Evaluation of two scheimpflug camera-based devices in the analysis of keratoconus

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Purpose
This study aimed to evaluate the measurements of the anterior segment of the eye by two Scheimpflug camera-based systems: the Pentacam HR imaging system and the Sirius imaging system in keratoconus patients.
Patients and methods
Keratoconus patients were recruited prospectively. Measurements with the Oculus Pentacam and with the CSO Sirius were performed according to the manufacturer's instructions. For every eye, the following parameters were analyzed statistically. The anterior ketatometric reading of the flattest meridian K1, anterior K2, anterior mean *K*, anterior K_{max}, pachymetry at the thinnest location, the highest anterior corneal elevation in the 3-mm pupillary area, the highest posterior corneal elevation in the 3-mm pupillary area, and the best-fit sphere for the anterior corneal surface and posterior corneal surface at the same diameter of analysis. Agreement between Sirius and Pentacam was assessed by calculating 95% limits of agreement and plotting Bland–Altman graphs.
Results
Fifty eyes from individuals (26 men, 24 women) aged 20–38 years were evaluated. The mean K_1 difference between the measurements of both machines was −0.54±1.02 D. The mean K_2 difference between the measurements of both machines was −1.40±1.53 D. The mean K_{max} difference between the measurements of both machines was −0.60±2.38 D. The mean avgerage *K* difference between the measurements of both machines was −0.89±1.06 D. The mean thinnest location pachymetry difference between the measurements of both machines was 9.20±14.14 μm. The mean highest anterior elevation difference between the measurements of both machines was 6.86±11.43. The mean highest posterior elevation difference between the measurements of both machines was 20.52±21.32. The mean anterior best-fit sphere difference between the measurements of both machines was 0.14±0.13. The mean posterior best-fit sphere difference between the measurements of both machines was 0.16±0.16. The difference was statistically significant.
Conclusion
All the measurements between both Pentacam and Schwind Sirius showed a significant positive correlation, except for the highest anterior and posterior elevation measurements. Schwind Sirius produces keratometry measurements higher than Pentacam in keratoconus patients. However, corneal thickness, the radius of the best-fit sphere, and the highest anterior and posterior elevation measurements by Pentacam were higher than Schwind Sirius measurements. The differences between the measurements of Sirius and Pentacam were statistically significant. Therefore, it is recommended that the measurements of these devices not be used interchangeably.

Keywords:
cornea, keratoconus, pentacam, scheimpflug

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Introduction

Keratoconus is a progressive corneal disease characterized by central thinning and decrease visual quality [1]. Onset is often during the second decade of life onwards, typically when the patient is still socially and physically active. The reduced visual quality leads many patients with keratoconus to present at refractive surgery centers for alleviation of their symptoms by LASIK. Keratoconus and formefrustekeratoconus are contraindications for LASIK because of the high risk of postoperative ectasia. The incidence of keratectasia after LASIK is ~0.5% [2]. Early detection of formefrustekeratoconus and keratoconus is often performed by a thorough

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topographic evaluation in conjunction with a clinical examination. Improvement in the ability to detect and diagnose suspicious to advanced keratoconus will enable the exclusion of patients at risk for corneal ectasia after corneal refractive surgery. Earlier detection of formefrustekeratoconus may lead to an earlier intervention. The specificity and sensitivity of the various automated keratoconus screening software are still not adequate for broad clinical use. Most of these automated detection programs cannot accurately classify suspicious topographies with an adequate degree of reliability [3,4]. The Pentacam HR uses a rotating Scheimpflug camera to image the anterior segment of the eye. It provides, in a single scan, anterior segment imaging (two-dimensional and three-dimensional), anterior and posterior corneal topography, complete corneal pachymetry, and lens densitometry. The repeatability of Pentacam central corneal thickness, corneal power, and anterior chamber depth measurements has been validated and the measurements were found to be comparable with other imaging modalities [5–9]. The Sirius topography system has been introduced recently. It combines two mechanisms of action: the Scheimpflug rotating camera with Placido disk topography [10].

