Comparison of common corneal and anterior segment parameters obtained from two different devices in a healthy pediatric population

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ABSTRACT

Purpose: To evaluate and compare the anterior segment parameters obtained with Sirius and IOL-Master 500 devices in children.

Materials and Methods: A total of 196 eyes of 100 children with no ocular pathology other than refractive errors were included in the study. The anterior segment parameters of all cases were performed using Sirius and IOL-Master devices. Flat keratometry (K1), steep keratometry (K2), central corneal thickness (CCT), anterior chamber depth (ACD), and pupil diameter (PD) were recorded and evaluated.

Results: The measurements of K2, CCT, ACD, and PD were significantly different between the devices ($p<0.05$). The mean flat keratometry (K1) values were 42.99±1.44 D and 42.98±1.41 D in Sirius and IOL-Master 500, respectively ($p=0.841$). The mean K2, ACD, CCT, and PD measurements were significantly higher in IOL-Master. Notably, the two devices exhibited significant non-interchangeability with respect to pupil diameter measurements, showing a mean difference of 1.306 mm and 95% limits of agreement between -1.42 and -1.183 mm.

Conclusion: Sirius and IOL-Master devices can be used interchangeably when evaluating the anterior segment parameters, including keratometry values, CCT, and ACD in children, even though these anterior segment parameters were significantly different between the devices.

Keywords: Anterior chamber depth, Corneal thickness, Pediatric, Sirius, IOL-Master.

INTRODUCTION

Accurate and reproducible measurements of anterior segment parameters are essential for various clinical applications, including intraocular lens power calculation in cataract surgery, the diagnosis and management of corneal diseases and glaucoma, and performing successful outcomes in refractive surgery. These parameters can be measured using a variety of devices, including manual or automatic keratometry, corneal topographers, Scheimpflug cameras, optical coherence tomography (OCT) devices, as well as optical and ultrasonic biometry.[1-3] Among these parameters, curvature measurements of keratometry, central corneal thickness (CCT), anterior chamber depth (ACD), corneal diameter, and pupil diameter (PD) are noteworthy.

Keratoconus often progresses faster in children compared to adults and the delay in diagnosis can lead to significant vision loss before necessary interventions are implemented.[4,5] Corneal thickness and corneal curvature values are essential in the diagnosis and monitoring of keratoconus.[6] Keratometry and ACD measurements are two of the factors used to determine the accurate power of intraocular lenses (IOLs), especially in new generation IOL calculation formulas such as Barret Universal II, Haigis, Shammas, and Ladas Super formulas.[7,8] The utilization of keratometry and ACD measurements in conjunction with advanced IOL calculation formulas represents a significant

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advancement in cataract surgery.[8] This approach allows for more precise IOL power determination, ultimately leading to improved visual outcomes and patient satisfaction.[9] Additionally, CCT is used in the diagnosis and management of glaucoma and ocular hypertension, and lastly, CCT and PD are significant tools in the planning of refractive surgery.[10,11] The consistent and accurate measurement of anterior segment parameters is paramount for their clinical utility, particularly when different instruments are employed. Ensuring the comparability of measurements across devices requires stringent standardization in both methodological practices and instrumentation.

In this study, we evaluated and compared the flat (K1) and steep keratometry (K2), CCT, ACD, and PD measurements in children using the Sirius (CSO, Costruzione Strumenti Oftalmici, Florence, Italy) and the IOL-Master 500 (Carl Zeiss Meditec AG, Germany) devices.

MATERIALS AND MEDHODS

The present study was conducted in a prospective and case-control design. Ethical approval was obtained from the Ethics Committee of Niğde Ömer Halisdemir University (approval number: 2023/95). The study adhered to the tenets of the Declaration of Helsinki, and written informed consent was obtained from the parents of each patient following a verbal and written explanation of the nature and possible consequences of this study.

