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ORIGINAL RESEARCH

Comparison of Anterion, MS-39, Pentacam, and Sirius in Corneal Assessment Prior to Refractive Surgery

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Background: Accurate corneal evaluation is crucial for determining candidacy for refractive surgery.Devices combining diverse technologies, such as Scheimpflug imaging (Pentacam, Sirius), swept-source OCT (Anterion), and hybrid OCT/Placido systems (MS-39), offer distinct advantages and limitations in screening.

Purpose: This study was conducted to compare corneal assessment with two Scheimpflug camera devices (Oculus Pentacam and CSO Sirius) and two spectral domain anterior segment optical coherence tomography devices (Heidelberg Engineering Anterion and CSO MS-39) in the preoperative screening of the cornea before refractive surgery.

Methods: In this retrospective, consecutive case series, we enrolled 110 patients undergoing refractive surgery. Simulated keratometry (Sim-K), posterior keratometry (PK), central corneal thickness (CCT), keratometric astigmatism magnitude (KAM), Corneal diameter, Anterior chamber depth (ACD), and total corneal power (TCP) were compared using different instruments. To compare the mean values of the measurements, a repeated measures ANOVA was used.

Results: Simulated keratometry (Sim-K), central corneal thickness (CCT), keratometric astigmatism magnitude (KAM), and total corneal power (TCP) showed a good agreement (ICC > 95%, ANOVA $p > 0.05$). Although posterior keratometry (PK) showed no significant differences, its Cronbach's alpha and ICC were low, indicating limited agreement. Corneal diameter showed moderate to poor ICC ($p<0.001$). Anterior chamber depth (ACD) showed the highest values when assessed with the Anterion; however, the results did not show a statistical significance ($p > 0.05$).

Conclusion: Both Scheimpflug camera devices and AS-OCT were suitable instruments for evaluating the cornea before refractive surgery. A strong correlation was seen for Sim-K, CCT, CD, and TCP; however, notable discrepancies were identified in posterior keratometry, astigmatism magnitude, and ACD. These findings underscore the importance of device-specific factors in assessing corneal and anterior segment measures during refractive surgery evaluations.

Keywords: keratometry, ophthalmic measurement techniques, refractive surgery, scheimpflug camera, anterior segment OCT, tomography

Introduction

Uncorrected refractive error is recognized as the primary cause of visual impairment and a leading factor contributing to poor eyesight worldwide.[1] The prevalence of refractive error disorders such as myopia has increased, with an estimate of further rise in the future.[2] Several factors were suggested to be related to the increase in refractive error development, including lifestyle changes, genetic predisposition, exposure to light levels, and the educational system in some countries, which may be intensive with high pressure on the recipients.[3,4]

Refractive surgery is a safe and effective alternative to correcting refractive errors with glasses or contact lenses. Corneal refractive surgical procedures, including laser-assisted in-situ keratomileusis (LASIK), photorefractive keratectomy (PRK), and keratorefractive lenticule extraction (KLEx), are commonly performed to correct refractive errors such

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as myopia, astigmatism, and hyperopia, aiming to reduce or eliminate dependence on corrective lenses by altering the eye's refractive power, significantly increasing the quality of life of patients.[5]

Before refractive surgery and during preoperative planning, corneal topography and tomography are essential for assessing corneal shape, thickness, and radii of curvature. They provide crucial data on corneal curvature, pachymetry, anterior chamber depth, and total corneal power. Abnormal corneal topography was identified as a predominant risk factor for corneal ectasia after surgery.[6,7] Corneal topography and tomography play a significant role in deciding on whether to perform refractive surgery and in determining which refractive procedure is most suitable in addressing the refractive error of an individual patient. Moreover, corneal topography is the primary imaging tool for visualising the effect of corneal laser refractive procedures on patient follow-up, enhancing the ability to detect subtle abnormalities, and aiding in treatment planning.

A key factor in achieving excellent surgical outcomes and avoiding postoperative complications is the exactness and accuracy of the preoperative corneal examination.[8,9]

Recently, technical progress in ophthalmic imaging technology, including Scheimpflug imaging and swept-source anterior segment optical coherence tomography (AS-OCT), has advanced in accuracy and the number of data points, enriching the reliability and quality of corneal measurements.

