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ORIGINAL RESEARCH

The Effect of Tear Film Stability on Variability of Posterior Corneal Curvature Readings with a Swept-Source Optical Biometer in Cataract Patients

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Purpose: To investigate the IOLMaster 700 variability of posterior curvature readings in relation to ocular surface parameters.

Patients and Methods: Eligible cataract patients underwent two consecutive IOLMaster 700 exams and ocular surface assessments including non-invasive and fluorescein tear film break-up time (NIKBUT first and average, FBUT) during one preoperative visit. Intradevice repeatability was assessed based on within-subject standard deviation (Sw), test-retest variability (TRT), and intraclass correlation coefficient (ICC). The device composite standard deviation (SD) for biometric data, anterior corneal radii (R, R1, R2) and posterior corneal radii (PR, PR1, PR2) were analyzed in relation to ocular surface indices. Subgroup analysis evaluated the effect of FBUT on repeatability of trimmed-mean astigmatism vectors.

Results: One hundred eyes of 67 patients were evaluated. Posterior keratometric indices had lower ICCs than anterior indices. The TRT for R and PR was 0.01 and 0.09 mm, respectively. The mean PR composite-SD was significantly higher than mean R composite-SD (34.49 vs 2.55 μm, respectively, $p < 0.001$, *t*-test). The mean R1 composite-SD was negatively correlated with FBUT ($\rho = -0.35$, $p < 0.001$). The mean PR composite-SD was not correlated with ocular surface parameters. A trend towards increasing PR composite-SD with age was observed, approaching statistical significance. Subgroup analysis showed no statistically significant differences for repeat astigmatism vectors in relation to FBUT.

Conclusion: The OCT-based posterior curvature readings show greater variability than the telecentric anterior keratometry. Unlike anterior corneal measurements, posterior corneal readings variability was not linked to tear film parameters.

Keywords: posterior astigmatism, tear film break-up time, posterior keratometry, cataract surgery

Introduction

The posterior corneal curvature can be measured using different technologies, such as optical coherence tomography (OCT), Scheimpflug imaging, or color LED reflectance-based devices. Measured posterior radii may be entered into intraocular lens (IOL) power calculators for the spherical equivalent and toric IOL power prediction, potentially improving the accuracy of astigmatism correction with toric IOLs. However, the results of the measured versus predicted posterior corneal astigmatism (PCA) calculations are contradictory. This may be due to suboptimal measurement precision. Regardless of the technology used, studies show inconsistent results regarding the repeatability of posterior corneal measurements. Some authors report high repeatability for both anterior and posterior cornea,[1–4] while others highlight lower repeatability of posterior keratometry compared to anterior keratometry.[5,6]

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Tear film stability is a well-known factor affecting the accuracy of biometric measurements.[7–9] Although the adverse effects of dry eye disease on anterior corneal readings are well-documented, we have not found studies reporting the influence of the ocular surface on posterior corneal measurements.

The IOLMaster 700 (Carl Zeiss Meditec AG), a swept-source OCT (SS-OCT) ocular biometer, measures both anterior and posterior corneal curvatures. Anterior telecentric keratometry measurements are calculated from the average of 15 images of 18 points of light reflecting off the anterior corneal surface.[10] The posterior corneal surface is mapped using pachymetry measured in six meridional SS-OCT scans and fitted to the anterior surface model to create the toric posterior surface model.[11] Variability in tear film quality can introduce artifacts in pachymetry and anterior corneal curvature measurements, thereby propagating error into the posterior corneal surface model on which device algorithms rely.

The SD of each IOLMaster 700 composite parameter is a single number that summarizes the variability of data. One IOLMaster 700 automatic data-acquisition procedure includes 3 axial SS-OCT measurements, each performed in 6 meridians, and 3 sets of 5 single automatic telecentric keratometric measurements. 10 Altogether, 18 raw axial biometric scans and 15 raw keratometric values are acquired during one automatic IOLMaster 700 measurement. Cannon et al showed that SD of mean keratometry on the IOLMaster 700 exam report ("composite-SD") correlated with the variability of corneal astigmatism vector; moreover, the mean keratometry SD can be used as an indicator of the quality of the IOLMaster exam.[12] Hence, the posterior corneal readings composite-SD reflects the variability of those measurements.

The aim of this cross-sectional study was to assess the variability of posterior corneal curvature readings by means of IOLMaster 700 composite-SD in relation to objective and subjective tear film stability and ocular surface health measures in otherwise healthy cataract patients.

Materials and Methods

This study was conducted as part of a broader prospective controlled clinical study consisting of 3 arms, with data collected in one private hospital in Wroclaw, Poland. Study subjects were recruited from among patients scheduled for cataract surgery from January 2022 to December 2024. The study was approved by the Ethical Committee of Wroclaw Medical University (No 734/2022) and followed the tenets of the Declaration of Helsinki and good clinical practice. Signed informed consents were obtained from all participants.

Inclusion criteria were indication for age-related cataract surgery, age between 50 and 90 years, capability to provide informed consent and the ability to adhere to the study protocol. Exclusion criteria were: any severe ocular surface disease/condition that potentially could confound the results of this study (for example, corneal scars, refractive surgery of the cornea, keratoconus), any ocular procedure performed during last 6 months, any known ocular allergy, chronic ocular disease such as glaucoma, uveitis, Sjögren syndrome or other autoimmune diseases or any general condition/medication that could significantly influence the ocular surface status. Patients with age related macular degeneration or any other macular and retinal diseases causing morphological changes in the fovea were also excluded.