Patients and methods

Keratoconus patients aged 20–38 years were recruited prospectively from among the medical personnel of the I care Medical Center. The inclusion criterion was the presence of keratoconus diagnosed according to Rabinowitz's four quantitative videokeratographic indices for screening keratoconic patients:

Central corneal power >47.2 D.
Inferior-superior dioptric asymmetry over 1.2 D.
Sim-K astigmatism >1.5 D.
Skewed radial axes >21°.

Patients with a history of extensive corneal scarring, previous ocular surgery, glaucoma, retinal disease, and Pellucid marginal degeneration were excluded.

All participants were informed about the study and signed an informed consent document.

Measurement system

The Sirius system (CostruzioniStrumentiOftalmici, Florence, Italy) is a new topography device that uses the principles of Scheimpflug photography and enables the acquisition and processing of 25 radial sections of the cornea and the anterior chamber. The combination between 1 monochromatic 360° rotating Scheimpflug camera and a Placido disk enables analysis of the cornea and anterior segment, providing 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, a corneal wavefront map with an analysis of visual quality, and corneal pachymetry maps. Specifically, this system enables measurement of 35 632 points of the anterior corneal surface and 30 000 points of the posterior corneal surface in a high-resolution mode in approximately less than 1 s [10].

With this point-by-point information of the anterior and posterior corneal surfaces, a pachymetric map is reconstructed. In the current study, software, version 1.0.5.72 (Phoenix; Costruzione Strumenti Of talmici) was used.

Only high-quality measurements (quality score 90%) were included for further analysis. Measurement was first performed using the Pentacam HR (Oculus OptikgerateGmbH, Wetzlar, Germany). After 10 min of rest, a measurement was made using the Sirius system. The following parameters were assessed. Anterior: for every eye, the following parameters were statistically analyzed: anterior ketatometric reading of the flattest meridian K_1, anterior K_2, anterior mean K, anterior K_{max}, pachymetry at the thinnest location, the highest anterior corneal elevation in the 3-mm pupillary area, the highest posterior corneal elevation in the 3-mm pupillary area, and the best-fit sphere for the anterior corneal surface and the posterior corneal surface at the same diameter of analysis.

Statistical analysis

Statistical analysis was carried out using the IBM SPSS software package, version 20.0. (IBM Corp., Armonk, New York, USA). Normality of all data distributions was confirmed using the Kolmogorov–Smirnov test. Quantitative data were described using range (minimum and maximum), mean, SD, and median. Significance of the obtained results was judged at the 5% level.

For normally quantitative variables, we used a Paired t-test to compare between the two devices, the Pearson coefficient to correlate between two normally quantitative variables, and the Wilcoxon signed ranks test was used for abnormally quantitative variables.

Furthermore, Spearman's correlation coefficients were used to correlate between the parameters evaluated. All statistical tests were two tailed and P values less than 0.05 were considered statistically significant. To assess

agreement and interchangeability between devices, the method suggested by Bland and Altman was used. Differences between measurements were plotted against their mean and the 95% limits of agreement were determined as the two mean difference±standard deviation of the differences.

Results

Fifty keratoconus patients (26 men, 24 women) aged 20–38 years (mean: 25.82±6.03 years) were recruited prospectively. Measurements of 50 eyes were analyzed. The mean values measured by the two instruments are reported in Table 1.

Agreement between the instruments is presented as Bland–Altman plots for all the measurements (Fig. 1).

Discussion

This study examined 50 eyes of keratoconus patients. We evaluated different parameters by Pentacam and Sirius (Keratometric readings: K_1, K_2, mean K, and K_{max}), pachymetry of the thinnest location, the highest anterior and posterior corneal elevation within the pupillary area, and the best-fit sphere of the anterior and posterior corneal surfaces.

The differences between Pentacam and Sirius measurements were statistically significant for all measured parameters, except for the K_{max}.