The Pentacam eye scanner (Pentacam AXL, Oculus, Germany) which utilizes a spinning Scheimpflug camera, provides a three-dimensional image of the corneal map and is a frequently used tool for preoperative evaluation prior to refractive surgery. The Sirius device (Sirius, CSO, Italy) is also a Scheimpflug camera system combined with a Placido-disc topography, for imaging of the anterior segment of the eye. Over the last few years, anterior segment optical coherence tomography (AS-OCT) has gained popularity. Swept-source systems provide a high-resolution scan of the anterior segment. The MS 39 (CSO, Italy) is an innovative tool combining SD - OCT imaging combined with Placido disk imaging.[10]

The Anterion (Heidelberg Engineering GmbH, Germany) is a commercially available OCT -based instrument which has shown a good agreement and repeatability as compared to the Avanti OCT system (Optovue) in anterior segment imaging.[11]

The purpose of this study is to assess and compare the accuracy and consistency of anterior segment measurements made with four widely used anterior imaging tools, including AS-OCT, Scheimpflug imaging and Placido disk imaging systems (Anterion, MS-39, Pentacam, and Sirius), in a real-life setting during the screening of refractive surgery candidate. This study aims to shed light on their performance for preoperative evaluation in refractive surgery planning along several vital dimensions. Furthermore, it also identifies for any potential drawbacks that can affect clinical judgment. The goal is to determine whether these devices can be used interchangeably and to identify any systematic differences that may influence clinical decision-making.

Materials and Methods

This retrospective study was conducted at the Department of Ophthalmology, St. John of God Hospital in Regensburg, Germany.

Ethical Approval

Approved by Ethics Committee at the University of Regensburg. All data were anonymized, and patient agreement was not necessary because the study was retrospective and non-interventional. The study was carried out in accordance with the Declaration of Helsinki.

Participants

One hundred ten eyes of consecutive patients seeking refractive surgery between February 2022 and February 2024 were investigated. Patients with abnormal slit-lamp biomicroscopy, <20/25 DCVA (Distance corrected visual acuity), previous eye surgery, or topical therapy other than artificial tears were excluded. All eyes were screened by Pentacam AXL (Oculus Optikgeräte), Sirius (CSO), Anterion (Heidelberg Engineering) and MS-39 (CSO).

Patients were asked to discontinue the use of soft contact lenses at least 1 week and rigid contact lenses 3 weeks before the examination. Experienced technicians took all all examinations. Only examinations of adequate quality were included. Each examination was repeated 3 times with each device. The image with the highest image quality was chosen for analysis. For a proper examination quality, each chosen examination was analyzed manually, frame by frame.

Each subject was appropriately positioned on the chin rest, with the forehead resting on the device, and the eye was aligned with a central fixation light. The patients were instructed to fully blink just before each measurement to gain a smooth tear film. All measurements were performed in a dark room between 9:00 a.m. and 5:00 p.m. to minimize the effects of diurnal ocular changes. Scans were taken in the automatic release mode. Only qualified scans, as indicated by the instrument, were used for analysis; otherwise, the measurements were repeated. The entire procedure lasted less than 30 minutes.

The following biometric measurements were obtained: Simulated keratometry (Sim- K), posterior keratometry (PK), central corneal thickness (CCT), keratometric astigmatism magnitude (KAM), keratometric astigmatism axis, corneal diameter (CD), Anterior chamber depth (ACD) and total corneal power (TCP).

Statistical Analysis

Statistical processing of data was conducted using MedCalc ver. 20 (MedCalc, Ostend, Belgium) and Excel (2023). The data were reported as mean ± standard deviation (SD). Only data from the right eye of each subject was analyzed to avoid intra-subject codependence. A repeated-measures analysis of variance (ANOVA) test was used to estimate the repeatability of the measurements.

Data input, processing, and statistical analysis were done in significance tests included Cochran's Q, repeated measures ANOVA, Cronbach's alpha, and Intraclass Correlation Coefficient. The kind of data (parametric or non-parametric) for each variable determined the analysis.