Dry Eye Assessments

All subjects were examined according to the study protocol, in the same standardized order established according to TFOS DEWS II recommendations and starting with the least invasive methods.[13] The order of measurements is presented in Figure 1 (Figure 1). The ocular surface disease symptoms (OSD) were assessed using the ASCRS SPEED II© OSD questionnaire (Ocular Surface Disease Standard Patient Evaluation of Eye Dryness questionnaire modified by the American Society of Cataract and Refractive Surgery).[14] Written permission for using it was given by its developer, Christopher E. Starr. Dry eye symptoms were assessed by fluorescein and non-invasive measurement of tear film break-up time (FBUT and NIKBUT, respectively), lid-parallel conjunctival folds (LIPCOF) and tear meniscus height (TMH).

The Oculus Keratograph 5M (K5M) (OCULUS®, Optikgeräte GmbH, Wetzlar, Germany, software version v3.10.0.0) was used to determine TMH, NIKBUT-f and NIKBUT-avg. TMH was photographed with K5M and measured with digital callipers in the central lid margin. NIKBUT-f was defined in the K5M software as the time between a blink and the first appearance of deformation of the reflected Placido rings whereas NIKBUT-avg was calculated as the average time from the appearance of the deformation to the next blink or automatic termination of the measurement after 25 seconds. Two K5M measurements were taken for each eye separated by 2 minutes and the mean of each parameter

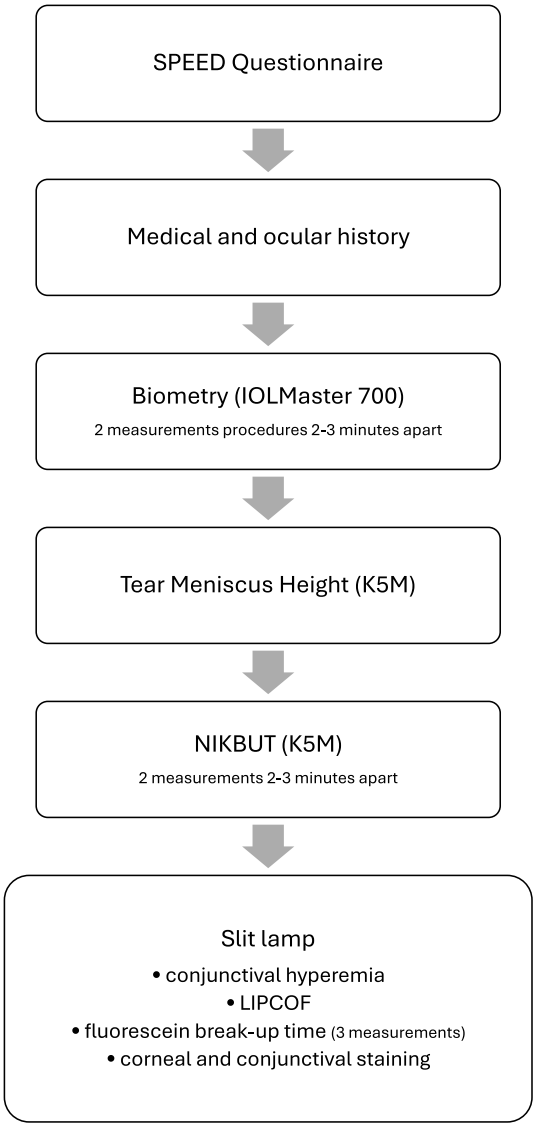

Figure 1 Flow diagram of the study protocol.

was further analysed. Using a 2-minute separation between measurements eliminates the influence of the previous interblink interval on the subsequent measurement. This is based on the research by Yokoi et al[15] who demonstrated that complete reorganization of the tear film lipid layer does not occur after every blink, but after several blinks. A break between measurements, which require the eyes to be open for a longer period, also allows the tear film to regenerate. In the previous study using this short break, no statistically significant differences in tear film breakup time between the first and second measurements were detected.[16]

The slit lamp assessments were conducted with the following parameters being evaluated: conjunctival hyperemia, LIPCOF grading, FBUT, corneal and conjunctival fluorescein staining.[13]

To measure FBUT a drop of saline solution was placed on fluorescein strip (Madhu Instruments Pvt. Ltd., New Delhi, India). The strip was applied to the temporal canthal lid margin area. The slit-lamp magnification was set at ×10; cobalt blue light and a Wratten 12 yellow filter were used to enhance observation of the tear film. The time between blink and the first appearance of the first dark spot was recorded using a stopwatch (in seconds). The FBUT was measured three times and the final score was averaged. Fluorescein corneal and conjunctival staining were based on the Oxford

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schema.[17] Staining ranges from 0–15 for the total exposed inter-palpebral conjunctiva and cornea as a sum of 0–5 grading for cornea, temporal conjunctiva and nasal conjunctiva.

The clinical criteria for diagnosing dry eye disease in the elderly, cataract population are not sufficiently well defined both in terms of clear cut-off values and a common diagnostic protocol.[18,19] Ocular staining > 3, LIPCOF > 2, severe conjunctival hyperemia or FBUT < 2 s[20] were considered signs of severe OSD and reason for exclusion.

