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Research Article

Investigation of Intraobserver Repeatability and Interobserver Reproducibility of Corneal Indices Obtained Using Three Different Topographers

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Abstract

Purpose: Investigating intraobserver and interobservers repeatability, reproducibility and limits of agreement of anterior corneal indices using three different topographers.

Methods: Forty five participants were recruited, involved two examiners and two sessions. They were assessed in random order with EyeSys Vista, Medmont E-300 and manual keratometer. The corneal indices were horizontal keratometer, vertical keratometer, eccentricity and inferior superior index. Repeatability and reproducibility of corneal power measurements were assessed based on the intersession, intrasession, Intraclass Correlation Coefficient (ICC), Spearman's correlations and agreement was evaluated by Bland Altman test (95% Limits Of Agreement, LoA).

Result: All devices showed high repeatability ($p < 0.01$) and reproducibility (ICC>0.75) of the corneal indices. Multivariate analysis of variance showed nonsignificant findings between visits and examiners ($p > 0.05$), while there was a significant difference between the devices among keratometric readings ($p < 0.0001$). The differences between the EyeSys, Medmont and manual keratometer were significant ($p < 0.01$). Moderate relationship was found between the keratometric readings with the three devices ($r = 0.60$, $p < 0.0001$). The 95% LoA for EyeSys and Medmont of the keratometric readings were larger than those for the Medmont and manual keratometer (±0.3 mm). The eccentricity and inferior superior index measurements were not significantly different between the EyeSys and Medmont ($p > 0.01$).

Conclusion: All devices exhibited excellent repeatability and reproducibility. The EyeSys is portable, repeatable, and reliable and have stable interobservers variability. Although EyeSys would not be used interchangeably with the other two devices due to lower agreement, corrected linear calculation was suggested to manage the differences between the EyeSys and the two devices.

Keywords: Corneal curvature; Corneal topography; Keratometry; EyeSys vista; Medmont

Abbreviations

IOL: Intraocular Lens; SD: Standard Deviation; D: Diopters; VA: Visual Acuity; OSDI: Ocular Surface Disease Index; Kh: Horizontal K-Reading; Kv: Vertical K-Reading; Ecc: Corneal Eccentricity; IS: Inferior Superior Index; ICC: Intraclass Correlation Coefficient; Loa: Limits of Agreement; IQR: Interqurtial Range; MANOVA: Multivariate Analysis Of Variance

Introduction

The cornea provides two-thirds of the total optical power of the eye. Determining corneal curvature and other corneal indices in a reliable and accurate method is vital in clinical procedures and research setting. Measuring corneal curvature is essential in assessing contact lenses, keratoconus signs, calculating intraocular lens (IOL) and refractive surgery procedure [1-4]. Numerous devices are commercially available for the assessment of corneal parameters. Several studies have investigated the accuracy and reliability of those measurements obtained using different devices [5-10]. Studies to evaluate the interchangeability of measurements obtained from the different devices are essential to confirm if they can provide comparable data.

One of the oldest and traditional device to measure the corneal curvature is the manual keratometer which widely considered to be a gold standard device [11]. In the last decades several automated computerized topographershas been developed and investigated. Two of those are placido disk–based corneal topographers, Medmont E300 (Medmont Pty. Ltd., Victoria, Australia) and EyeSys Vista (EyeSys INC., Texas, USA)). The main aim of this study is to assess the accuracy, reliability and reproducibility between two examinersover two visits with those two devices as well as the manual keratometer.

The desktop Medmont E-300 is a placido disk-based topography, has 32 placido rings, which utilize arc-step reconstruction algorithm

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and incorporates a range finder [12,13]. It measures the distance from the corneal apex to the device camera and then automatically takes images. For each image captured a score out of 100 based on focus, movement and centering was given and the image scores >75 was considered of good quality. The Medmont measures the central 3 mm diameter field of the corneal radius of curvature in both the flat and steep meridians.

Silmilar to the Medmont E-300, the portable EyeSys Vista is a placido-based corneal topography that has 25 placido rings and its measurement can be taken within 3, 5 and 7mm diameter field of the corneal. The topography map then sent to the iTrace system with integrated software [5]. The EyeSys Vista advantageous features over the other similar devices are portability and freedom of use outside the conventional clinic or lab. In this study, the 3 mm diameter field readings were selected in order to match areas of measurement in the other two devices.