The present study was conducted to investigate the anterior segment parameters of 196 eyes of 100 subjects with no ocular pathology other than refractive error. The exclusion criteria were a history of ocular surgery or trauma, refractive error of greater than ±6.00 D spherical or ±3.00 D cylindrical diopters, abnormal corneal topography (e.g., keratoconus), ocular surface disease, elevated intraocular pressure (above 21 mmHg), or the presence of retinal or optic disk pathology, dry eye disease, and cataract. The patients' age and gender were recorded. A detailed ophthalmological examination was performed on all patients, including visual acuity testing, slit-lamp biomicroscopic examination, intraocular pressure (IOP) measurement with a non-contact pneumatic tonometer, and dilated fundus examination. To minimize potential confounders and ensure internal validity, the anterior segment parameters were measured three times consecutively with each of the two devices. These measurements were performed by an experienced examiner under meticulously standardized scotopic room conditions, maintained at approximately 1 lux illumination. This rigorous protocol aimed to reduce artificial variations in the results that could arise from device idiosyncrasies, operator technique, or ambient lighting fluctuations. Only measurements with good quality (displayed by the respective device software) were used for analysis.

Optic Devices

Sirius Combined Scheimpflug-Placido Disk System: This device, which has been in use since 2009, combines a 360-degree rotating Scheimpflug camera with a 22-ring Placido disk technology to better analyze the anterior corneal curvature. In a single imaging, anterior segment measurements, anterior and posterior corneal topography, wavefront analysis, and corneal pachymetry are obtained.[12] The Sirius system uses a combination of two imaging technologies to provide comprehensive anterior segment imaging. The Scheimpflug camera uses a slit beam of light to create a series of images of the eye as it rotates. These images are then used to calculate the curvature and thickness of the cornea, as well as the shape of the anterior chamber. The Placido disk technology uses a series of concentric rings to create a map of the corneal surface. This information can be used to calculate the topography of the cornea as well as the refractive error of the eye.[12]

IOL-Master 500 System: This system is an optical biometry device that uses partial optical coherence interferometry (OCT) technology and infrared light at 780 nm to measure corneal curvatures, axial length, anterior chamber depth, and corneal diameter. Keratometry values are obtained using six reference points arranged in a hexagonal pattern on the approximately 2.4 mm optical probe.[13] The anterior chamber depth is calculated using 0.7 mm of wide lateral light at 30 degrees of illumination.[14]

Statistical Analysis

Statistical analysis was performed using SPSS 25.0 (IBM Co., Armonk, NY, USA). Descriptive statistics were presented as numbers, mean, standard deviation, minimum, and maximum was used for numerical variables. Normality analysis was performed using the Kolmogorov-Smirnov test. To compare the two devices, paired t-tests were performed in K1, K2, CCT, ACD, and PD measurements. Bland-Altman plots were used to analyze the difference in measurement against the mean of the measurements as a measure of agreement between the two devices. Statistical significance was defined as $p<0.05$.

RESULTS

One hundred ninety-six eyes of 100 children were measured. The mean age of the participants was 8.95±3.02 (range, 4-15) years and the mean refractive error (spheric equivalent) was -0.24 ± 3.44 diopters. Of the 100 children, 49 were female and 51 were men. The mean intraocular pressure of children was 12.2±3.6 mmHg.

The mean measured K1, K2, CCT, ACD, and PD values using Sirius and IOL-Master are shown in Table 1. The mean K1 values were 42.99±1.44 D and 42.98±1.41 D in Sirius and IOL-Master, respectively. This difference between the devices was not statistically significantly different (p=0.841). The mean K2 values were 43.66±1.49 D and 43.77±1.48 D in Sirius and IOL-Master, respectively (p=0.010). The values of CCT, ACD, and PD showed statistically significant differences between the two devices (p<0.05 for all). Table 2 shows the mean and 95% confidence interval of the difference between the measurements taken with the Sirius and IOL-Master devices for the anterior segment parameters.

Regarding the device agreements, Figure 1, 2, and 3 shows Bland-Altman plots that represent the differences between both devices against their mean CCT, ACD, and PD measurements.