There was no formal power calculation done because this was retrospective research. However, the sample size is in line with comparable previously published research, and all consecutive eligible right eyes tested were included (n = 110).

Results

110 right eye (OD) measurements (mean age: 34.8 ± 6.8 years; range: 21–53 years) were included in this analysis. All individuals were included in the repeatability analysis, and the cohort was composed of 43.6% males and 56.4% females.

Comparing Devices

We examined and contrasted serial ocular measures taken with the Anterion, MS-39, Pentacam, and Sirius devices. The performance of these devices was assessed across a range of corneal characteristics, and the tables and figures that follow provide a summary of the findings.

Measurements of simulated keratometry (Sim-K) showed identical performance across all devices, with overlapping means and standard deviations (Figure 1). PK showed no statistically significant difference across devices (p=0.259), with Pentacam performing the best and MS39 performing the worst. Keratometric astigmatism magnitude varied significantly among devices (p = 0.758), with Sirius often underestimating values. In contrast, the axis exhibited no significant differences (p = 0.970), indicating good inter-device agreement.

Pentacam had the shallowest anterior chamber depth (ACD) and Anterion the deepest. ACD values did not vary significantly (p=0.795), indicating strong interdevice agreement. Anterion and Sirius exhibited larger corneal diameters (CD) than MS-39 and Pentacam (p<0.001) (Figure 2). Center corneal thickness (CCT) was consistent and not statistically significant.

According to Anterion evaluations, none of the eyes was found suspicious for an ectatic corneal disorder. However, using MS-39 and Pentacam, 0.9% of eyes were categorized as subclinical, while corneal screening with the Sirius system categorised 2.7% of cases as such. Hence, the overall prevalence of borderline eyes across all screening measures was 4.5%. (Table 1).

Cronbach's alpha values above 95% implied the credibility Sim-K, KAM, TCP, CCT, CD, and ACD agreement analysis. Keratometric and TCP astigmatism axis measurements were reliable with Cronbach's alpha values > 80%. Four devices had almost identical Sim-K, KAM, Cronbach's alpha scores above 90%, which means that the agreement analysis for simulated keratometry (Sim-K), keratometric astigmatism magnitude (KAM), (TCP) (CD) and (CCT) were very reliable (>0.95). The keratometric astigmatism axis and TCP astigmatism axis readings have a Cronbach's alpha value of above 80%, which indicates good reliability. Measurements taken with four different devices were compared and found to be very similar (intraclass correlation coefficient [ICC] > 90%) for essential metrics, including Sim-K, TCP