As the Medmont E-300 and the EyeSys Vista devices have the same optical principles behind them, therefore it is likely to have minimal differences when assessing corneal measurements. Prior study investigated the intrasession and intersession of those two devices among other 6 devices [5]. Although, a single examiner took all measurements in the two sessions, that procedure would not show variability of the devices between examiners.

The main aim of the present study is to prospectively determine the variability (between examiners), repeatability (intrasession) and reproducibility (intersession) of corneal indices using the 3devices mentioned earlier and to investigate differences in keratometric and corneal asphericity for each of the different devices in order to check the interchangeability between those devices in healthy eyes.

Materials and Methods

This study obtained an institutional ethical board approval. The aims of the study and any potential consequences were fully described for all participants, and self-informed written consent was collected. This study adhered to the tenets of the Helsinki Declaration at all stages.

The study is a cross sectional in design and recruited participants aged 18-45 years. The study aimed to comprehensively compare three instruments: the Vista system (Eye Sys Vision, Houston, TX, USA), the Medmont E-300(Medmont Pty. Ltd., Victoria, Australia) and the Bausch and Lomb manual keratometer (Bausch and Lomb, Quebec, Canada).

Sample Size

The sample size was calculated with a PS Power and Sample Size Calculation Software (version 3.1.6, Vanderbilt University, USA). The pooled Standard Deviation (SD) of the differences in corneal radius of curvature between several instruments was found in previous study to be approximately 0.10 diopters (D) [14]. The criteria entered was two-sided test of a level of significance (α) = 0.05 and a power of 99%, a sample size of 21 pairs (42 participants) was suggested to be the required sample in order to detect a difference of 0.10 D between different instruments.

Procedure

The recruited participants were excluded if they have 1) distance Visual Acuity (VA) worse than 20/25 to avoid any miss-fixation, 2) dryness based on the ocular surface disease index (OSDI) questionnaire (with a cut off of 13 as suggested by Schiffman et al.) [15], 3) contact lens wearers, 4) have any corneal opacities, corneal scars, cataracts, or any previous ocular surgery.

The refraction assessment was conducted using the Nidek OPD-Scan III (Nidek Technologies, Gamagori, Japan) in accordance with the manufacturer's directions by means of the auto-tracking and auto-shot functions. Briefly, the participants were instructed to fixate on the image inside the device, which has an auto fogging feature to relax the accommodation. The device automatically takes for each eye three readings and the representative reading signposted by parentheses which was then selected [16].

Each participant was tested with the three devices in random order on two visits by two examiners. Both examiners were masked to each other's record and both were trained and experienced in using the 3 topographers. The participant was tested at the same location, between 9:00 AM to 4:00 PM to minimize variations in the results. In each visit, the examiners collected the measurements with each instrument for all participants according to the manufacturers' instructions.

The protocol of measuring the anterior corneal indices followed the same procedure of a previous study [5]. Briefly, each examiner asked each participants to blink completely just before each scan. Then asked to sit back after each measurement. The instrument was readjusted before each measurement. The measurements with the 3 topographers were in continual procedure, and without any significant time intervals. The repeated measurements were scheduled within one week at approximately the same time as the first visit, using the same protocol.

This study compared several corneal shape descriptors between the Medmont E300 and the vista system while the Keratometer focuses only on K-readings. For each instrument: horizontal and vertical K-reading (Kh and Kv), eccentricity (Ecc), eccentricity indicates the departure of the peripheral curvature of the cornea from the apical radius and refers to degree of asphericity (the average normal corneas would have an eccentricity of about 0.55); [17] Inferior Superior index (IS), which refers to inferior-superior dioptric asymmetry an indicative risk factor keratoconus[18].These descriptors are the key determinates of the corneal power, shape, and integrity [17,19,20].

Data Analysis

The data analysis was conducted using IBM SPSS Statistics (IBM Corp., Armonk, N.Y., USA). The data was not normally distributed (Kolmogorov-Smirnov test, $p<0.05$), the median± Interqurtial Range (IQR) were used to report the data. The differences between examiners, devices and visits were considered statistically significance when the p value was <0.01, in order to consider the Bonferroni correction.

It has been suggested that there is eventual correlation existing between right and left eyes of a single patient. [21,22] The relationship between the right and left eye measurements in the 3 instruments were investigated, and very strong and significant relationship was found ($r > 0.80$, $p <0.05$). Therefore, to follow previous studies procedures and to avoid any bias the outcome of right eye from each participant

with the 3 instruments was selected in the further analysis.