DISCUSSION

Accurate keratometry measurements are foundational for both both IOL calculations and successful contact lens fitting.[15,16] In cataract surgery, precise knowledge of corneal curvature is crucial for determining the appropriate IOL power to achieve targeted post-operative refractive error. IOL formulas rely on keratometry readings to estimate the eye's optical power and predict the IOL's refractive contribution. Miscalculations due to inaccurate keratometry can lead to significant refractive surprises, compromising visual outcomes and patient satisfaction.[17] Similarly, for contact lens fitting, accurate keratometry is essential for selecting the optimal lens design and parameters.[18] The corneal shape and curvature directly influence lens stability, centration, and tear distribution. Improperly fitted contact lenses due to inaccurate keratometry can cause discomfort, decreased visual acuity, and corneal complications.[18,19] Additionally, for specialty lenses like toric contacts intended to correct astigmatism, precise keratometry measurements are required to determine the appropriate axis orientation for optimal correction.[16] While K1 values showed no statistically significant difference between the two devices, K2 values were significantly higher in IOL-Master measurements. Considering the 95% limits of agreement (LoA) for K2 measurements, Sirius and IOL-Master showed a difference of 0.109 D with 0.256 D width. In calculating the intraocular lens power for cataract surgery, a 0.25 D error in measuring the corneal refractive power can lead to a correction error of approximately 0.28 ± 0.04 to 0.31 ± 0.05 D.[20] This difference can be considered clinically acceptable.[21]

Table 1: *Anterior segment parameters obtained with Sirius and IOL-Master*

	Sirius (mean± SD)	IOL-Master 500 (mean± SD)	p
Flat Keratometry (K1), (D)	42.99 ± 1.44	42.98 ± 1.41	0.841
Steep Keratometry (K2), (D)	43.66 ± 1.49	43.77 ± 1.48	**0.001**
Central Corneal Thickness (µ)	546.1 ± 37.6	550.0 ± 34.1	**<0.001***
Anterior Chamber Depth (mm)	3.26 ± 0.25	3.55 ± 0.24	**<0.001***
Pupil Diameter (mm)	4.39 ± 0.68	5.60 ± 0.92	**<0.001***

D: diopter, SD: Standard deviation, *: Paired t-test

Table 2: *Pairwise comparison of anterior segment parameters obtained with Sirius and IOL-Master*

	Mean difference ± SD	95% Limits of agreement
Flat Keratometry (K1), (D)	0.006 ± 0.440	-0.056 to 0.068
Steep Keratometry (K2), (D)	-0.109 ± 0.461	-0.132 to 0.124
Central Corneal Thickness (µ)	-3.98 ± 17.36	-6.421 to 1.552
Anterior Chamber Depth (mm)	-0.343 ± 0.102	-0.358 to -0.328
Pupil Diameter (mm)	-1.306 ± 0.863	-1.429 to -1.183

SD: Standard deviation

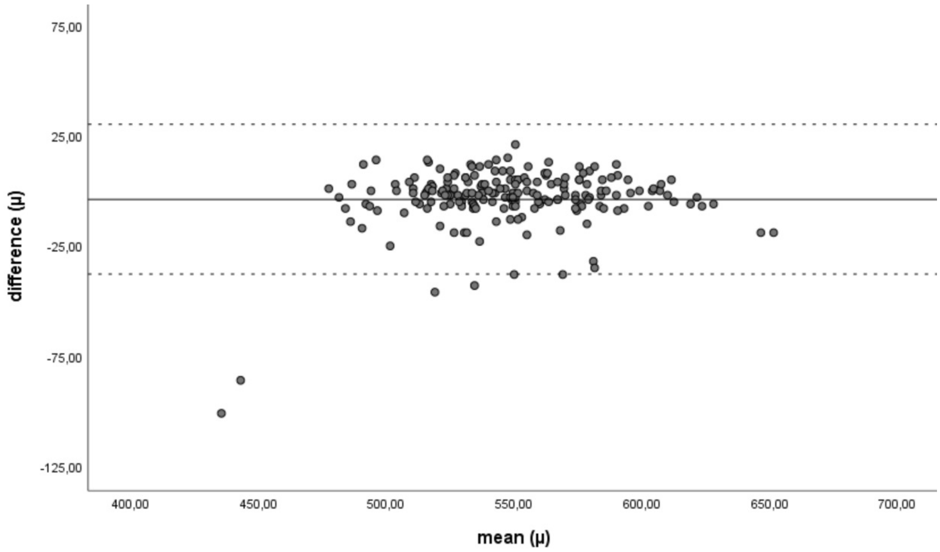

Figure 1: *Bland-Altman plot comparing the Sirius and IOL-Master in measuring the central corneal thickness.*