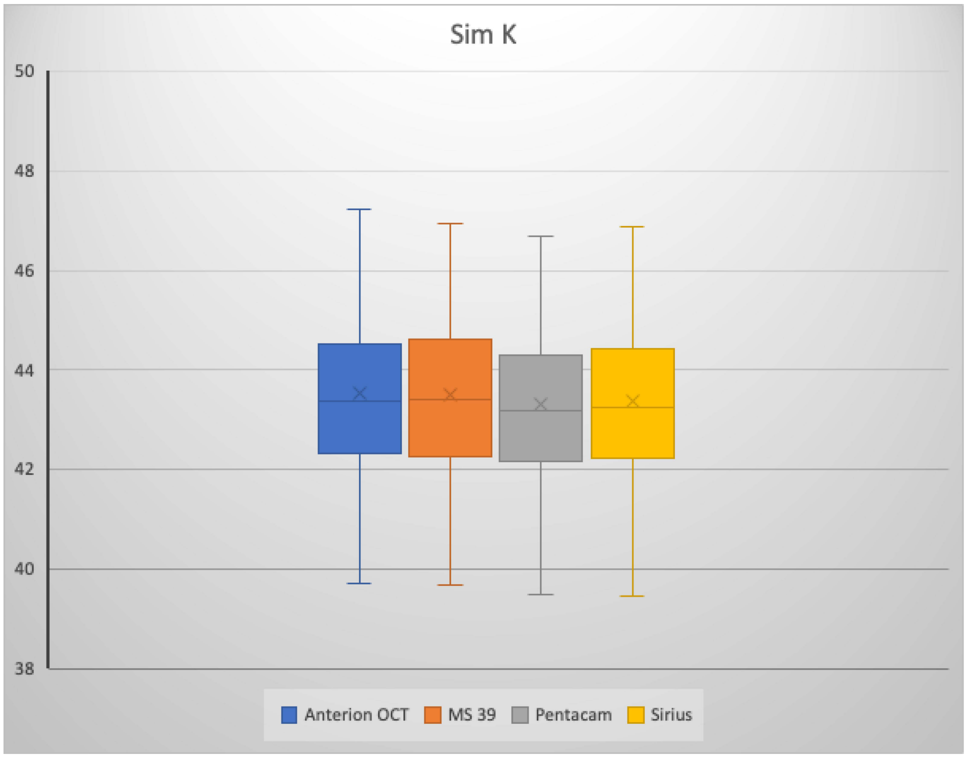

Figure 1 Comparison between 4 different ophthalmic Sim-K measurements. The boxplot compares Sim K in four devices: Blue, Anterion; Orange, MS-39; Grey, Pentacam; and Yellow, Sirius. MS 39 and Sirius show slightly wider variability compared to Anterion and Pentacam.

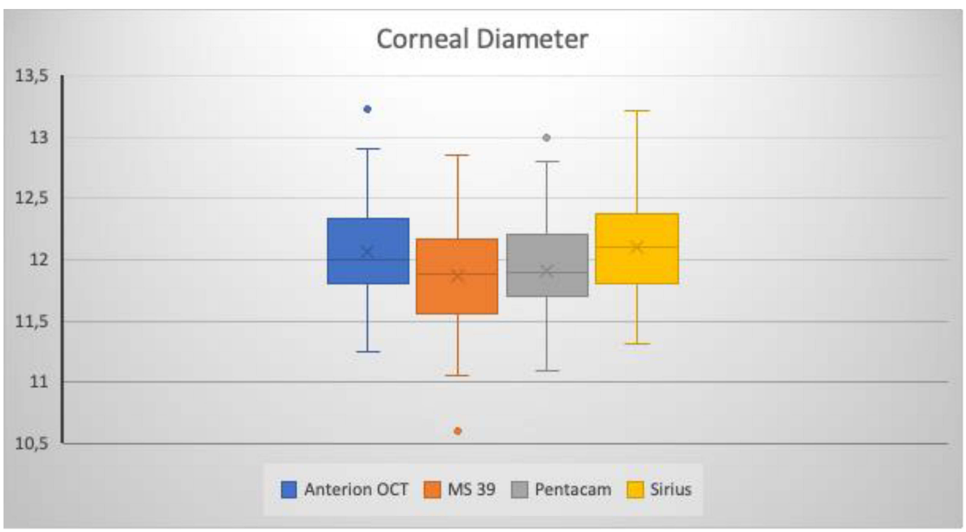

Figure 2 Comparison between 4 different ophthalmic Corneal Diameter measurements. The boxplot compares the corneal diameter measurements in four devices. Sirius indicates the highest corneal diameter at 12.09 mm, Anterion OCT measured 12.00 mm, but MS-39 and Pentacam had the smallest measurements at 11.90 mm.

astigmatism axis and CCT. The keratometric astigmatism axis, the TCP astigmatism axis, and the anterior chamber depth were all very similar (ICC > 80%). The amplitude of PK and TCP astigmatism magnitude exhibited low concordance (ICC < 70%). These results underscore the importance of accounting for device-specific variation. While ACD had a high Cronbach's Alpha (0.9886), the 95% lower confidence limit (0.076) highlights considerable variability and warrants further investigation (Table 2).