Comparison within Instruments

Intrasession repeatability was assessed with Intraclass Correlation Coefficient (ICC) and their respective 95% CI. The ICC measure the consistency for data sets of repeated measurements. According to previous suggestion the closer the ICC is to 1, the better the measurement consistency [5]. Specifically, the ICC score of >0.75 indicates "excellent," 0.40 to 0.75 "fair to good," and <0.40 "poor" reliability [23]. Additionally, Wilcoxon signed rank test was used to investigate the difference within each examiners, while the Mann-Whitney test was used to investigate the difference between the two examiners and topogrpahers.

Bland-Altman analysis (95% Limits Of Agreement (LoA)) were also used to express the extent of agreement between test-retest outcomes [24]. In this test the difference of the paired intra and intersession measurements is plotted against the corresponding average. It has been recommended that 95% of the data points lies within the mean ± 1.96 SD of the differences for the intrasession and intersession measurements, which corresponds to the 95% confidence interval. A narrower 95% limit of agreement suggests better agreement between instruments and/or examiners.

Inter-session reproducibility was investigated by exploring both the ICC for the repeated measurements obtained during the first and second visit. And the Bland-Altman analysis was conducted to determine the extent of agreement between measurements during the first and second visit.

Comparison between Instruments

Multivariate Analysis Of Variance (MANOVA) was conducted while also taking into account the Bonferroni correction to show pairs that were significantly different ($p < 0.01$). Bland-Altman analysis was further applied to investigate the 95% LoA between instruments. Finally, the Spearman's test was conducted to explore the relationship between the three topographers' scores as well as the corrected linear calculation in order to suggest how to correct those findings to match each other perfectly.

Result

This study recruited 45 participants, each one of them tested twice with two independent examiners. The participants' age ranged from 22 to 45 years with a median of 21 ± 4.00 years. The spherical component was Plano ± 1.25 (ranges +2.00 to -7.00); while the spherical equivalent was Plano ± 1.00 (ranges 1.75 to -7.50). The astigmatism component was converted into vector representation, J_0 (cylinder at 0-degree meridian) and J_{45} (cylinder at 45-degree meridian). The median of vector J_0 was 00 ± 0.80 (ranged from -1.50 to 1.00), and vector J_{45} was 00± 0.12 (ranged from -1.50 to 1.50).

The summary of the measured Kh, Kv, eccentricity and the IS are listed in (Table 1). In general, it was observed that the EyeSys Vista provided flatter K-readings than those observed with the other two devices (Table 1). Both the Medmont E300 and EyeSys Vista provided similar eccentricity readings and indicated that the participants had slightly higher score than the suggested average normal corneas. Although, both devices provided similar IS scores, the Vista device had a larger interquartile range than the Medmont E300 device.

Intrasession Repeatability

The ICC in the 3 devices were significantly excellent >0.75 to 0.98 (Table 2). In the three devices, the mean difference between the examiners in the same visits for the K readings, eccentricities and IS were less than 0.1 (Table 3,4 & 5). The Mann-Whitney test showed that there are no significant difference between the two examiners during the first and second visit (Table 3,4 & 5). The LoA between examiners within first and second visit of the three devices were listed in Table 3, 4 and 5.

Table 1: Summary of the median± interqurtial range for corneal indices measured with the three different devices.

Variables		Medmont E300 1st visit (2nd visit)	EyeSys Vista 1st visit (2nd visit)	Keratometry 1st visit (2nd visit)
Kh	1st examiner	7.88 ± 0.38	8.35 ± 0.52	7.91 ± 0.42
		(7.88 ± 0.36)	(8.32 ± 0.54)	(7.90 ± 0.45)
Kh	2nd examiner	7.84 ± 0.36	8.28 ± 0.58	7.80 ± 0.35
		(7.90 ± 0.40)	(8.35 ± 0.61)	(7.83 ± 0.34)
Kv	1st examiner	7.73 ± 0.35	8.12 ± 0.56	7.76 ± 0.37
		(7.71 ± 0.35)	(8.04 ± 0.54)	(7.79 ± 0.39)
Kv	2nd examiner	7.65 ± 0.33	8.10 ± 0.62	7.70 ± 0.38
		(7.69 ± 0.34)	(8.12 ± 0.70)	(7.70 ± 0.39)
Ecc.	1st examiner	0.63 ± 0.18	0.59 ± 0.26	*NA*
		(0.62 ± 0.17)	(0.61 ± 0.32)	
Ecc.	2nd examiner	0.65 ± 0.17	0.60 ± 0.33	=======
		(0.64 ± 0.15)	(0.62 ± 0.38)	
IS	1st examiner	-0.16 ± 0.64	-0.22 ± 1.11	*NA*
		(-0.10 ± 0.83)	(-0.27 ± 1.68)	
IS	2nd examiner	-0.17 ± 0.81	-0.30 ± 1.26	=======
		(-0.19 ± 0.80)	(-0.30 ± 1.34)	

