different non-contact biometers that can measure the anterior segment (including the cornea) in a few seconds. All of these instruments are based on different techniques, such as optical coherence tomography (OCT), Scheimpflug imaging, or optical low coherence reflectometry.

In order to gain widespread use in clinical and research settings, a new device must provide measurements that are repeatable and in agreement with other currently established devices that measure the same parameter [1]. Nevertheless, it should be taken into account that ocular biometers could have insensitivities and errors intrinsic to the measure procedure that could result in differences between measurements, observers, or equipment [2]. As a result, many clinical studies have assessed the repeatability (consecutive measurements taken by the same observer), reproducibility (consecutive measurements taken by different observers), and agreement among ocular biometers, as is reflected in the reviews and meta-analyses published [2–4].

Regarding developments done in OCT biometers, the new instruments have been shown to be useful to assess corneal and conjunctival thickness in contact lens users [5], to diagnose closed angles [6], or to evaluate changes in the ciliary muscle *in vivo* [7,8]. The Cirrus HD-5000 OCT (Carl Zeiss Meditec, Jena, Germany) is a retinal OCT that can be converted into an anterior segment OCT through an external module. In this regard, the repeatability and reproducibility have been proven to be good [9], although the refractive error, which could affect the precision of the instrument, has not been assessed.

On the other hand, Scheimpflug biometers have also been proven to be versatile since they have been used to assess the effect of the accommodation in the anterior segment [10,11], grade lens opacities objectively [12,13], or evaluate the corneal topography and anterior segment biometry. The Sirius (Costruzione Strumenti Oftalmici, Florence Italy) is a rotating Scheimpflug camera that has been shown to be repeatable and reproducible, and has been shown to have good agreement with the Cirrus OCT [9]. Nevertheless, the repeatability of this equipment has not been assessed as a function of the refractive error.

In this context, the main purpose of the present study was to assess the repeatability of the Cirrus OCT and Sirius Scheimpflug instrument as a function of the participant's refractive error. At the same time, an agreement analysis was also performed to reveal whether the refractive error could have any impact in the interchangeability of these instruments.

Material and Methods

Participants

Sixty phakic and healthy participants were measured in this study and contact lens users were asked to attend the examination session without wearing them. All participants had all measurements taken during the same sessions, and only one eye per participant was measured in order not to artificially reduce the confidence interval around the limits of agreement [14]. Each participant was allocated into the myopic, hyperopic, or emmetropic group depending on the refractive error. The myopic group included refractive errors ≤–0.50 D, and the hyperopic group did refractive errors ≥+0.50 D. The ethical approval was given by the Swedish Regional Ethics Committee in Stockholm, and the study was performed in adherence with the tenets of Declaration of Helsinki.

Anterior segment devices

The Cirrus HD-OCT 5000 is a high-resolution posterior segment OCT that can be converted into an anterior chamber OCT. To do so, 2 external lenses should be placed on the equipment to allow the image acquisition of the cornea or anterior chamber. The former lens measures automatically the apex and thinnest pachymetry through a scan size of 9×2 mm. Nevertheless, the anterior segment biometry should be measured manually with the anterior chamber lens and the scan dimensions are 15.5×5.8 mm.

The Sirius (Costruzione Strumenti Oftalmici, Florence Italy) is an anterior segment instrument that combines a Placido disk topographer and a rotating Scheimpflug camera. This system takes one image every 7 degrees (i.e., 25 images per eye), and monochromatic light, with wavelength of 475 nm, is used to take the measurements. This equipment reports automatically the measurements of the cornea and anterior segment of the eye.

Experimental procedure

All measurements took place at the St. Erik Eye Hospital (Karolinska Institutet, Stockholm, Sweden). A skilled operator took 2 measurements on each observer with both systems, and all measurements were taken under repeatability conditions [15]. The repeatability was calculated from the 2 measurements taken with each equipment, one measurement was used to assess the agreement.

Each image was taken 4 seconds after that participant's last blink to let the tear film spread over the cornea [16] and blinking was not allowed during the image acquisition. In case the patient had problems maintaining stable fixation, an external fixation target was used. For analysis purposes, the internal anterior chamber depth (ACD), angle-to-angle, nasal and temporal

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Table 1. Demographic data of the participants included in the study as a function of the refractive error.