Biometer

Two sequential ocular biometry exams with IOLMaster 700 (Carl Zeiss Meditec AG, Jena, Germany, software version 1.90.30.09) were performed, asking the patient to sit back and blink naturally for a few minutes between measurements to avoid ocular surface drying. Each measurement was triggered after achieving alignment, as soon as possible after a few natural blinks. No artificial tears were allowed in between, and all subjects were measured under non-mydriatic conditions between 8:00 am and 12 a.m. The IOLMaster 700 telecentric, 3-zone reflectance keratometry measurements are calculated from the average of 15 images of 18 points of light reflecting off the anterior corneal surface. The reflections measure anterior corneal curvature, which is converted to corneal power (K) using the keratometric index of 1.3375. The posterior corneal surface is mapped using pachymetry measured in six meridional SS-OCT scans and fitted to the anterior surface model to create the toric posterior surface model.[11] The posterior corneal surface values are an intermediate step of determining Total Keratometry (TK) but are also displayed to the user.[10]

The IOLMaster 700 Corneal Values Report contains data for both corneal surfaces: anterior (R, R1, R2, ΔK) and posterior (PR, PR1, PR2, ΔPK). Each of these parameters is presented as the composite value, which is the non-arithmetic average from a set of 3 average values of 5 single measurements. The composite values are displayed with standard deviation (composite-SD), a measure of intra-device repeatability of one composite measurement (Figure 2). The Biometric

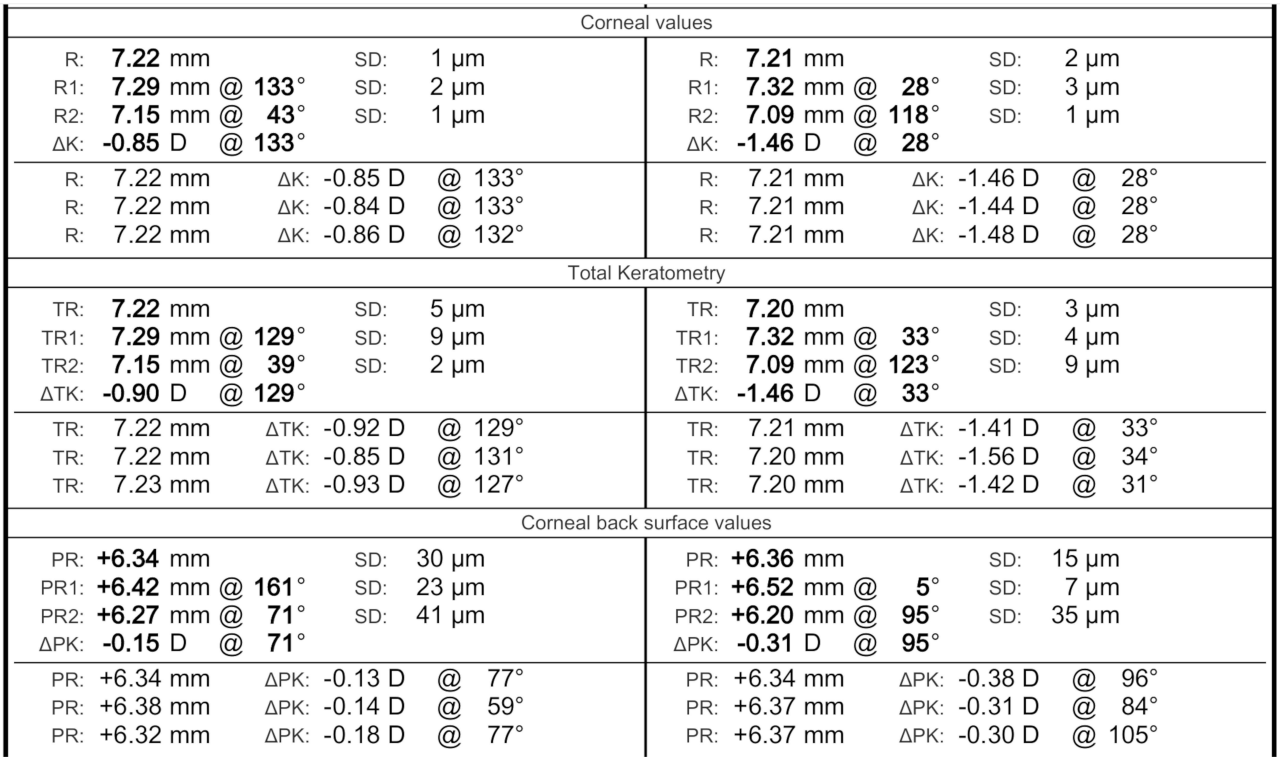

Figure 2 An example of IOLMaster 700 report on Corneal Values, Total Keratometry and Corneal Back Surface values.
Note: Data shown in bold are composite values and are reported with standard deviation (SD).
Abbreviations: R, anterior corneal mean radius; R1, anterior corneal radius in flat meridian; R2, anterior corneal radius in steep meridian; SD, standard deviation; ΔK, difference between R2 and R1 in diopters; TR, total keratometry mean radius; TR1, total keratometry radius in flat meridian; TR2, total keratometry radius in steep meridian; ΔTK, difference between TR2 and TR1 in diopters; PR, posterior corneal mean radius; PR1, posterior corneal radius in flat meridian; PR2, posterior corneal radius in steep meridian; ΔPK, difference between PR2 and PR1 in diopters.