Kh, horizental keratometer; Kv, vertical ketratometery; Ecc, eccentricity; IS, inferior superior index; NA, not applicable

Table 2: The intrasession repeatability and intersession reproducibility for the first examiner, second examiner and between examiners with the three different devices.

Variables	*Within 1st Examiner*	*Within 2nd Examiner*	*Between Examiners*
	Medmont E300 ICC (95% CI)		
Kh	ICC = 0.99, p < 0.0001	ICC = 0.91, p < 0.0001	ICC = 0.94, p < 0.0001
	(0.99 – 0.99)	(0.83 – 0.95)	(0.90 – 0.96)
Kv	ICC = 0.98, p < 0.0001	ICC = 0.91, p < 0.0001	ICC = 0.95, p < 0.0001
	(0.97 – 0.99)	(0.84 – 0.95)	(0.92 – 0.97)
Ecc.	ICC = 0.95, p < 0.0001	ICC = 0.90, p < 0.0001	ICC = 0.83, p < 0.0001
	(0.90 – 0.97)	(0.81 – 0.94)	(0.75 – 0.89)
IS	ICC = 0.99, p < 0.0001	ICC = 0.91, p < 0.0001	ICC = 0.87, p < 0.0001
	(0.93 – 0.98)	(0.83 – 0.95)	(0.80 – 0.91)
	EyeSys Vista ICC (95% CI)		
Kh	ICC = 0.84, p < 0.0001	ICC = 0.94, p < 0.0001	ICC = 0.85, p < 0.0001
	(0.70 – 0.91)	(0.90 – 0.96)	(0.77 – 0.90)
Kv	ICC = 0.85, p < 0.0001	ICC = 0.96, p < 0.0001	ICC = 0.87, p < 0.0001
	(0.73 – 0.92)	(0.94 – 0.98)	(0.80 – 0.92)
Ecc.	ICC = 0.73, p < 0.0001	ICC = 0.88, p < 0.0001	ICC = 0.82, p < 0.0001
	(0.70 – 0.80)	(0.79 – 0.93)	(0.73 – 0.88)
IS	ICC = 0.83, p < 0.0001	ICC = 0.93, p < 0.0001	ICC = 0.80, p < 0.0001
	(0.70 – 0.91)	(0.87 – 0.96)	(0.70 – 0.87)
	Keratometry ICC (95% CI)		
Kh	ICC = 0.98, p < 0.0001	ICC = 0.95, p < 0.0001	ICC = 0.92, p < 0.0001
	(0.96 – 0.99)	(0.92 – 0.97)	(0.88 – 0.95)
Kv	ICC = 0.99, p < 0.0001	ICC = 0.98, p < 0.0001	ICC = 0.92, p < 0.0001
	(0.98 – 0.99)	(0.97 – 0.99)	(0.88 – 0.95)

Kh, horizental keratometer; Kv, Vertical ketratometery; Ecc, eccentricity; IS, inferior superior index; ICC, intraclass correlation coefficient, CI; confidence interval

Table 3: The Medmont E300 mean difference, limit of agreement and comparison statistical test of the corneal indices measured by the two examiners.