	Age (years)	Spherical equivalent (diopters)	Gender
Emmetropic	28.35±6.58 [22 to 47]	0.06±0.14 [–0.25 to 0.25]	75% Female 25% Male
Myopic	27.45±7.98 [20 to 57]	–3.82±2.16 [–8.85 to –0.63]	60% Female 40% Male
Hyperopic	27.70±6.67 [20 to 50]	0.78±0.49 [0.38 to 1.88]	80% Female 20% Male

angles, and the thinnest and apex pachymetries were measured after the last participant was measured with both devices.

Statistical analysis

Two Student's *t*-tests were performed in this study. One of them was used to reveal statistically significant differences between the 2 measurements taken with the same equipment for the same parameter. The other Student's *t*-test was aimed to assess whether differences between both instruments were statistically significant. In both cases, statistically significant differences were considered for $P<0.05$.

The Bland-Atlman analysis was used to assess the agreement between the OCT and Scheimpflug instruments as a function of the participant's refractive error [17]. Due to the limits of agreement are estimators, the 95% confidence interval (CI) of each limit was calculated [14]. On the other hand, the within participant standard deviation (SD) and the repeatability limit was used to describe the repeatability of each equipment. It should be kept in mind that the repeatability limit assesses the interval within the 95% CI of the measurements will fall within when repeatable measurements are taken [14].

Results

All in all, 60 eyes of 60 patients were included in the study, from which 28% were male and 72% were female. Their mean age was 28.83±6.99 years (range: 20 to 57 years), and the average spherical equivalent was –0.99±2.39 D (range: –8.50 to 1.88 D). Table 1 summarizes the demographic results as a function of the ametropic group.

Anterior chamber depth

Tables 2 and 3 summarize the repeatability results as a function of the refractive error for the OCT and Scheimpflug instruments, respectively. Regarding the results obtained for the ACD, no statistically significant differences ($P>0.05$) were obtained between the 2 measurements taken with both systems for each refractive group. Nevertheless, the results showed that the Sirius (Scheimpflug system) tended to have better repeatability results than the Cirrus OCT, even though the repeatability limit was smaller than 0.15 mm for all refractive groups.

Table 4 depicts the Bland-Altman results for each anterior segment biometry as a function of the refractive group. On average, the Scheimpflug system measured about 0.10 mm deeper ACD than the OCT for all refractive groups, and in all cases, differences were not statistically significant ($P>0.05$). This table also shows that the Scheimpflug instrument measured as a maximum 0.30 mm deeper and 0.1 mm shallower ACD than the OCT. The confidence interval around each limit of agreement varied from 0.118 (for the myopic group) to 0.151 mm (for the hyperopic group).

Angle-to-angle

The OCT instrument showed comparable measurements between the first and second acquisitions ($P>0.05$) for all refractive groups (Table 2). The repeatability limit obtained for each refractive group was similar, where the minimum and maximum values were 0.22 mm (for the emmetropic group) and 0.29 mm (for the other 2 groups), respectively. Similarly, the Scheimpflug topographer obtained comparable measurements within each group ($P>0.05$), and in all cases the repeatability limit was smaller than 0.40 mm.

Regarding the agreement between these 2 instruments (Table 4), the Cirrus OCT tended to measure shorter ATA than the Sirius Scheimpflug system, where statistically significant differences were obtained in the myopic and hyperopic groups ($P<0.05$). At the same time, based on the limits of agreement, the OCT measured about 1 mm shorter and 0.4 mm larger ATA than the Scheimpflug instrument. Furthermore, the confidence interval around the limits of agreement ranges between 0.3 mm (for the myopic group) and 0.5 mm (for the hyperopic group).

Thinnest pachymetry

The Cirrus OCT and Sirius Scheimpflug topographer obtained similar thinnest pachymetry outcomes between both measurements for each refractive group (Tables 2, 3). Furthermore, the

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Table 2. Repeatability outcomes obtained with the anterior segment optical coherence tomographer to measure the anterior eye segment.