Values Report shows data derived from axial SS-OCT measurements: axial length (AL), central corneal thickness (CCT), anterior chamber depth measured to corneal epithelium (ACD) and lens thickness (LT). The above listed composite values are derived from average values of the 3 axial SS-OCT scans of 6 meridians: 0°, 30°, 60°, 90°, 120° and 150°.[10]

The IOLMaster output is accompanied with quality indicator (QI): green (signal quality acceptable), yellow (signal quality is decreased and the exam should be repeated) and red (poor signal, no measurements available). QIs are displayed for CCT, ACD, AL, LT, K and TK data. Each indicator of signal quality refers to an individual measured value (eg AL) or a group of measured values (eg keratometry).[10] For the purpose of this study, only quality check green indicator exams were included in the analysis.

The reflectance keratometry uses the relationship between object size, image size, and the distance between the reflective surface and the object to calculate the radius of the reflective surface. All these variables are measures of length reported in metric system units. Converting length units to dioptric power, using fictional indexes based on Snell's law, can obscure the raw data variability. Specifically, the small difference between refractive indices of corneal stroma and aqueous humor may lead to the underestimation of posterior corneal radius measurements variability. Therefore, analyzing corneal radius measurements variability by means of composite-SD was performed in metric system. The anonymized IOLMaster corneal and biometric composite mean in mm and SD in μm were exported for the following parameters: R, R1, R2, PR, PR1, PR2, AL, ACD, LT, CCT.

For the anterior corneal astigmatism analysis, anterior corneal radii values in mm were converted into dioptric power using the following equation:

$$K = \frac{nk - 1}{R}$$

were K = anterior corneal power in Diopters, nk = 1.3375 is a keratometric index, and R = posterior radius of curvature in meters.

For the posterior corneal astigmatism, posterior corneal radii values in mm were converted into dioptric power using the following equation:

$$PK = \frac{na - ns}{PR}$$

were PK = posterior corneal power in Diopters, na = 1.336 is the refractive index of the aqueous humor, ns = 1.376 is the refractive index of the corneal stroma and PR = posterior radius of curvature in meters. Anterior (ΔK) and posterior (ΔPK) astigmatism values were calculated. The vector analysis was performed according to Thibos et al,[21] converting the anterior and posterior astigmatism power values to rectangular vectors J0 and J45 (J0K, J45K – for anterior astigmatism, J0PK, J45PK – for posterior astigmatism), using the following equations: $J0 = -(C/2) \times \cos(2\alpha)$ and $J45 = -(C/2) \times \sin(2\alpha)$, where J0 represents the Jackson cross-cylinder power at axis 90 and 180, J45 is the Jackson cross-cylinder power at axis 45 and 135, C is the astigmatism magnitude, and α is the axis of the astigmatism. Double angle plots were generated with Eyetemis software[22] for paired comparisons between 2 consecutive measurements of anterior and posterior corneal astigmatism of the same eye. This was done for two subgroups: with short FBUT and long FBUT, whereas the cut-off value used (5 s)[23] was also close to the median FBUT value for entire cohort. The Eyetemis software as well as IOLMaster 700 use vector analysis for ΔK, ΔPK and SD, what was independently verified.

All K5M and IOLMaster 700 exams were performed by the same experienced optometrist (IK), all clinical assessments were performed by the same experienced ophthalmologist (MM-W) in the same examination room.

Statistics

Sample size calculation was performed according to McAlinden and at least 63 subjects were considered for a Kmean 0.1D difference with a 0.1D Kmean SD.[24] Statistical analyses were completed using Statistica v.13.3 (StatSoft), Stat Plus PRO v7.8.4 for Microsoft Excel (AnalystSoft Inc.) and the Eyetemis analysis tool (www.eyetemis.com).[22] The Shapiro–Wilk test was used to check the normality of data distribution. To determine the intra-observer repeatability of IOLMaster 700 measurements a one-way analysis of variance (ANOVA) was used to calculate the within-subject standard deviation (Sw) with α set at 0.05. Intrasession test–retest variability (TRT) was calculated by multiplying the pooled within-subject

SD (Sw) by 2.77.[25] Based on repeatability, the difference between two measurements for the same subject shall be less than 2.77 Sw for 95% of paired observations. Intraclass correlation coefficient (ICC) was calculated with one-way random-effects model for consistency of repeated measurements. A value between 0.75 and 0.90 indicates moderate repeatability, whereas >0.90 is considered to be highly consistent.

Astigmatism variability was analyzed with Eyetemis software using the "paired-population corneal astigmatism" option (analysis configuration: p value adjustment method: Holm, α value: 0.05). The anterior and posterior astigmatism trimmed means were compared for trueness, precision and accuracy utilizing the robust 2-sample *t*-test. Accuracy is assessed by comparing the trimmed mean values of the astigmatic magnitude; trueness refers to the closeness of agreement between the centroid value of test results and a reference centroid value; precision refers to the closeness of agreement between first and second measurement.[26]

Spearman's rank correlation coefficient (ρ) was calculated to assess the relationship between IOLMaster derived SD (composite-SD) of mean K, PK, AL, ACD, LT, CCT, R, R1, R2, PR, PR1, PR2 values with ocular surface health indices and patients' age.