Variable	Mean difference Mm ± IQR	Statistical test	95% LoA (Mm)
Kh: 1st examiner – 2nd examiner	0.023 ± 0.11	Z = -0.40, p = 0.69[2]	-0.21 – 0.25
Kh: within 1st examiner	0.0002 ± 0.03	Z = -0.65, p = 0.51[1]	-0.047 – 0.048
Kh: within 2nd examiner	-0.005 ± 0.18	Z = -0.14, p = 0.89[1]	-0.26 – 0.25
Kv: 1st examiner – 2nd examiner	0.019 ± 0.09	Z = -0.26, p = 0.79[2]	-0.19 – 0.23
Kv: within 1st examiner	0.0086 ± 0.46	Z = -1.13, p = 0.20[1]	-0.11 – 0.12
Kv: within 2nd examiner	0.0036 ± 0.17	Z = -1.15, p = 0.25[1]	-0.40 – 0.42
Ecc: 1st examiner – 2nd examiner	0.033 ± 0.12	Z = -0.79, p = 0.43[2]	-0.24 – 0.31
Ecc: within 1st examiner	0.006 ± 0.043	Z = -0.29, p = 0.77[1]	-0.10 – 0.11
Ecc: within 2nd examiner	-0.03 ± 0.22	Z = -0.89, p = 0.38[1]	-0.57 – 0.52
IS: 1st examiner – 2nd examiner	-0.08 ± 0.41	Z = -0.73, p = 0.47[2]	-0.76 – 0.61
IS: within 1st examiner	-0.03 ± 0.21	Z = -0.89, p = 0.38[1]	-0.56 – 0.50
IS: within 2nd examiner	0.04 ± 0.24	Z = -0.91, p = 0.36[1]	-0.54 – 0.63

Kh, horizental keratometer; Kv, Vertical ketratometery; Ecc, eccentricity; IS, inferior superior index; Mm, millimeter, IQR, interqurtial range; LoA, limit of agreement; [1]Wilcoxon signed rank test, [2]Mann-Whitney test, ** indicate statistical significant where *p*<0.01

Intersession Reproducibility

The Wilcoxon test showed that there are no significant difference within each examiner during the two visits (Table 3, 4 and 5). For each device comparison, the differences between both visits were lower than 0.2 mm (Table 3, 4 & 5). The intersession reproducibility showed a similarity to that of the intra-session repeatability finding, and the ICC was >0.80 to 0.94 (Table 2). The LoA between visits for each examiner of all devices were recorded in (Table 3, 4 & 5).

Comparing the Three Devices

The MANOVA test exhibited a non significant statistical findings between visits and examiners (p > 0.05), while there was a statistical

Table 4: The EyeSys Vista mean difference, limit of agreement and comparison statistical test of the corneal indices measured by the two examiners.

Variable	*Mean difference Mm ± IQR*	*Statistical test*	*95% LoA (Mm)*
Kh: 1st examiner – 2nd examiner	0.023 ± 0.11	Z = -0.40, p = 0.69[2]	-0.21 – 0.25
Kh: within 1st examiner	0.0002 ± 0.03	Z = -0.65, p = 0.51[1]	-0.047 – 0.048
Kh: within 2nd examiner	-0.005 ± 0.18	Z = -0.14, p = 0.89[1]	-0.26 – 0.25
Kv: 1st examiner – 2nd examiner	0.019 ± 0.09	Z = -0.26, p = 0.79[2]	-0.19 – 0.23
Kv: within 1st examiner	0.0086 ± 0.46	Z = -1.13, p = 0.20[1]	-0.11 – 0.12
Kv: within 2nd examiner	0.0036 ± 0.17	Z = -1.15, p = 0.25[1]	-0.40 – 0.42
Ecc: 1st examiner – 2nd examiner	0.033 ± 0.12	Z = -0.79, p = 0.43[2]	-0.24 – 0.31
Ecc: within 1st examiner	0.006 ± 0.043	Z = -0.29, p = 0.77[1]	-0.10 – 0.11
Ecc: within 2nd examiner	-0.03 ± 0.22	Z = -0.89, p = 0.38[1]	-0.57 – 0.52
IS: 1st examiner – 2nd examiner	-0.08 ± 0.41	Z = -0.73, p = 0.47[2]	-0.76 – 0.61
IS: within 1st examiner	-0.03 ± 0.21	Z = -0.89, p = 0.38[1]	-0.56 – 0.50
IS: within 2nd examiner	0.04 ± 0.24	Z = -0.91, p = 0.36[1]	-0.54 – 0.63

Kh, horizental keratometer; Kv, Vertical ketratometery; Ecc, eccentricity; IS, inferior superior index; Mm, millimeter, IQR, interqurtial range; LoA, limit of agreement; [1]Wilcoxon signed rank test, [2]Mann-Whitney test, ** indicate statistical significant where p <0.01

Table 5: The manual Keratometry mean difference, limit of agreement and comparison statistical test of the K-readings measured by the two examiners.