Table 1 Comparison Between 4 Different Ophthalmic Measurements Using Repeated Measures ANOVA Test

Variable	Anterion Measurement	MS-39 Measurement	Pentacam Measurement	Sirius Measurement	Repeated Measures ANOVA Test
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	P value
Sim-K	43.52 ± 0.14	43.49 ± 0.15	43.3 ± 0.14	43.37 ± 0.14	= 0.656
Posterior Keratometry	−6.1 ± 0.02	−6.07 ± 0.01	−6.2 ± 0.02	−6.09 ± 0.02	= 0.259
Keratometric astigmatism magnitude	1.27 ± 0.07	1.19 ± 0.07	1.23 ± 0.07	1.17 ± 0.07	= 0.758
Keratometric astigmatism axis	80.6 ± 7.6	79.6 ± 8.6	76.08 ± 11.6	79.9 ± 7.6	= 0.970
TCP	43.05 ± 0.15	43.23 ± 0.15	42.83 ± 0.14	43.06 ± 0.15	= 0.281
TCP astigmatism magnitude	1.15 ± 0.08	1.1 ± 0.08	0.99 ± 0.06	1.08 ± 0.07	= 0.444
TCP astigmatism axis	90.1 ± 7.4	91.6 ± 7.1	85 ± 7.2	90.4 ± 7.07	= 0.913
CCT	549 ± 2.9	550 ± 2.9	546.5 ± 2.8	550 ± 3	= 0.842
CD	12 ± 0.05	11.9 ± 0.04	11.9 ± 0.04	12.09 ± 0.04	<0.0001*
ACD	3.9 ± 0.03	3.75 ± 0.03	3.72 ± 0.03	3.76 ± 0.03	0.795
Variables	**OCT measurement**	**MS-39 measurement**	**Pentacam measurement**	**Sirius measurement**	**Cochran's Q test**
	+ve	**+ve**	**+ve**	**+ve**	**P value**
Screening ectasia (subclinical)	0 (0%)	1 (0.9%)	1 (0.9%)	3 (2.7%)	0.284

Note: *= Significant.
Abbreviations: Sim-K, Simulated Keratometry; TCP, Total Corneal Power; CCT, Central Corneal Thickness; CD, Corneal Diameter; ACD, Anterior Chamber Depth.

Table 2 Test Agreement Using Cronbach's Alpha

Variable	Cronbach's Alpha	95% Lower Confidence Limit	Intraclass Correlation Coefficient (ICC)	95% Confidence Interval
Sim-K	0.995	0.991	0.9827	−0.188 to 0.881
Posterior keratometry	0.471	0.297	0.003	−0.1850 to 0.191
Keratometric astigmatism magnitude	0.991	0.987	0.9118	−0.188 to 0.1881
Keratometric astigmatism axis	0.817	0.743	0.6743	0.5627 to 0.7633
TCP	0.995	0.993	0.9902	0.9784 to 0.9946
TCP astigmatism magnitude	0.068	−0.017	0.0236	−0.1858 to 0.1903
TCP astigmatism axis	0.831	0.757	0.6398	0.5164 to 0.7381
CCT	0.990	0.981	0.9882	0.9839 to 0.9916
CD	0.970	0.945	0.9495	0.8881 to 0.9729
ACD	0.988	0.076	0.9454	−0.076 to 0.076

Abbreviations: Sim-K, Simulated Keratometry; TCP, Total Corneal Power; CCT, Central Corneal Thickness; CD, Corneal Diameter; ACD, Anterior Chamber Depth.

Sim-K, TCP, and CCT showed significant ICC values (≥0.98). TCP reached an ICC of 0.9964, with a confidence interval ranging from 0.9785 to 0.9950, while CCT's ICC was 0.9882, accompanied by a narrow confidence interval of 0.9839 to 0.9916. The keratometric astigmatism axis and the TCP astigmatism axis showed moderate agreement, with ICC values of 0.6743 (95% CI: 0.5627 to 0.7633) and 0.6398 (95% CI: 0.5164 to 0.7381), respectively. The consistency of posterior keratometry and TCP astigmatism magnitude was low, with ICC values of 0.003 (95% CI: −0.1850 to 0.191) and 0.0236 (95% CI: −0.1858 to 0.1903), suggesting inconsistency across devices (Table 2).

Simulated keratometry (Sim-K) and keratometric astigmatism axis showed strong agreement across devices (ICC > 0.90, Cronbach's $\alpha > 0.95$), with no significant differences ($p > 0.05$).