Results

Intra-Device IOLMaster 700 Variability

One hundred eyes of 67 patients (16 men, 51 women) with the mean age of 67 ± 8.6 years (range: 50–90) were eligible for the analysis. Overall, the repeatability for IOLMaster 700 measured parameters in the whole group was good, with no statistically significant differences between repeated measurements (Table 1). However, ICCs for all posterior cornea measurements (PR, PR1, PR2, ΔPK) were lower than for all other IOLMaster 700 parameters. Lower ICCs were also observed for the posterior astigmatism vectors J0 and J45, as compared to anterior astigmatism J0 and J45, with the lowest ICC for J0 PK (ICC = 0.546). The TRT variability was larger for PR than R (0.09 mm versus 0.01 mm, respectively).

The IOLMaster 700 composite-SDs for R and PR values for single automated measurement acquisition reflect the variability of a single composite output IOLMaster value. Mean composite-SD values were 2.55 μm, 3.82 μm, 3.96 μm for R, mean R1 and R2, and 34.49 μm, 47.00 μm and 45.32 μm for PR, PR1 and PR2, respectively. The IOLMaster composite-SD values of posterior curvature measurements were significantly higher than SD for anterior radii values ($p < 0.001$, *t*-test) (Figure 3). Converting posterior radii readings from micrometres to diopters resulted in obscuring the variability of data, with composite-SD values of 0.18 D, 0.11D, 0.11D for KSE, K1, K2 −0.05, −0.03, −0.04 D for PSE, PK1, and PK2, respectively.

Dry Eye Assessments

The SPEED questionnaire result was 6.32 ± 4.92 points, the TMH was 0.33 ± 0.15 mm, NIKBUT-f was 8.63 ± 5.64 s, NIKBUT-avg was 12.63 ± 6.07 s and FBUT was 6.33 ± 3.96 s. The hyperemia score was 0.46 ± 0.63, LIPCOF grading was 0.56 ± 0.72 and Oxford ocular surface staining score was 1.18 ± 1.8. These results correspond to normal or mild dry eye disease. There was a statistically significant, positive correlation between NIKBUT-f and NIKBUT-avg ($\rho = 0.82$; $p < 0.001$), and moderate positive correlation between FBUT and NIKBUT-f and FBUT and NIKBUT-avg ($\rho = 0.35$, $p < 0.001$; $\rho = 0.36$; $p < 0.001$, respectively).

FBUT was the only ocular surface index that showed a significant negative correlation with R1-composite SD ($\rho = -0.35$, $p < 0.001$) and with mean R composite-SD ($\rho = -0.29$; $p = 0.004$). The mean PR composite-SD showed no correlation with any of the ocular surface assessments. A trend towards increasing PR composite-SD with age was observed, approaching statistical significance. No correlation between age and mean R-composite SD was found. No correlation was also observed between age and composite-SD of other IOLMaster parameters as well as between age and ocular surface parameters.

Table 1 Intraobserver Repeatability of Biometric and Corneal Values for IOLMaster 700

Parameter	Measurement 1 Mean (SD)	Measurement 2 Mean (SD)	TRT	Sw	ICC	p
AL (mm)	23.27 (1.36)	23.25 (1.35)	0.28	0.10	0.999	0.94
CCT (μm)	553 (39.30)	554 (39.75)	14.88	5.37	0.995	0.89
ACD (mm)	3.08 (0.43)	3.06 (0.43)	0.33	0.12	0.999	0.77
LT (mm)	4.56 (0.37)	4.56 (0.38)	0.08	0.03	0.998	0.93
R (mm)	7.62 (0.25)	7.62 (0.25)	0.01	0.003	0.995	0.99
R1 (mm)	7.70 (0.25)	7.70 (0.25)	0.06	0.02	0.992	0.96
R2 (mm)	7.54 (0.27)	7.54 (0.27)	0.03	0.01	0.990	0.97
PR (mm)	6.76 (0.26)	6.75 (0.28)	0.09	0.03	0.847	0.90
PR1 (mm)	6.88 (0.26)	6.88 (0.28)	0.15	0.05	0.837	0.84
PR2 (mm)	6.63 (0.29)	6.63 (0.31)	0.04	0.02	0.864	0.95
J0 K (D)	0.10 (0.52)	0.09 (0.50)	0.08	0.03	0.955	0.93
J45 K (D)	0.01 (0.31)	0.00 (0.30)	0.25	0.09	0.939	0.77
ΔK (D)	0.95 (0.81)	0.93 (0.83)	0.52	0.19	0.936	0.82
J0 PK (D)	0.08 (0.08)	0.06 (0.10)	0.33	0.12	0.546	0.14
J45 PK (D)	0.02 (0.06)	0.02 (0.06)	0.05	0.02	0.732	0.67
ΔPK (D)	0.23 (0.14)	0.24 (0.16)	0.20	0.07	0.760	0.65

Note: For astigmatism, vector analysis is presented.

Abbreviations: ACD, anterior chamber depth; AL, axial length; CCT, central corneal thickness; ICC, intra-class coefficient; LT, lens thickness PR, posterior mean corneal radius; PR1, posterior flat corneal radius; PR2 posterior steep corneal radius; R, anterior mean corneal radius; R1, anterior flat corneal radius; R2 anterior steep corneal radius; SD, standard deviation; Sw, within-subject standard deviation; TRT, test-retest variability; J0 K, anterior astigmatism Jackson cross-cylinder power at axis 90 and 180; J45 K, anterior astigmatism Jackson cross-cylinder power at axis 45 and 135; J0 PK—posterior astigmatism Jackson cross-cylinder power at axis 90 and 180; J45 PK, posterior astigmatism Jackson cross-cylinder power at axis 45 and 135; ΔK, anterior corneal astigmatism; ΔPK, posterior corneal astigmatism.