Variable	*Mean difference Mm ± IQR*	*Statistical test*	*95% LOA (Mm)*
Kh: 1st examiner – 2nd examiner	0.07 ± 0.15	Z = -1.79, p = 0.08[2]	-0.21 – 0.35
Kh: wirhin 1st examiner	-0.003 ± 0.09	Z = -0.59, p = 0.60[1]	-0.13 – 0.12
Kh: within 2nd examiner	-0.018 ± 0.14	Z = -0.2, p = 0.88[1]	-0.35 – 0.25
Kv: 1st examiner – 2nd examiner	0.08 ± 0.15	Z = -2.00, p = 0.04[2]	-0.16 – 0.32
Kv: wirhin 1st examiner	-0.013 ± 0.06	Z = -1.2, p = 0.20[1]	-0.15 – 0.07
Kv: within 2nd examiner	-0.012 ± 0.08	Z = -0.23, p = 0.82[1]	-0.22 – 0.11

Kh, horizental keratometer; Kv, Vertical ketratometery; Mm, millimeter, IQR, interqurtial range; LoA, limit of agreement; [1]Wilcoxon signed rank test, [2]Mann-Whitney test, ** indicate statistical significant where p <0.01

Table 6: Comparison of the three different devices in horizontal and vertical keratometers, eccentricity and inferior superior index.

Variable	*Mean difference Mm ± SD*	*Statistical test2*	*95% LOA (Mm)*
Kh: Medmont – EyeSys	-0.48 ± 0.28	Z = -10.70, p < 0.0001**	-1.00 – 0.10
Kh: Medmont – Keratometer	-0.002 ± 0.09	Z = -0.3, p = 0.72	-0.28 – 0.28
Kh: EyeSys – Keratometer	0.48 ± 0.27	Z = -10.3, p <0.0001**	-0.08 – 1.04
Kv: Medmont – EyeSys	-0.47 ±0.28	Z = -11, p <0.0001**	-1.1
Kv: Medmont – Keratometer	-0.05 ± 0.10	Z = -1.69, p = 0.09	-0.32 – 0.22
Kv: EyeSys – Keratometer	0.43 ± 0.26	Z = -10, p <0.0001**	-0.09 – 0.96
Ecc: Medmont – EyeSys	0.03 ± 0.22	Z = -2.2, p = 0.03	-0.40 – 0.48
IS: Medmont – EyeSys	0.18 ± 0.88	Z = -1.38, p = 0.17	-1.36 – 1.72

Kh, horizental keratometer; Kv, Vertical ketratometery; Ecc, eccentricity; IS, inferior superior index; [2]Mann-Whitney test, ** indicate statistical significant where *p*<0.01

Table 7: The Spearman's correlation coefficient test between the three devices in horizontal and vertical keratometers.

Variable	*Spearman's test*	*Corrected linear calculation*
Kh: Medmont – EyeSys	r = 0.60, p <0.0001**	EyeSys= 1.73+0.84*Medmont
Kh: EyeSys – Keratometer	r = 0.62, p <0.0001**	EyeSys= 0.77+0.95*Keratometer
Kv: Medmont – EyeSys	r = 0.64, p <0.0001**	EyeSys = 0.68+0.97* Medmont
Kv: EyeSys – Keratometer	r = 0.65, p <0.0001**	EyeSys= 1.08+0.92* Keratometer

Kh, horizental keratometer; Kv, Vertical ketratometery; ** indicate statistical significant where *p*<0.01

difference between the devices (p <0.0001). The paired comparison of the three devices are listed in (Table 6). The highest mean difference in Kh and Kv was 0.4 mm for all of them. The LoA between the Medmont and Keratometer were within 0.3mm. While it was broader LoA between the EyeSys vista and the other two devices, where it reached 1 mm. The Mann-Whitney test showed there was statistically significant difference between the EyeSys vista and the Medmont and Keratometer in Kh and Kv readings (Table 6). The eccentricity and the IS scores were not significantly different between the Medmont and the EyeSys vista (Table 6).

The Spearman's test was carried out for each pair of devices (Table 7). The relationship between all three devices were statistically significant moderate relationship ($r = 0.6$, $p < 0.0001$). The corrected linear calculation of EyeSys vista readings to match the readings obtained from the Medmont and Keratometer in Kh and Kv were detailed in Table 7.