	Emmetropic				Myopic				Hyperopic			
	Meas. 1	Meas. 2	Sw	Repeata-bility limit	Meas. 1	Meas. 2	Sw	Repeata-bility limit	Meas. 1	Meas. 2	Sw	Repeata-bility limit
ACD	3.1±0.3 [2.4 to 3.6]	3.0±0.3 [2.4 to 3.6]	0.03	0.09	3.1±0.3 [2.4 to 3.6]	3.1±0.3 [2.5 to 3.6]	0.02	0.05	2.9±0.3 [2.4 to 3.5]	2.9±0.3 [2.5 to 3.5]	0.04	0.10
ATA	12.2±0.5 [11.4 to 12.9]	12.3±0.5 [11.4 to 13.1]	0.08	0.22	12.5±0.5 [11.5 to 13.3]	12.6±0.4 [11.6 to 13.3]	0.11	0.29	11.9±0.4 [11.3 to 12.9]	11.9±0.4 [11.3 to 12.9]	0.10	0.29
Thinnest pachymetry	0.52±0.04 [0.4 to 0.6]	0.52±0.04 [0.4 to 0.6]	0.001	0.002	0.51±0.02 [0.5 to 0.6]	0.52±0.02 [0.5 to 0.6]	0.001	0.002	0.51±0.04 [0.4 to 0.6]	0.51±0.04 [0.4 to 0.6]	0.001	0.001
Apex pachymetry	0.53±0.04 [0.4 to 0.6]	0.52±0.04 [0.4 to 0.6]	0.001	0.004	0.51±0.02 [0.5 to 0.6]	0.52±0.02 [0.5 to 0.6]	0.001	0.002	0.52±0.04 [0.4 to 0.6]	0.52±0.04 [0.4 to 0.6]	0.001	0.004
Nasal angle	36±5 [27 to 50]	37±5 [30 to 45]	2	6	36±5 [25 to 47]	36±5 [27 to 44]	2	5	35±6 [28 to 53]	35±6 [24 to 53]	2	5
Temporal angle	37±5 [27 to 47]	37±5 [29 to 48]	1	4	36±5 [25 to 45]	37±5.4 [24 to 46]	1	4	38±6 [30 to 52]	37±6 [30 to 51]	1	4

Each measurement was expressed as the mean ± standard deviation, with the corresponding minimum and maximum interval. All outcomes are expressed in mm, except both angles that are done in degrees. Meas – measurement; Sw – within subject standard deviation; ACD – anterior camber depth; ATA – angle-to-angle.

repeatability limit of each instrument was smaller than 10 µm for all refractive groups.

On average, the Cirrus OCT measured between 10 µm and 20 µm thicker corneas (Table 4), although differences were not statistically significant ($P>0.05$). From these results, the OCT measured as a maximum 53 µm thicker and 21 µm thinner corneas than the Scheimpflug topographer.

Apex pachymetry

No statistically significant differences were obtained between the 2 measurements taken with each instrument ($P>0.05$). Nevertheless, the Cirrus OCT showed better repeatability limits than the Sirius Scheimpflug topographer for all refractive groups. In this regard, the maximum value for the OCT was 4 µm and for the Scheimpflug instrument it was 15 µm (Tables 2, 3).

Regarding the agreement between these instruments, the mean apex pachymetry was thinner with the Cirrus OCT than with the Sirius Scheimpflug equipment, with a mean difference of 10 µm for each refractive group (Table 4). Furthermore, based on the results of the limits of agreement, the Cirrus OCT measured about 40 µm thicker and 23 µm thinner corneas than the Sirius Scheimpflug system. In all cases, the confidence interval was smaller than 30 µm.

Nasal angle

The repeatability results obtained for the Cirrus OCT (Table 2) and Sirius Scheimpflug topographer (Table 3) were similar among all refractive groups. Concretely, the repeatability limit of each system was smaller than 10 degrees for all refractive groups.

Regarding the agreement between these systems (Table 4), the mean bias was almost 0 degrees for the emmetropic and hyperopic groups, meanwhile the OCT measured on average 10 degrees wider nasal angle than the Scheimpflug topographer. Based on the limits of agreement, the Cirrus OCT measured 18 degrees wider and 18 degrees narrower nasal angles than the Sirius Scheimpflug equipment.

Temporal angle

The repeatability analysis showed comparable values ($P>0.05$) between the first and second measurement taken with each instrument and within each refractive group. Furthermore,

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Table 3. Repeatability outcomes obtained with the Scheimpflug system to measure the anterior eye segment.