The Sirius system yielded higher keratometry values than the Pentacam. There was a significant positive correlation between the measurements of both instruments (r=0.963). For all the keratometry readings, except the mean K_{max}, the differences were statistically significant.

Wang *et al.* [11] also reported significant differences between Sirius and Pentacam in the mean keratometry measurements, with the Sirius measurements being higher than the Pentacam, but reported that these differences, although significant, were below 0.1 diopters, which is not clinically meaningful.

Shetty *et al.* [12] found significant differences in the measurements between the Pentacam, the Schwind Sirius, and the Galilei devices and concluded that they cannot be used interchangeably for anterior segment measurements in keratoconus patients.

Finis *et al.* [13] reported differences between the mean keratometry of the flat meridian at 3 mm distance to the apex between both devices, but this was not statistically significant; however, the keratometry of the steep meridian of the corneal back surface was significantly different between the two devices.

Another study comparing pentacam, Sirius, and Galilei in normal individuals reported significant differences in the measurements of keratometry between the three devices (P<0.001). Similar results were found in the same study on keratoconic eyes, with all machines showing a statistically significant difference for all parameters [14].

In contrast to these results, Savini and colleagues reported no difference in the keratometry measurements of the Pentacam and Sirius. This discrepancy may be related to the different ages of the two samples as the mean age of the participants in Savini's study (57.9 years) was older than the mean age of our participants (25.8 years). Young patients have better fixation and stability of the tear film than older patients [15].

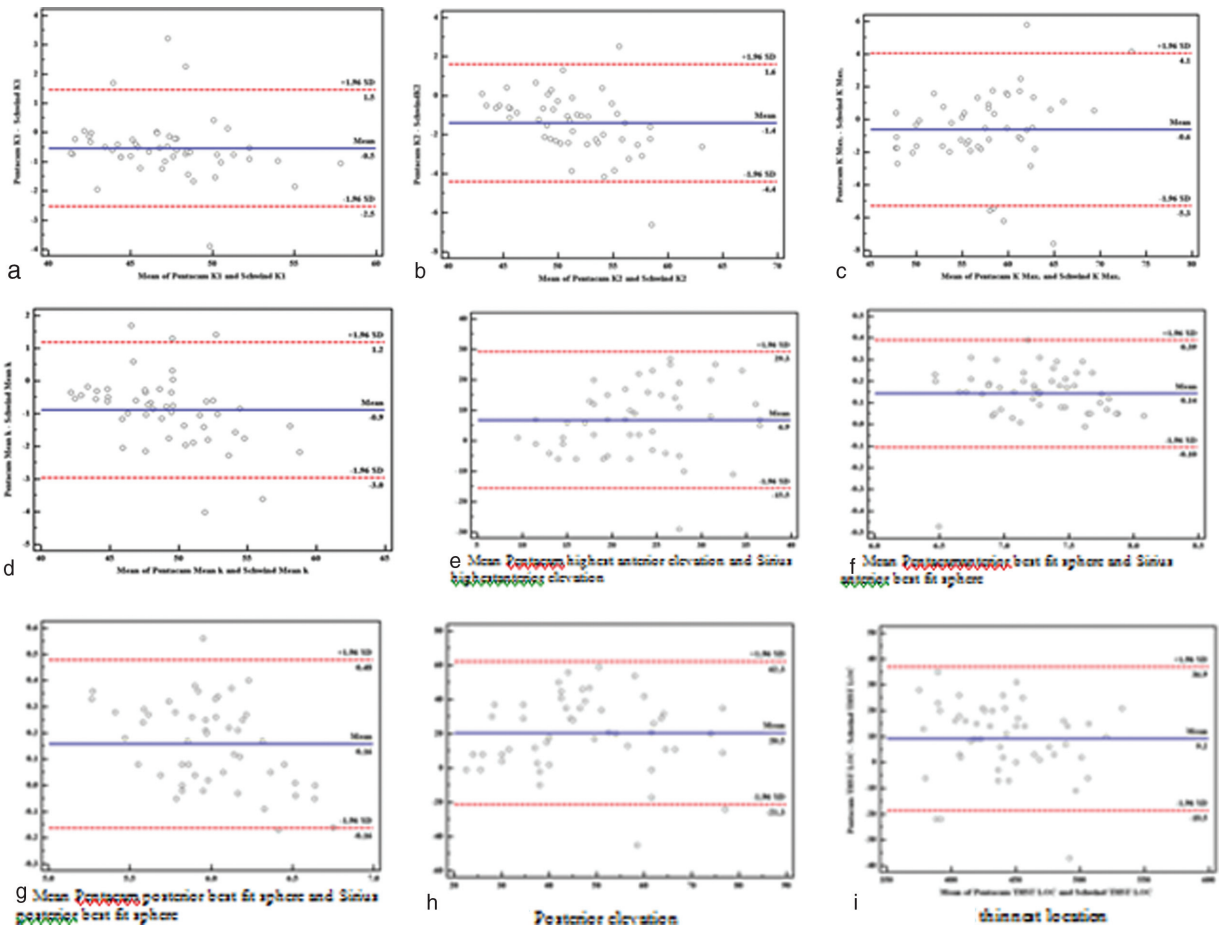
Also, De la Parra-Colin *et al.* [16] reported that the Pentacam provides systematically higher mean keratometric values than those of the Schwind Sirius; however, only keratometry values of the steep meridian reached statistical significance, with a mean difference of 0.31 diopters.