Discussion

Measuring corneal characteristics with accuracy in this period of time is crucial for refractive surgery, cataract procedure and toric IOL implant. In the present study, we assessed the variability in scores between examiners, visits and devices and interchangeability obtained from portable topographer, commercially available topographer and a gold standard device. This is to obtain precision, repeatability and reproducibility. To the best of our knowledge, no earlier study has investigated the portable EyeSys Vista and desktop Medmont E300 with two examiners over two separate visits. Although the portable EyeSys Vista was commercially available several years ago which can be used outside conventional clinic and can be used for mass screening program, a very scarce studies were conducted to compare it with other desktop topographers.

The Medmont E300 have been previously established to be an accurate and repeatable corneal topographer [5,12,13,25]. In the present study, the Medmont E300 showed excellent intrasession repeatability and intersession reproducibility in measuring K readings (ICC >0.83).Further, previous study suggested that the EyeSys Vista showed accuracy good repeatability and reproducibility [5,26,27]. This study findings also supported that conclusion with excellent repeatability and reproducibility in measuring K readings (ICC >0.75).Finally, the manual keratometer was precise, repeatable and reproducible (ICC >0.9).

Comparing the 3 devices, the means differences of the K-readings between the Medmont and the manual keratometer was < 0.01 mm. This result could suggest that a high degree of agreement among them. Whereas, the means differences of the K-readings of the EyeSys with the other 2 devices was < 0.50 mm, this suggest that the agreement between them is only fair and caution is recommended when using them interchangeably. The corrected linear calculation presented in this study shall be used to match the K- readings from the Medmont or the keratometer. However, the eccentricity and IS readings was in match with the Medmont which could indicate that the EyeSys is valuable tool for keratoconus screening and mass population screening programs due to its portability features. Previous studies concluded that the Medmont provides steeper corneal curvature than other devices [4,5,10]. Further, a prior study has also found that the EyeSys Vista provides flatter corneal curvature than other devices [5]. This is could explain the reason behind the moderate agreement between Medmont and EyeSys in the present study.

The 95% LoAs between the EyeSys and the other 2 devices were > 0.50 mm. clinically this does not permit these devices to be used interchangeably. These findings were in consistence with the result of previous studies. Differences were found previously between EyeSys and other devices including manual keratometer, Medmont, although they found a high correlation between the K-readings measurements [5,8,9]. They suggested that these 95%LoAs were marked to consider them interchangeable. The Medmont was also previously suggested that it cannot be used interchangeably with other placido-based topographers [5,13]. Prior studies have also conveyed comparable result when readings were taken from placido-based topographer and manual keratometer [6,7].

The study sample was representive of the targeted population and was higher than previous studies [4,5,7,27]. The present study has some limitations; it was limited to healthy young participants with normal corneas. Different variability may be found in older population, patient with corneal abnormalities or whom with history of refractive surgery. Future studies are required to assess the repeatability and reproducibility of corneal characteristics measurements obtained by different topographers in such patients.

Conclusion

The three devices provided a high repeatability, reproducibility and inter-observers reproducibility in measuring anterior corneal indices. The results obtained from them correlated well, although cautious is required when using measurements obtained by the EyeSys Vista and the Medmont interchangeably. The corrected linear calculation suggested in this study could be valuable tool to manage the differences between them. The eccentricity and IS measurements were not significantly different between the EyeSys Vista and the Medmont E300, which suggested that it can be used interchangeably.

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Disclosures

No author has any conflict of interest.

References

1. Lee AC, Qazi MA, Pepose JS. Biometry and intraocular lens power calculation. Current Opinion in Ophthalmology. 2008; 19: 13-17.
2. Tomidokoro A, Oshika T, Amano S, Higaki S, Maeda N, Miyata K. Changes in anterior and posterior corneal curvatures in keratoconus. Ophthalmology. 2000; 107: 1328-1332.
3. Jinabhai A, Radhakrishnan H, O'Donnell C. Pellucid corneal marginal degeneration: A review. Cont Lens Anterior Eye. 2011; 34: 56-63.
4. CHUI WS, CHO P. A Comparative Study of the Performance of Different Corneal Topographers on Children with Respect to Orthokeratology Practice. Optometry and Vision Science. 2005; 82: 420-427.
5. 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.
6. Varssano D, Rapuano CJ, Luchs JI. Comparison of keratometric values of healthy and diseased eyes measured by javal keratometer, EyeSys, and PAR. Journal of Cataract and Refractive Surgery. 1997; 23: 419-422.
7. Dave T, Ruston D, Fowler C. Evaluation of the EyeSys Model II Computerized Videokeratoscope. Part I: Clinical Assessment. Optometry and Vision Science. 1998; 75: 647-655.
8. Stefano VSD, Junior LASM, Mallmann F, Schor P. Interchangeability between Placido disc and Scheimpflug system: quantitative and qualitative analysis. Arquivos brasileiros de oftalmologia. 2010; 73: 363-366.
9. Mehravaran S, Asgari S, Bigdeli S, Shahnazi A, Hashemi H. Keratometry with five different techniques: a study of device repeatability and inter-device agreement. International Ophthalmology. 2013; 34: 869-875.