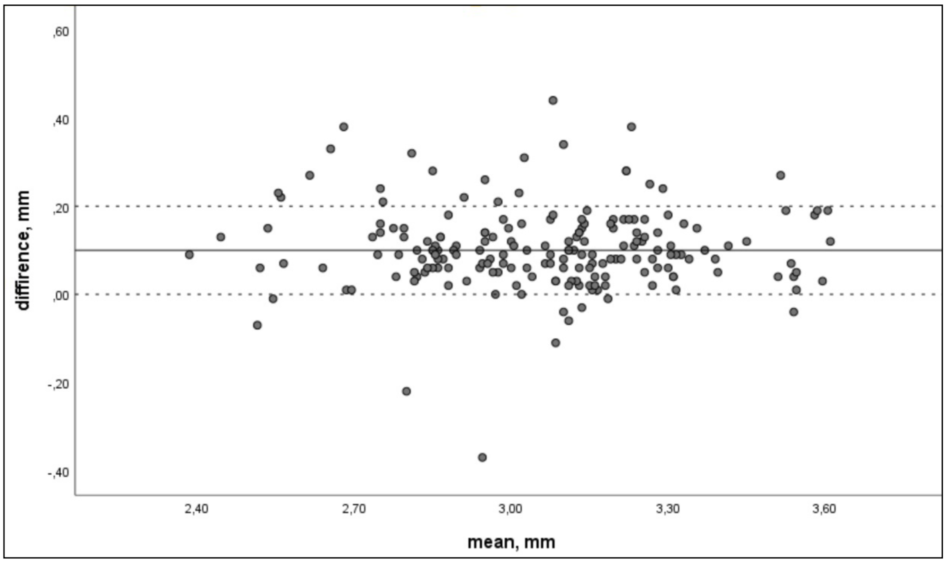

Figure 2: *Bland-Altman plot comparing the Sirius and IOL-Master in measuring the anterior chamber depth.*

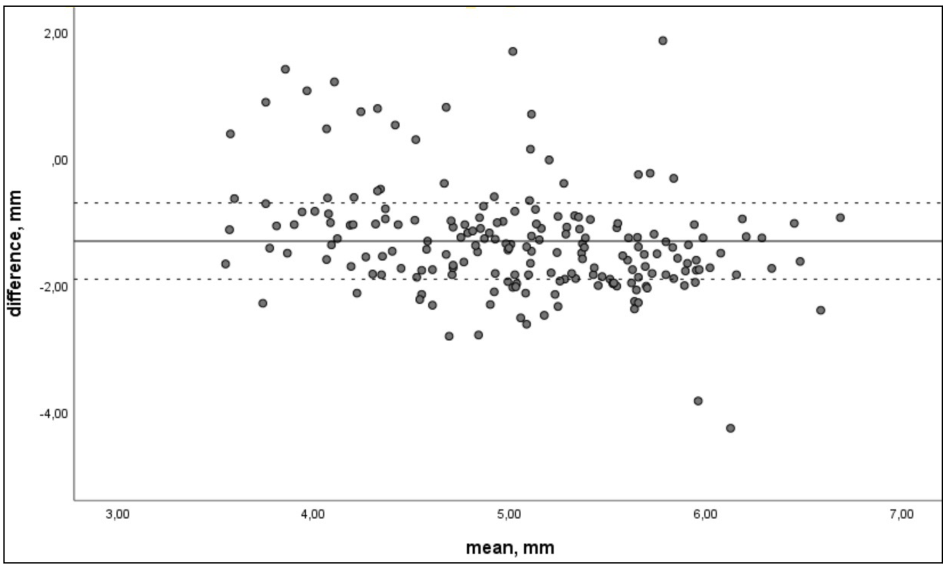

Figure 3: *Bland-Altman plot comparing the Sirius and IOL-Master in measuring the pupil diameter.*

Central corneal thickness plays a pivotal role in the diagnosis and management of corneal pathologies. A thinned cornea, for instance, can be indicative of keratoconus, a progressive condition that weakens and distorts the corneal shape.[22] Monitoring CCT changes becomes vital in this case, allowing for early detection of disease progression and timely intervention. Similarly, increased CCT can be associated with corneal edema, potentially linked to endothelial dysfunction or inflammatory processes.[23] By tracking CCT fluctuations, clinicians can gain valuable insights into the underlying disease etiology and tailor treatment strategies accordingly. Additionally, CCT affects intraocular pressure measurement by applanation tonometry and is an independent risk factor for the progression of ocular hypertension to primary open-angle glaucoma.[24] While we found that CCT values were significantly different between the devices, they had narrow 95% LoA of -6.4 to 1.5 µm for CCT measurements suggesting good agreement.[25] This results showed that Sirius and IOL-Master can be used interchangeably in terms of CCT measurements in pediatric population.