Subgroup Astigmatism Vector Analysis

The entire cohort was divided into two groups: "long BUT" (50 eyes) and "short BUT" (50 eyes) based on FBUT cut-off value set at 5 s. For these 2 groups, anterior and posterior astigmatism repeated measurements analysis by means of trueness, precision and accuracy are presented in Table 2. (Table 2). There were no statistically significant differences between trimmed means of both anterior and posterior corneal measurements for eyes with "short BUT" or "long BUT", except for anterior curvature measurements accuracy in eyes with "long BUT" ($p = 0.03$). Figure 4 depicts anterior and posterior astigmatism trimmed vector repeatability based on first and second measurements in eyes with short FBUT or long FBUT presented as polar diagrams (Figure 4A–D).

There were no statistically significant differences between first and second measurement for AL, CCT, ACD and LT in either group (long and short BUT).

Discussion

We have shown that the variability of posterior corneal radii measurements was larger than the variability of anterior corneal radii. While the R composite-SD was negatively correlated with tear film BUT, the PR composite-SD was not correlated with any of the ocular surface assessments. Therefore, other factors must be considered. Our data showed a trend towards increasing PR composite-SD with age for the 67 eyes considered. Interestingly, the variability of other variables measured with the IOLMaster 700 was not associated with age.

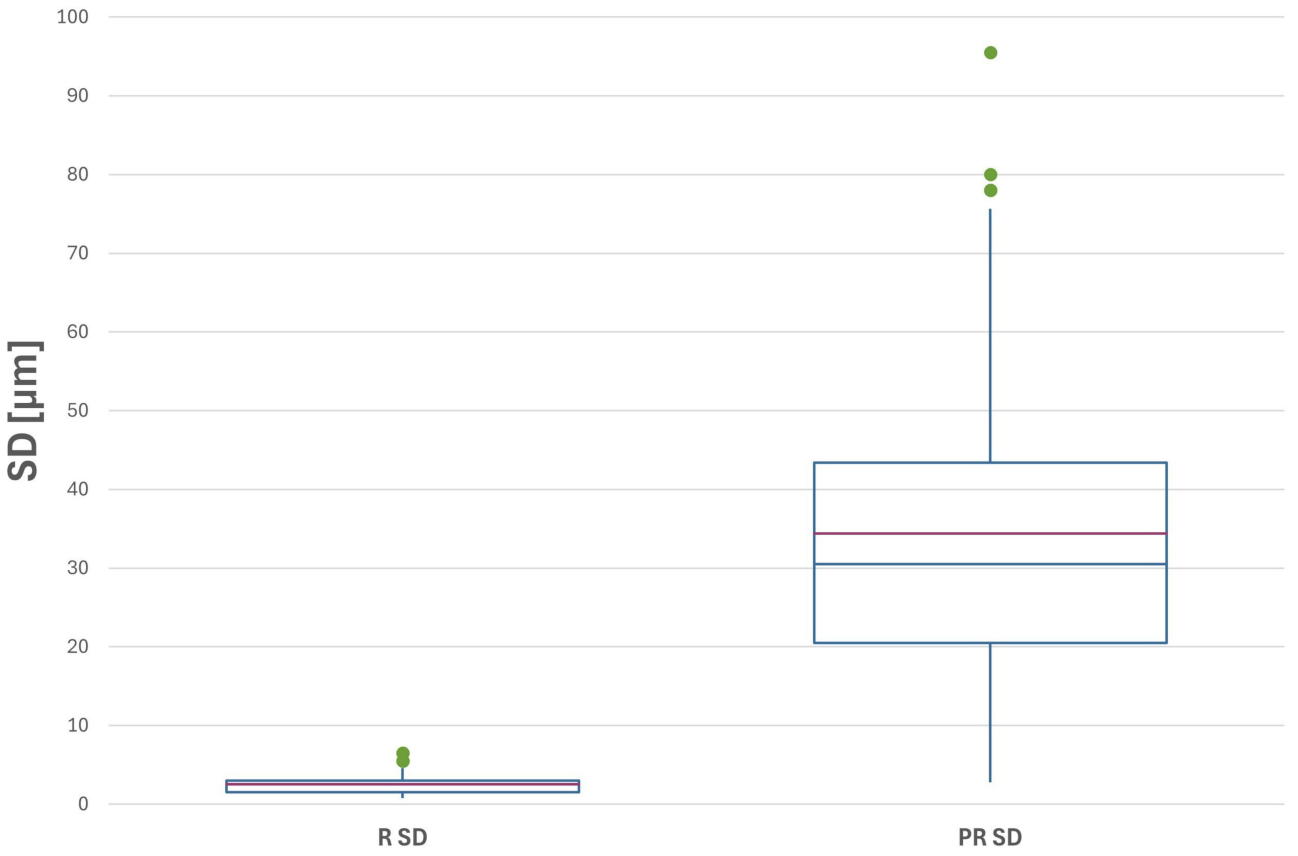

Figure 3 Box plot of R mean composite-SD (R_SD) and PR mean composite-SD values (PR_SD) in µm for single automated IOLMaster 700 measurements ($p < 0.001$, ANOVA).