Another study comparing pentacam, Sirius, and Galilei in normal individuals reported significant differences in

Table 1 Scheimpflug camera data obtained in both devices

Measured values	Pentacam	Sirius	Mean difference	*P* value
K_1 (D)	46.87±3.56	47.4±3.77	0.54±1.02	<0.001
K_2 (D)	50.73±4.18	52.12±4.88	1.4±1.53	<0.001
Average K (D)	42±57.7	42.35±59.88	0.89±1.06	<0.001
K_{max} (D)	57.65±5.63	57.05±6.11	0.6±2.38	<0.001
Thinnest location pachymetry (μm)	445.6±39.62	436.44±41.84	9.2±14.14	<0.001
Highest anterior elevation within the 3 mm pupillary area (μm)	26.44±9.82	19.58±7.8	6.86±11.43	<0.001
Highest posterior elevation within the 3 mm pupillary area (μm)	57.82±18	37.3±18.28	20.52±21.32	<0.001
Mean anterior best-fit sphere (mm)	7.33±0.40	7.18±0.4	0.14±0.13	<0.001
Mean posterior best-fit sphere (mm)	6.08±0.31	5.92±0.39	0.16±0.16	<0.001

Fig. 1



Bland–Altman plots for the nine parameters measured by the Pentacam and Sirius. The mean difference is represented by the solid line and 95% limits of agreement (LoA) are presented by the dotted lines. (a) K_1. (b) K_2. (c) avgerage K. (d) K_{max}. (e) Highest anterior elevation. (f) Highest posterior elevation. (g) Anterior best-fit sphere. (h) Posterior best-fit sphere. (i) Thinnest location pachymetry.

the measurements of keratometry between the three devices ($P<0.001$). Similar results were found in the same study on keratoconic eyes, with all machines showing a statistically significant difference for all parameters [14].

Pachymetry at the thinnest location is one of the main variables required to detect keratoconus. There is a significant difference between the two devices, with higher measurements obtained by Pentacam. Also, there was a significant positive correlation between both devices.

In agreement with our results, Nasser and colleagues also found that minimal corneal thickness measurements were consistently higher using the Pentacam. Their study was carried out on healthy individuals [17]. Furthermore, Lee *et al.* [18] reported a difference between the corneal thinnest location measurements between the two devices, with higher values obtained by pentacam. Also, Finis *et al.* [13] reported a difference between the corneal thinnest location measurements between the two devices, with higher values obtained by pentacam.