Central corneal thickness (CCT) and anterior chamber depth (ACD) also showed excellent inter-device agreement (ICC ≥ 0.98 for CCT, Cronbach's $\alpha > 0.95$). However, ACD values varied slightly, with Pentacam yielding the shallowest and Anterion the deepest.

Corneal diameter (CD) showed significant inter-device differences ($p < 0.001$), with Anterion and Sirius reporting larger values.

Total corneal power (TCP) demonstrated high agreement (ICC = 0.9964), but TCP astigmatism axis and keratometric astigmatism axis showed only moderate consistency (ICC ~0.64–0.67).

Posterior keratometry (PK) and TCP astigmatism magnitude had poor agreement (ICC < 0.07), suggesting notable device-related variability.

Most metrics demonstrated high internal consistency, with Sim-K, CCT, CD, TCP, and ACD achieving Cronbach's α values greater than 0.95, while the astigmatism axes achieved α values greater than 0.80.

Discussion

More female than male patients were included in this study. A sociodemographic survey by Quintana et al 2013 of refractive surgery also identified a higher proportion of female patients (64.2%).[12]

It is essential to examine the differences between the measurement values and policies of the devices used to understand our outcomes. Scheimpflug-based systems utilize visible light and necessitate longer examination durations, which can lead to motion artifacts. In contrast, Placido disc systems offer shorter examination durations but depend on center-intrapolated data.

Anterion examination is based on Optical Coherence Tomography (OCT) technology, which utilizes infrared light, and involves over 1000 individual measurements with each scan. To enhance accuracy, these measurements are automatically averaged. The methods used for acquisition differ, and these differences have an impact on both the precision of corneal curvature measurements and the potential sources of error specific to each modality.

This variation may also influence the identification of pathological changes, such as keratoconus. An ideal methodological comparison would entail the analysis of raw datasets using standardized external software to eliminate calculation biases specific to the device used. However, due to this study's practical orientation, we focus on comparing the results produced by each system's integrated software, in line with the typical clinical use of these devices.

Corneal assessment using four diagnostic instruments —Anterion, MS-39, Pentacam, and Sirius — was investigated in this study. Planning refractive surgery depends on careful evaluation of corneal characteristics. The results show a good agreement among most parameters, therefore confirming their diagnostic validity. The Sim-K values ($p = 0.656$) showed no statistically significant variation.

Furthermore, indicating good agreement are high intraclass correlation coefficients (ICC > 0.90) and Cronbach's alpha values over 90%. Previous findings have been reported by Tawfik et al 2024 and Chan et al 2017 found that Sim K was raised relative to Scheimpflug devices, thereby supporting our results.[13,14]

The posterior keratometry readings showed no statistically significant variability ($p = 0.259$), with Pentacam reporting the highest values and MS 39 the lowest. These results align with a study by Said et al 2023 that highlighted the impact of device-specific biases by observing systematic discrepancies in posterior keratometry values across AS-OCT and Scheimpflug systems.[15] These results highlight that it is essential to take device-specific factors into account when interpreting corneal measurements taken using various technologies.

Astigmatic measurements revealed differences between devices. The keratometric astigmatism degree showed no significant variation ($p = 0.758$), except for Sirius measurements, which tended to underestimate astigmatism compared to the other devices. Furthermore, a moderate agreement (ICC < 80%) was found regarding astigmatism axis measurements. These findings align with earlier studies by Shetty et al 2017, which revealed similar variability in astigmatism-related metrics across several measurement techniques.[16] Due to the observed variability, it is essential to use caution when comparing astigmatism data from different imaging modalities.