Many studies reported high repeatability of IOLMaster 700 anterior keratometry and total keratometry.[11,27,28] Cannon et al reported that for IOLMaster 700 exams with acceptable, green quality indicator no difference was noted in the variability of K and TK measurements. However, the SD of these measurements was significantly bigger for eyes with anterior or TK astigmatism difference >0.50 D between two repeated exams.[12] Nevertheless, TK is a secondary

Table 2 The Trueness, Precision and Accuracy Data of 2 Paired Measurements of Anterior (ΔK) and Posterior (ΔPK) Corneal Astigmatism in Eyes with Short and Long FBUT

Parameter/Group	Measurement 1 Centroid (D) (x,y)	Measurement 2 Centroid (D) (x,y)	Trueness p	Precision p	Accuracy p
ΔK/short FBUT	0.12 @ 80° (−0.12, 0.04)	0.17 @ 86.5° (−0.17, 0.02)	0.44	0.93	0.84
ΔK/long FBUT	0.33 @ 81.7° (−0.32, 0.10)	0.25 @ 79.3° (−0.23, 0.09)	0.33	0.57	0.03[a]
ΔPK/short FBUT	0.17 @ 9.9° (0.16, 0.06)	0.15 @ 11.2° (0.14, 0.06)	0.49	0.88	0.84
ΔPK/long FBUT	0.17 @ 8.4° (0.16, 0.05)	0.14 @ 6.9° (0.14, 0.03)	0.09	0.95	0.34

Note: [a]Statistically significant (2 sample robust t-test).

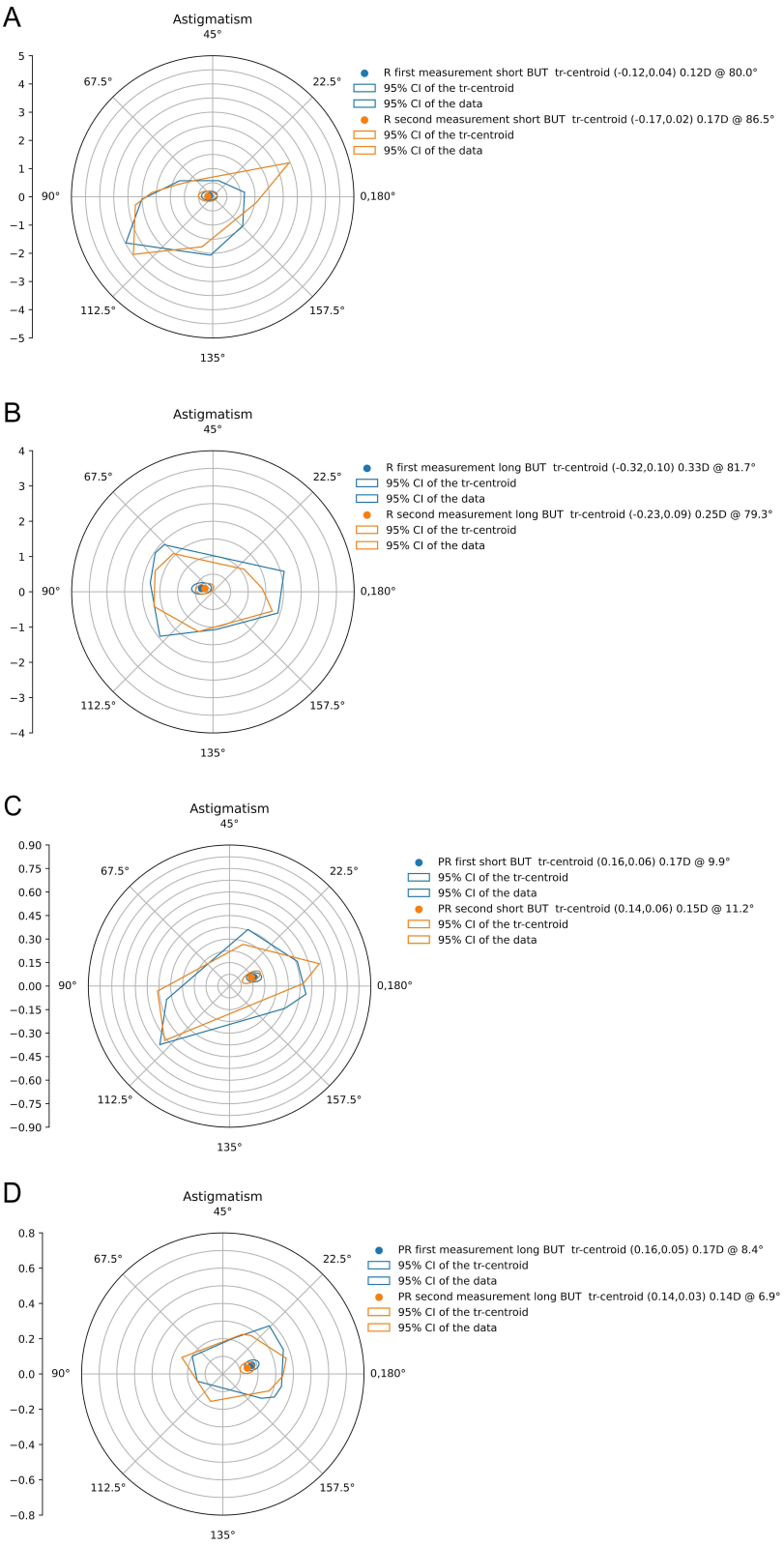

Figure 4 Double angle plots of anterior (ΔK) and posterior (ΔPK) astigmatism trimmed centroid repeatability based on first (blue) and second (Orange) measurements in eyes with short FBUT or long FBUT, (**A**) ΔK in eyes with short FBUT, (**B**) ΔK in eyes with long FBUT, (**C**) ΔPK in eyes with short FBUT, (**D**) ΔPK in eyes with long FBUT.