Shetty and colleagues found statistically significant differences in the measurements between the two devices and the Galilei system, and concluded that the devices cannot be used interchangeably for anterior segment measurements in keratoconus patients. The measurements were statistically significantly lower with Sirius compared with Pentacam ($P<0.001$, *t*-test) and Galilei ($P<0.001$) [12].

Also, De la Parra-Colin *et al.* [16] reported that the Pentacam provides statistically significantly higher mean pachymetry values than Pentacam.

Bedei *et al.* [19] found that the mean central corneal thickness values obtained by Pentacam were higher (by ~20 μm) than those of Sirius in 30 healthy eyes of 30 individuals.

Anayol and colleagues reported that there was a significant difference between the three devices Galilei, Pentacam, Sirius ($P=0.001$) in the thinnest location pachymetry in healthy individuals. Galilei

overestimated the thinnest pachymetry measurements compared with both Pentacam and Sirius; also, Pentacam values were higher than Sirius values. Similar results were found in this study on keratoconic eyes, with all machines showing a significant difference for all parameters. Ninety-five percent limits of agreement of thinnest corneal thickness values indicated that the Pentacam and Sirius systems showed better agreement with each other than with the Galilei [14].

In contrast to all previous studies, Savini *et al.* [15] reported that the Sirius system provided slightly higher thinnest corneal thickness measurements compared with those obtained from the Pentacam system.

In our study, we measured the highest anterior elevation within the 3 mm pupillary area and the highest posterior elevation within the 3 mm pupillary area from all patients by both devices; we found that there was a statistically significant difference between the two devices, with the higher values obtained by the pentacam. The mean highest posterior corneal elevation in the 3-mm pupillary area was 57.82±18.0 D as measured by Pentacam and 37.30±18.28 D as measured by Schwind Sirius. Ramirez-Miranda and colleagues found that there was no inter device agreement for maximum anterior and posterior corneal elevation and total higher-order aberrations between Sirius and Pentacam HR. The Pentacam values were higher for both anterior and posterior elevations. Although statistically significant, the differences in the highest anterior elevation may be clinically judged as irrelevant [20].

There were statistically significant differences between the radius of the best-fit sphere of both anterior and posterior corneal surfaces between both devices, with the measurements by Sirius being lower in comparison with those of the Pentacam.

The difference between the measurements of the two instruments may be because of the following reasons:

(1) Pentacam HR obtains images of the anterior segment only by a rotating Scheimpflug camera, whereas Schwind Sirius combines a three-dimensional rotating Scheimpflug camera with an integrated Placido disc topographer (arc step).
(2) Pentacam HR captures up to 100 high-resolution Scheimpflug images to provide a detailed analysis of the cornea, whereas Schwind Sirius captures 25 Scheimpflug images and 1 Placido disc image simultaneously.
(3) Pentacam HR measures up to 138 000 true elevation points, whereas Schwind Sirius measures 32 632 points for the anterior surface and 30 000 points for the posterior surface on high-resolution systems and 21 632 points for the anterior surface and 16 000 points for the posterior surface on low-resolution systems.

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Conflicts of interest
There are no conflicts of interest.