Anterior chamber depth stands as a crucial bridge between IOL power calculation and the selection of an appropriate refractive surgery approach. Its accurate assessment and integration into pre-operative planning pave the way for successful cataract surgery with optimal visual outcomes, ensuring a clear future for patients embarking on this journey to restored vision. Anterior chamber depth directly influences the feasibility and potential outcomes of various cataract or refractive surgery options. Deeper chambers may offer greater flexibility for lens selection and implantation techniques, particularly in procedures like phacoemulsification. Conversely, shallow chambers pose technical challenges, potentially limiting the choice of IOLs or necessitating modifications in surgical technique to avoid complications. Understanding ACD in relation to the patient's anatomy and desired refractive outcome allows surgeons to tailor the procedure for optimal performance and minimize risks. According to the present study, mean ACD difference was 0.343 mm and the devices had 95% LoA of -0.358 to -0.328 mm. This range is not clinically relevant to the IOL power calculation (IOL power varies by 0.05 D for each 0.10 mm of ACD).[26,27] Rastogi et al. reported that the Barret Universal II formula demonstrated the lowest mean absolute prediction error for IOL power calculations in children. Notably, the Barret Universal II formula incorporates ACD as a factor in its calculation.[28]

Children with rapidly fluctuating refractive errors are generally not considered suitable for refractive surgery due to the challenges in achieving accurate preoperative measurements and predicting the long-term stability of the corrected vision. Although the FDA does not currently consider children under the age of 18 to be suitable candidates for refractive surgery,[29] they may become eligible for these procedures in the future. Pupil diameter is one of the most critical values, especially for patients undergoing corneal refractive surgery, when it comes to optimal optical zone calculation. A pupil diameter that is too large or an ablation zone that is too small will inevitably result in significantly high-order aberrations as well as a loss of contrast sensitivity. To minimize these potential complications the accuracy and repeatability of pre-operative PD measurements are very curial. The measurements obtained with IOL-Master were significantly higher and the devices had a 1.306 mm mean difference with a 95% LoA of -1.42 to -1.183 mm in this study. These differences are significant from a clinical point of view regarding the ablation zone and IOL's optic zone.[30]

The early diagnosis and regular follow-up of childhood eye diseases such as keratoconus and glaucoma are essential. This is because children have a longer expected lifespan, and their visual acuity is critical for their learning and development.[31] Cataract surgery in children is also a complex procedure, and the implantation of an inappropriate intraocular lens (IOL) can lead to serious long-term problems. Any additional surgical intervention to correct a complication or replace the IOL can have even more pronounced and lasting consequences in children.[32] For these reasons, it is important that children have their anterior segment parameters measured accurately and that the devices used to diagnose and follow up on these diseases can be interchanged. This will ensure that the most accurate measurements are obtained and that the best possible treatment decisions can be made.

This study has some limitations. Firstly, the age range of the children included in the study was wide, and no comparison was made between age groups. Secondly, the different technologies and illumination techniques used by the Sirius and IOL Master devices may have created potential differences, especially in measurements of ACD and PD. Lastly, although the study had an acceptable number of participants, it may not be appropriate to generalize the results to children.

In conclusion, K2, ACD, CCT, and PD measurements of IOL-Master were significantly higher than the measurements of Sirius. K2 measurements were not statistically significantly different between the devices. According to the present study, the Sirus and IOL-Master devices can be used interchangeably when evaluating the anterior segment parameters including keratometry values, CCT, and ACD in children.

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Conflicts of Interests

The authors have no financial interest to disclose.

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Data Availability

The data sets generated during or analyzed during the current study are available from the corresponding author [Ömer ÖZER] upon reasonable request.

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