	Emmetropic				Myopic				Hyperopic			
	Meas. 1	Meas. 2	Sw	Repeata-bility limit	Meas. 1	Meas. 2	Sw	Repeata-bility limit	Meas. 1	Meas. 2	Sw	Repeata-bility limit
ACD	3.13±0.27 [2.45 to 3.53]	3.16±0.27 [2.45 to 3.61]	0.02	0.05	3.3±0.3 [2.5 to 3.7]	3.27±0.34 [2.49 to 3.86]	0.03	0.08	2.98±0.27 [2.49 to 3.61]	2.98±0.26 [2.49 to 3.60]	0.02	0.05
ATA	12.5±0.4 [11.78 to 13.44]	12.5±0.5 [11.9 to 13]	0.13	0.38	13.2±0.4 [12.36 to 14.02]	13.21±0.41 [12.35 to 14.02]	0.07	0.21	12.35±0.47 [11.5 to 13.19]	12.34±0.48 [11.56 to 13.21]	0.06	0.16
Thinnest pachymetry t	0.53±0.04 [0.4 to 0.6]	0.53±0.04 [0.4 to 0.6]	0.003	0.008	0.53±0.04 [0.47 to 0.62]	0.53±0.04 [0.48 to 0.63]	0.002	0.007	0.528±0.03 [0.44 to 0.573]	0.53±0.03 [0.45 to 0.57]	0.003	0.007
Apex pachymetry	0.53±0.04 [0.45 to 0.59]	0.53±0.04 [0.45 to 0.59]	0.003	0.010	0.53±0.03 [0.48 to 0.63]	0.54±0.04 [0.48 to 0.63]	0.003	0.008	0.53±0.03 [0.45 to 0.58]	0.53±0.04 [0.45 0.58]	0.005	0.015
Nasal angle	36±11 [10 to 52]	37±10.4 [5 to 52]	2	6	44±6 [29 to 52]	44±5 [30 to 52]	2	5	38±9 [23 to 51]	38±9 [24 to 59]	2	6
Temporal angle	41±7 [25 to 53]	42±6 [30 to 51]	1	3	41±7 [26 to 55]	41±6 [24 to 54]	2	5	42±8 [27 to 58]	42±8 [27 to 59]	1	4

Each measurement was expressed as the mean ± standard deviation, with the corresponding maximum and minimum interval. All measurements are expressed in mm, except both angles that are done in degrees. Meas – measurement; Sw – within subject standard deviation; ACD – anterior camber depth; ATA – angle-to-angle.

Table 4. Bland-Altman comparison between the Optical Coherence Tomographer and the Scheimpflug instrument in the measurement of each anterior segment and corneal biometry as a function of the refractive error.

	Emmetropic				Myopic				Hyperopic			
	Bias (MD ±SD)	p-Value	95% LoA	CI	Bias (MD ±SD)	p-Value	95% LoA	CI	Bias (MD ±SD)	p-Value	95% LoA	CI
ACD	–0.11 ±0.105	0.257	[–0.317 to 0.096]	0.141	–0.11 ±0.086	0.183	[–0.280 to 0.057]	0.118	–0.09 ±0.11	0.286	[–0.314 to 0.128]	0.151
ATA	–0.35 ±0.34	0.051	[–1.036 to 0.333]	0.480	–0.66 ±0.22	<0.001*	[–1.097 to –0.217]	0.309	–0.37 ±0.38	0.009*	[–1.128 to 0.397]	0.521
Thinnest pachymetry	–0.01 ±0.01	0.218	[–0.036 to 0.013]	0.018	–0.01 ±0.01	0.135	[–0.023 to –0.004]	0.007	–0.02 ±0.02	0.176	[–0.053 to 0.021]	0.027
Apex pachymetry	–0.01 ±0.02	0.214	[–0.041 to 0.023]	0.023	–0.01 ±0.01	0.104	[–0.027 to –0.002]	0.009	–0.01 ±0.01	0.299	[–0.033 to 0.007]	0.014
Nasal angle	0.11 ±9.56	0.803	[–18.636 to 18.847]	13.14	–8.00 ±5.18	<0.001*	[–18.142 to 2.142]	7.110	–1.75 ±7.54	0.462	[–16.525 to 13.025]	10.096
Temporal angle	–5.16 ±5.01	0.011	[–14.985 to 4.670]	6.89	–4.28 ±6.63	0.044	[–17.276 to 8.720]	9.314	–4.55 ±5.57	0.064	[–15.481 to 6.381]	7.469

All measurements are expressed in mm, except both angles that are done in degrees. MD – mean difference; SD – standard deviation; LoA – limits of agreement; CI – confident interval; ACD – anterior camber depth; ATA – angle to angle.

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the repeatability limit obtained with the Cirrus OCT and Sirius Scheimpflug topographer was smaller than 10 degrees for each refractive group (Tables 2, 3).