Strong inter-device agreement ($p = 0.281$) and good dependability (Cronbach's alpha > 0.90, ICC > 0.90) were shown by measurements of total corneal power (TCP). Conversely, the degree of TCP astigmatism displayed significant variations ($p = 0.288\%$), which is consistent with the results of those who observed systematic changes in TCP parameters when comparing readings from Scheimpflug and AS-OCT systems.[17,18]

In this study, Anterion showed the highest values of Anterior Chamber Depth (ACD) measurements. Good agreement across modalities was indicated by an Intraclass Correlation Coefficient (ICC) of more than 90%. These findings align with earlier studies by Said et al 2023 and Li Y et al 2021, which suggest that Anterion typically produces deeper ACD values than Scheimpflug systems.[15,19] With intraclass correlation coefficients (ICC > 90%), good repeatability (Cronbach's alpha > 0.90), and inter-device agreement ($p = 0.842$) were found from measurements of central corneal thickness (CCT). Unlike what we initially discovered, CCT values were higher when measured using Pentacam compared to Anterion-OCT. Our findings align with earlier studies done by Gadamer et al 2025 and Youssef et al 2024 that found that CCT values showed good consistency.[20,21]

With Intraclass Correlation Coefficients (ICCs) above 90%, the agreement study showed outstanding inter-device dependability for Sim-K, Total Corneal Power (TCP), and Central Corneal Thickness (CCT). Anterior Chamber Depth (ACD) and TCP astigmatism axis showed moderate agreement (ICC > 80%), whereas posterior keratometry and TCP astigmatism magnitude and axis showed poor agreement (ICC < 70%). These results are consistent with a study by Abdi et al 2023 that showed astigmatism-related factors varied across devices.[22]

Devices varied in their ability to identify corneas suspicious of an ectatic disorder. Anterion found no cases, while MS-39 and Pentacam found 0.9% of cases, and Sirius found 2.7%. The reported inter-device variability in keratoconus identification underscores the importance of employing multiple diagnostic approaches in clinical practice. These findings are consistent with an earlier study by Shetty et al 2017, which found that Scheimpflug imaging analysis software has higher sensitivity for identifying minute ectasia changes.[16] Agreement studies using Intraclass Correlation Coefficients (ICCs) above 90% revealed exceptional inter-device dependability for Sim-K, Total Corneal Power (TCP), and Central Corneal Thickness (CCT). Whereas posterior keratometry and TCP astigmatism magnitude and axis showed poor agreement (ICC < 70%), Anterior Chamber Depth (ACD) and TCP astigmatism axis showed modest agreement (ICC > 80%). These findings align with a study by Shetty et al 2017 and Abdi et al 2023, showing varying astigmatism-related factors across devices.[16,22]

The limitations of this study should be considered when interpreting the results. Firstly, the retrospective methodology inherently limits control over potential confounding variables and data consistency. Second, due to variations in proprietary calculation methods and software algorithms specific to each device, the readings could not have been directly comparable even if the devices had been calibrated and handled by experts. Third, larger, multicenter studies may enhance generalizability, even though 110 eyes is an adequate sample size for statistical power. Additionally, extrapolation to eyes with corneal disease, such as keratoconus or instances following refractive surgery, is limited by the inclusion of only healthy or borderline eyes.

In measuring anterior segment parameters, all four devices showed satisfactory agreement; however, in some clinical situations, one device may be preferred over the others. For instance, the MS-39, which combines SD-OCT and Placido-based topography, would be the better option for early keratoconus identification and comprehensive epithelium mapping. With its swept-source OCT technology, the Anterion provides excellent imaging of the posterior region and may be the best option for preoperative cataract planning or combined anterior–posterior evaluations. Widely used and thoroughly tested, the Pentacam is still a reliable choice for standard preoperative screening in refractive surgery. Particularly in high-volume clinical settings, the Sirius offers a cost-effective and comprehensive solution for standard corneal diagnostics, providing both Scheimpflug and Placido imaging. The device should be chosen by clinicians based on workflow integration, picture quality, availability, and particular diagnostic requirements.

Conclusion

Appropriate tools for assessing corneal parameters for refractive surgery are both Scheimpflug imaging devices and Anterior Segment Optical Coherence Tomography devices. Both modalities provide accurate data; thus, they are valuable tools for the planning and evaluation stages of refractive surgery, even if there are minor but statistically significant differences between them for some parameters, such as corneal diameter. Ultimately, our work highlights the importance of accounting for device-specific variables to accurately interpret corneal measurements before refractive operations.

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Disclosure

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