10. González-Méijome JM, Jorge J, Queiros A, Almeida JB, Parafita MA. A comparison of the ARK-700A autokeratometer and Medmont E300 corneal topographer when measuring peripheral corneal curvature. Ophthalmic and Physiological Optics. 2004; 24: 391-398.

11. Gutmark R, Guyton DL. Origins of the keratometer and its evolving role in ophthalmology. Survey of ophthalmology. 2010; 55: 481-497.

12. Read SA, Collins MJ, Iskander RD, Davis BA. Corneal topography with Scheimpflug imaging and videokeratography: Comparative study of normal eyes. Journal of Cataract and Refractive Surgery. 2009; 35: 1072-1081.

13. CHO P, LAM AKC, MOUNTFORD J, NG L. The Performance of Four Different Corneal Topographers on Normal Human Corneas and Its Impact on Orthokeratology Lens Fitting. Optometry and Vision Science. 2002; 79: 175-183.

14. Shirayama M, Wang L, Weikert MP, Koch DD. Comparison of corneal powers obtained from 4 different devices. American journal of ophthalmology. 2009; 148: 528-535.e1.

15. Schiffman RM, Christianson MD, Jacobsen G, Hirsch JD, Reis BL. Reliability and validity of the Ocular Surface Disease Index. Archives of ophthalmology. 2000; 118: 615.

16. McGinnigle S, Naroo SA, Eperjesi F. Evaluation of the auto-refraction function of the Nidek OPD-Scan III. Clinical and Experimental Optometry. 2014; 97: 160-163.

17. Lindsay R, Smith G, Atchison D. Descriptors of Corneal Shape. Optometry and Vision Science. 1998; 75: 156-158.

18. Schwiegerling J, Greivenkamp JE. Keratoconus Detection Based on Videokeratoscopic Height Data. Optometry and Vision Science. 1996; 73: 721-728.

19. Burns DM, Johnston FM, Frazer DG, Patterson C, Jackson AJ. Keratoconus: an analysis of corneal asymmetry. British Journal of Ophthalmology. 2004; 88: 1252-1255.

20. Maeda N, Klyce SD, Smolek MK, Thompson HW. Automated keratoconus screening with corneal topography analysis. Investigative ophthalmology & visual science. 1994; 35: 2749-57.

21. Montalbán R, Piñero DP, Javaloy J, Alio JL. Correlation of the Corneal Toricity Between Anterior and Posterior Corneal Surfaces in the Normal Human Eye. Cornea. 2013; 32: 791-798.

22. Montalbán R, Piñero DP, Javaloy J, Alió JL. Scheimpflug photography–based clinical characterization of the correlation of the corneal shape between the anterior and posterior corneal surfaces in the normal human eye. Journal of Cataract and Refractive Surgery. 2012; 38: 1925-1933.

23. Fleiss JL. Reliability of Measurement. The Design and Analysis of Clinical Experiments. 1999: 1-32.

24. Bland JM, Altman DG. Statistics notes: Measurement error. Bmj. 1996; 312: 1654.

25. Hamer CA, Buckhurst H, Purslow C, Shum GL, Habib NE, Buckhurst PJ. Comparison of reliability and repeatability of corneal curvature assessment with six keratometers. Clinical and Experimental Optometry. 2016; 99: 583-589.

26. Pérez JG, Cerviño A, Giraldez MJ, Parafita M, Yebra-Pimentel E. Accuracy and Precision of EyeSys and Orbscan Systems on Calibrated Spherical Test Surfaces. Eye & Contact Lens: Science & Clinical Practice. 2004; 30: 74-78.

27. Jeandervin M, Barr J. Comparison of Repeat Videokeratography: Repeatability and Accuracy. Optometry and Vision Science. 1998; 75: 663-669.