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parameter, derived from both corneal surfaces, hence it does not deliver information on posterior corneal keratometry repeatability alone. Therefore, we did not analyze TK, but evaluated the composite standard deviations of the raw posterior corneal readings measured in millimeters. Expressing these data in length units reveals variability in the posterior corneal radius readings that becomes obscured when the values are converted to dioptric power. This masking effect arises from the small difference between the refractive indices of the corneal stroma and the aqueous humor. Presenting posterior corneal readings variability geometrically, without conversion, provides greater insight into the results. The "noise" in posterior corneal radius measurements may help explain why toric IOL calculations based on predicted astigmatism can outperform those derived from actual measurements.[29–31]

The reported results of the measured versus predicted PCA for toric IOL calculations are controversial. Wang et al found that measured PCA yields lower prediction error in a cohort of patients with monofocal IOLs.[32] Stewart et al reported that using measured PCA improves results only when the astigmatism axis is not vertically oriented.[33] On the contrary, Yang at al showed that the predicted residual astigmatism using Barrett Integrated Keratometry Toric Calculator was smaller while using predicted PCA mode than while using measured PCA.[29] Other study also showed that measured PCA (both with IOLMaster 700 and Pentacam) did not perform better than the estimated PCA in toric IOL calculations.[30] As mentioned before, this can be explained by the suboptimal accuracy of posterior corneal measurements, highlighted in our study. The inferior repeatability of posterior corneal radii measurements performed with IOLMaster 700 and Casia 2 was also reported by other authors.[5,6]

The IOLMaster 700 TK feature was supposed to overcome systematic weaknesses of anterior keratometry by reducing model assumptions (ie the assumption of a constant anterior/posterior corneal surface ratio and a constant central corneal thickness implied by the keratometric index).[10] However, it was shown that using the IOLMaster 700 TK does not increase the prediction accuracy of the ESCRS IOL calculator formulas.[34] Likewise, utilizing the Anterion (Heidelberg Engineering) total corneal power does not improve the refractive outcomes of IOL power calculations in comparison to calculations based on anterior keratometry only.[35] One possible explanation can be that the posterior corneal radii measurements are less than perfect and that technology may need further advancements.

The assessment of the variability of posterior corneal readings poses several confounding factors: 1. The difference between the refractive index of the corneal stroma and the aqueous humor is smaller than that between the refractive index of air and the corneal stroma. Therefore, converting radii from mm to D obscures the variability in posterior measurements. 2. The posterior cornea has lower refractive power compared to the anterior cornea. Consequently, both the numerical values and deviations will also be smaller than those of the anterior cornea. 3. The anterior curvature exhibits greater variation within the population than the posterior curvature. As a result, the corresponding power vectors are larger.

Our study demonstrated significant variability of IOLMaster700 posterior corneal radii readings in older cataract patients, which was not related to the tear film stability. This raises the question of how other devices, based on other technologies, such as Scheimpflug camera, perform in comparison. In young, healthy adults (mean age 25 years), other SS-OCT devices – Anterion, and Casia 2 (Tomey) – have shown higher repeatability of posterior K measurements than the Pentacam.[4] Because the cohort in our study was much older, the results may have been influenced by age related changes in the corneal tissue. Future studies could examine the repeatability of posterior corneal measurements across different age groups and using various measurement technologies.

The strengths of our study include a prospective design and complex assessments of tear film parameters for each measured eye. We have confirmed the well-recognized correlation between FBUT and NIKBUT, as well as between anterior keratometry measurement variability and FBUT. This validates the importance of the tear film assessment in preoperative screening for patients with cataracts.[36] At the same time, we demonstrated that the variability of posterior corneal curvature measurements, obtained with an SS-OCT based biometer, is not related to tear film stability. Furthermore, we concentrated our analysis on the composite-SD value, which can be quickly accessed on the IOLMaster report in cataract clinics.

There are some limitations to this project. Firstly, a second instrument measuring posterior corneal curvature, such as Scheimpflug-based device, would allow for comparison of data variability. Secondly, we excluded cataract patients with more severe dry eye, resulting in generally very good repeatability of examined parameters. Less homogeneous

group could have result in more robust results. Larger studies are needed to establish the potential relationship between age related changes in corneal stroma and endothelium with the repeatability of posterior corneal curvature measurements.

Conclusion

In conclusion, the variability of posterior corneal readings on the SS-OCT biometer was bigger than that of anterior keratometry and was not linked to ocular surface parameters. Posterior corneal measurements may require further technical advancements to achieve optimal accuracy.

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Disclosure

The authors report no conflicts of interest in this work.

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