The Cirrus OCT measured on average 5 degrees wider temporal angles than the Sirius Scheimpflug equipment (Table 4), although statistically significant differences were only obtained for the myopic group ($P<0.05$). Based on the limits of agreement, the Sirius Scheimpflug topographer measured as a maximum about 17 degrees narrower and 8 degrees wider temporal angles than the Cirrus OCT for all refractive groups.

Discussion

The main objective of the present study was to evaluate the repeatability of 2 anterior segment biometers as a function of the refractive error. On the other hand, the agreement between these 2 instruments was assessed as a function of the refractive error. Consequently, clinicians might benefit from the objective evidences reported in the present study.

Anterior chamber depth

The repeatability limits to measure the ACD were similar among the 3 refractive groups for each instrument (Tables 2, 3). At the same time, the repeatability limit between the Cirrus OCT and Sirius Scheimpflug instrument was also similar for the same refractive group. In all cases, the value was smaller than 0.15 mm. Thus, it can be concluded that both instruments are repeatable, and their repeatability does not dependent on the participant's refractive error.

A former study assessed the precision of the Cirrus OCT in 80 healthy eyes [9] and found that the repeatability limit of this instrument was 0.07 mm to assess the ACD, which was in agreement with the results obtained in the present study (Table 2). On the other hand, the repeatability of the Scheimpflug instrument to measure the ACD has been assessed in several studies [9,18–21]. One of these studies reported a repeatability of 0.02 mm, which agrees with the results obtained in the present study [18]. Other studies described the repeatability of the Sirius Scheimpflug instrument in terms of coefficients of variation [20,21]. In this regard, one of these studies obtained a coefficient of variability of 0.28 [20], meanwhile, the other study obtained a coefficient of variation of 0.56 [21]. Unfortunately, direct comparisons are not possible due to the repeatability is expressed in different metrics.

Regarding the agreement between the Cirrus OCT and Sirius Scheimpflug instrument, the former instrument measured on average about 0.10 mm deeper ACD than the other instrument for all refractive groups (Table 4). Based on the limits of agreement and confidence interval, it should be considered that the Sirius Scheimpflug instrument measured about 0.2 mm deeper and 0.4 mm shallower ACD than the Cirrus OCT. Besides these results, the agreement between these instruments seems not to be affected by the participant´s refractive error. In order to judge whether these instruments could be used interchangeable, clinical criteria are needed [14,15]. For example, it has been reported that an error in the ACD measurement of 0.60 mm is associated with a change in the IOL power of 0.25 D [2]. Thus, based on this criterion, it could be concluded that the Cirrus OCT and Sirius Scheimpflug instrument could be interchangeable to calculate the IOL power.

Angle-to-angle

The Sirius Scheimpflug and Cirrus OCT instruments showed a repeatability limit smaller than 0.40 mm for all refractive groups (Tables 2, 3). As has been reported previously, this value represents the interval within the 95% CI of the measurements when repeatable measurements are taken. Thus, based on these results, we could conclude that both systems are repeatable independently of the refractive error. A previous study evaluated the reproducibility of these instruments [9]. According to the results obtained, the reproducibility of the Cirrus OCT was about 2 times its repeatability, meanwhile the Sirius Scheimpflug showed similar repeatability and reproducibility outcomes. Those results were expected because the angle-to-angle is measured manually in the OCT instrument and automatically in the Scheimpflug one. Thus, different criteria between observers to measure the angle-to-angle could lead to those results.

The OCT instrument measured on average between 0.4 mm and 0.6 mm bigger angle-to-angle distances than the Scheimpflug instrument (Table 4). Furthermore, the OCT measured as a maximum 1.4 mm shorter and 0.6 mm larger angle-to-angle than the Scheimpflug instrument. Currently, the angle-to-angle could be used to estimate the anterior chamber lens diameter, which could vary in general in 0.50 mm steps. Thus, based on this criterion, we could conclude that the measurement of the angle-to-angle provided by these instruments should not be used interchangeably.

Thinnest pachymetry

The Cirrus OCT instrument showed a repeatability of about 2 µm, meanwhile for the Sirius Scheimpflug instrument it was about 7 µm for all refractive groups (Tables 2, 3). Thus, these results showed that the instruments analyzed in this study were repeatable when it comes to measurement of the thinnest pachymetry. Furthermore, the repeatability of these instruments seems to be independent of the participant's refractive error. Several studies assessed the repeatability and

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reproducibility of the Sirius instrument [9,22]. According to those studies, the precision values were similar between each other and smaller or equal to 5 µm. The results obtained seem to agree with those obtained previously.