References

1 Rabinowitz YS. Keratoconus. Surv Ophthalmol 1998; 42:297–319.
2 Krachmer JH, Feder RS, Belin MW. Keratoconus and related noninflammatory corneal thinning disorders. Surv Ophthalmol 1984; 28:293–322.
3 Tuft SJ, Moodaley LC, Gregory WM, Davison CR, Buckley RJ. Prognostic factors for the progression of keratoconus. Ophthalmology 1994; 101:439–447.
4 Prisant O, Legeais JM, Renard G. Superior keratoconus. Cornea 1997; 16:693–694.
5 Barkana Y, Gerber Y, Elbaz U, Schwartz S, Ken-Dror G, Avni I, Zadok D. Central corneal thicknessmeasurement with the Pentacam Scheimpflug system, opticallow-coherence reflectometrypachymeter, and ultrasoundpachymetry. J Cataract Refract Surg 2005; 31: 1729–1735.
6 Kawamorita T, Uozato H, Kamiya K, Bax L, Tsutsui K, Aizawa D, Shimuzu K. Repeatability,reproducibility, and agreement characteristics of rotating Scheimpflug photography and scanning-slit corneal topographyfor corneal power measurement. J Cataract Refract Surg 2009; 35: 127–133.
7 Lackner B, Schmidinger G, Pieh S, Funovics MA, Skorpik C. Repeatability and reproducibility of central corneal thickness-measurement with Pentacam, Orbscan, and ultrasound. OptomVis Sci 2005; 82:892–899.
8 O'Donnell C, Maldonado-Codina C. Agreement and repeatabilityof central thickness measurement in normal corneas usingultrasound pachymetry and the OCULUS Pentacam. Cornea 2005; 24:9 20–924.
9 Meinhardt B, Stachs O, Stave J, Beck R, Guthoff R. Evaluationof biometric methods for measuring the anterior chamber depthin the non-contact mode. Graefes Arch ClinExp Ophthalmol 2006; 244: 559–564.
10 Sirius imaging system manual. Florence, Italy: CSO; Available online http://www.csoitalia.it/en/prodotto/info/47-sirius. [Last accessed 2016 Jan].
11 Wang Q, Savini G, Hoffer KJ, Xu Z, Feng Y, Wen D, *et al.* A comprehensive assessment of the precision and agreement of anterior corneal power measurements obtained using 8 different devices. PLoS One 2012; 7:e45607.
12 Shetty R, Arora V, Jayadev C, Nuijts RM, Kumar M, Puttaiah NK, *et al.* Repeatability and agreement of three Scheimpflug-based imaging systems for measuring anterior segment parameters in keratoconus. Invest Ophthalmol Vis Sci 2014; 55:5263–5268.
13 Finis D, Ralla B, Karbe M, Borrelli M, Schrader S, Geerling G. Comparison of two different scheimpflug devices in the detection of keratoconus, regular astigmatism, and healthy corneas. J Ophthalmol 2015; 2015: 315281.
14 Anayol MA, Güler E, Yağc R. Comparison of central corneal thickness, thinnest corneal thickness, anterior chamber depth, and simulated keratometry using Galilei, Pentacam, and Sirius devices. Cornea 2014; 33:582–586.
15 Savini G, Carbonelli M, Sbreglia A, Barboni P, Deluigi G, Hoffer KJ. Comparison of anterior segment measurements by 3 Scheimpflugtomographers and 1 Placido corneal topographer. J Cataract Refract Surg 2011; 37: 1679–1685.

16 De la Parra-Colín P, Garza-León M, Barrientos-Gutierrez T. Repeatability and comparability of anterior segment biometry obtained by the Sirius and the Pentacam analyzers. Int Ophthalmol 2014; 34:27–33.

17 Nasser CK, Singer R, Barkana Y. Repeatability of the Sirius imaging system andagreement with the Pentacam HR. J Refract Surg 2012; 28:493–497.

18 Lee DM, Ahn JM, Seo KY, Kim EK, Kim TI. Comparison of corneal measurement values between two types of topography. J Korean Ophthalmol Soc 2012; 53:1584–1590.

19 Bedei A, Appolloni I, Madesani A, Pietrelli A, Franceschi S, Barabesi L. Repeatability and agreement of 2 Scheimpflug analyzers in measuring the central corneal thickness and anterior chamber angle, volume, and depth. Eur J Ophthalmol 2012; 22(Suppl 7):S29–S32.

20 Hernández-Camarena JC, Chirinos-Saldaña P, Navas A, Ramirez-Miranda A, de la Mota A, Jimenez-Corona A, *et al.* Repeatability, reproducibility, and agreement between three different Scheimpflug systems in measuring corneal and anterior segment biometry. J Refract Surg 2014; 30:616–621.