On average, the Cirrus OCT measured about 10 µm thicker corneas than the Sirius Scheimpflug instrument for each refractive group. At the same time, the limits of agreement and confident intervals showed that as a maximum, the OCT measured about 45 thicker and 22 µm thinner corneas than the Scheimpflug (Table 4). Thus, according to these results, the participant´s refractive error seems not to affect the agreement between these instruments. Nowadays, the corneal pachymetry can be used to recalculate the intraocular pressure [23], calculate the residual stromal thickness, decide the proper corneal refractive procedure, and assess changes in the corneal pachymetry during the follow-up of a specific pathological condition [22]. Since differences between both instruments could be clinically significant for all refractive groups, their interchangeability is not recommended.

Apex pachymetry

The repeatability limit obtained for the OCT instrument was smaller than 5 µm, meanwhile for the Scheimpflug was about 15 µm for all refractive groups (Tables 2, 3). Thus, based on these results, it can be concluded that the repeatability of each instrument is good and independent of the participant's refractive error. A previous study assessed precision of these instruments and obtained a repeatability limits smaller than 15 µm [9]. On the other hand, several studies evaluated the repeatability of the Sirius Scheimpflug instrument in terms of the within-patient standard deviation. For one study, the repeatability value was 3.10 µm [24] and for the other study it was 3.17 µm [22]. In this study, the within-patient standard deviation was about 3 µm for all refractive groups, which agreed with the previous results obtained.

On the other hand, the Cirrus OCT measured 10 µm thicker corneas than the Sirius Scheimpflug instrument for each refractive group. Nevertheless, the Scheimpflug instrument measured as a maximum 39 thicker and 57 µm thinner corneas than the OCT (Table 4). Although the agreement seems to be independent of the refractive error, these differences could be clinically significant. Consequently, interchangeability between these 2 instruments should not be recommended.

Nasal angle

The Sirius Scheimpflug and Cirrus OCT instruments showed a repeatability limit smaller than 10 degrees for all refractive groups (Tables 2, 3). According to these results, it can be concluded that the repeatability limit of these instruments is good and independent of the refractive error. The results obtained in the present study were in accordance to the results obtained in a previous study [9] in which the within-patient standard deviation was 1 µm and 3 µm for the Cirrus OCT and Sirius Scheimpflug instruments, respectively.

Regarding the agreement between these 2 instruments, the Cirrus OCT system tended to measure wider angles than the Sirius Scheimpflug instrument for the myopic and hyperopic groups (Table 4). Nevertheless, the mean bias for the emmetropic group was almost zero. These results could be the result of differences in the participant's accommodation or variations in the pupil size due to differences in the room lightning conditions. Additionally, the OCT measured as a maximum about 25 degrees wider and narrower angles than the Scheimpflug instrument. Thus, based on these results, differences between both devices might be clinically significant, and as a result their interchangeability should not be recommended.

Temporal angle

The repeatability limits of both instruments were smaller than or equal to 5 degrees for all refractive errors. These results agree with those obtained previously [9] in which the within patient standard deviation was smaller than 5 degrees in a population of healthy eyes. Thus, based on these results, it can be concluded that the repeatability of these instruments is good and robust against differences in the refractive error.

On the other hand, the OCT measured about 5 degrees wider angles than the Scheimpflug system for all refractive errors (Table 4). Besides these results, the Scheimpflug equipment measured as a maximum 21 degrees wider and 13 degrees narrower angle than the OCT. Even though the angle measurement has various clinical uses, the differences between these 2 instruments are big enough in order not to recommend their interchangeability. Nevertheless, the refractive error seems not to affect the agreement between these instruments.

Differences in the agreement between the OCT and Scheimpflug instruments could be related to variations in the participant's accommodation between instruments. Further studies could use paralysis of accommodation to avoid this possible effect. Furthermore, healthy and phakic eyes were included in this study, and as a result, the conclusions obtained in this study should not be inferred to pathological or post-surgery corneas. Further studies would be useful to analyze the repeatability and agreement of these instruments including participants with irregular or post-surgery corneas. At the same time, the sample size could be a limiting factor, since only 20 eyes per group were included.

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Conclusions

The repeatability of the Sirius Scheimpflug instrument and Cirrus OCT instrument was good and independent of the refractive error. Nevertheless, clinical criteria would be needed to conclude if these instruments could be used interchangeable.

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