Intrasession Repeatability and Intersession Reproducibility Measurements Using VX120 Multidiagnostic Unit

Irene Sanchez, Ph.D., Sara Ortiz-Toquero, Ph.D., and Raul Martin, Ph.D.

Objective: The VX120 multidiagnostic unit is a multidiagnostic instrument that combines several functions: autorefraction, keratometry, corneal topography, aberrometry, pachymetry, and noncontact tonometry. The purpose of this study was to determine the intrasession repeatability and the intersession reproducibility of all parameters measured by the VX120 multidiagnostic unit in a sample of normal healthy eyes.

Methods: Three repeated measurements in the right eye of the volunteers were taken with VX120. Repeatability of the sphere, cylinder, axis, anterior corneal powers (K flat and K steep, 3-mm pupil), high- and low-order aberration root mean square (HOA-RMS and LOA-RMS, 3-mm pupil), eccentricity, white-to-white (WTW), anterior chamber depth (ACD), and central corneal thickness (CCT) (2-mm central) was analyzed. Within-subject SD (Sw), precision, repeatability, coefficient of variation (CV), and the intraclass correlation coefficient (ICC) were calculated.

Results: The CV was low for K flat and K steep, WTW, ACD, and CCT with a range from 0.34% to 1.16%. The CV was higher for sphere, cylinder, HOA-RMS, and LOA-RMS and eccentricity with a range among 6.92% to 54.24%. The ICC showed high values in all parameters except in HOA-RMS (0.720–0.776) and eccentricity (0.889) in first session with moderate agreement. Comparing the intrasession repeatability of first and second session, statistically significant differences ($P<0.01$) were found between both sessions just to the CV for all parameters (except cylinder values) measured with VX120. However, nonstatistically significant differences ($P>0.13$) were found for Sw, precision, and repeatability values.

Conclusions: The VX120 multidiagnostic unit provides repeatable measurements in anterior corneal power (K flat and K steep), WTW, ACD, and CCT. However sphere, cylinder, HOA-RMS, LOA-RMS, and eccentricity showed worse repeatability. Intersession reproducibility showed good results with little differences between sessions in healthy subjects.

Key Words: Repeatability—Reproducibility—VX120—Hartmann–Shack sensor—Placido-based videokeratography—Scheimpflug camera.

(*Eye & Contact Lens* 2018;0: 1–7)

From the Departamento de Física Teórica, Atómica y Óptica (S.I., O.-T.S., M.R.), Universidad de Valladolid, Valladolid, Spain; Instituto Universitario de Oftalmobiología Aplicada (IOBA) (S.I., O.-T.S., M.R.), Universidad de Valladolid, Valladolid, Spain; Optometry Research Group (S.I., O.-T.S., M.R.), School of Optometry, IOBA Eye Institute, University of Valladolid, Valladolid, Spain; School of Health Professions (S.I., O.-T.S., M.R.), Plymouth University, Plymouth, United Kingdom.

The authors have no conflicts of interest to disclose.

S. Ortiz-Toquero was supported by Junta Castilla y León (Consejería de Educación) Program: Estrategia Regional de Investigación Científica, Desarrollo Tecnológico e Innovación 2007Y2013, cofunding by Social European Fund.

Address correspondence to Irene Sanchez, Ph.D., Departamento de Física Teórica, Atómica y Óptica, Universidad de Valladolid, Paseo de Belén, 7—Campus Miguel Delibes, 47011 Valladolid, Spain; e-mail: isanchezp@ioba.med.uva.es

Accepted January 8, 2018.

DOI: 10.1097/ICL.0000000000000486

The VX120 multidiagnostic unit (version 2.0; Visionix, Luneau Technology, Dortmund, Germany) is a new device fully automatic (XYZ autoalignment, autotracking, autofocusing, and automeasurement) with multiple functions designed by eye care practitioners. The VX120 multidiagnostic unit is a multidiagnostic instrument that combines several functions: autorefraction, keratometry, corneal topography, aberrometry, pachymetry, and noncontact tonometry.

Currently, a complete and thorough eye examination is aided by technological advances such as refraction estimation using a Hartmann–Shack sensor system,[1] a corneal shape assessment using the placido-based videokeratography[2] or wavefront aberrometry,[1,3] intraocular pressure (IOP) assessments using pneumatonometers,[4] and an assessment of lens opacification, central corneal thickness (CCT), anterior chamber depth (ACD), or iridocorneal angle using a Scheimpflug camera.[5] All devices have demonstrated their utility for such procedures as fitting contact lenses, ocular health screenings (phakic intraocular lens calculation,[6] refractive surgery selection,[7] detection of angle closure glaucoma,[6] and corneal ectasia[2]), and reliability[6,8] in clinical practice. However, to date, these measurements have required different technologies in different devices. The VX120 multidiagnostic unit includes all these technologies in one device. Knowledge of the repeatability and reproducibility of instrumentation is mandatory when introducing any device into clinical practice[9]; however, to the best of our knowledge, only one report[10] has analyzed the repeatability of the corneal geometric and aberrometric measurements provided by the VX120 multidiagnostic unit.

For this reason, the purpose of this study was to determine the intrasession repeatability and the intersession reproducibility of all parameters measured by the VX120 multidiagnostic device in a sample of normal healthy eyes.

MATERIALS AND METHODS

Subjects

This study involved healthy volunteers between 18 and 30 years. A complete optometric exploration was performed to verify the ocular health. All subjects had good corrected distance visual acuity equal to or better than 20/25 to allow for adequate fixation. The exclusion criteria were previous ocular surgery, history of ocular pathology, positive corneal fluorescein staining, and systemic or eye pathology. The tenets of the Declaration of Helsinki were followed, and informed consent was obtained from all volunteers after thorough explanation of the nature of the study after the Human Sciences Ethics Committee of the University of Valladolid granted approval of the study.

TABLE 1. *Intraobserver Repeatability Coefficients (Sw, CV, LoA, and ICC) for All the Parameters Measured With VX120 Multidiagnostic Unit y Session 1 (S1) and Session 2 (S2) With Statistically Significant Differences Between Sessions in Row* P *value*

	Session	Mean±SD (Range)	Sw	CV (%)	Range of 95% LoA	ICC
Shack–Hartmann wavefront sensor	Sphere (D)					
	S1	−2.44±2.19 (−6.42 to 2.58)	0.12	11.66	0.40 to −0.40	0.999
	S2	−2.42±2.17 (−6.50 to 2.75)	0.15	11.42	0.57 to −0.57	0.997
	P	0.76	0.40	<0.01	—	—
	Cylinder (D)					
	S1	−0.80±0.64 (−2.50 to 0.00)	0.08	15.44	0.35 to −0.33	0.988
	S2	−0.83±0.60 (−2.75 to −0.17)	0.09	19.70	0.36 to −0.36	0.985
	P	0.09	0.52	0.40	—	—
	J0 (D)					
	S1	−0.21±0.41 (−1.26 to 0.45)	0.05	35.76	0.19 to −0.27	0.991
	S2	−0.20±0.42 (−1.28 to 0.48)	0.05	28.38	0.18 to −0.26	0.992
	P	0.32	0.82	<0.01	—	—
	J45 (D)					
	S1	0.80±0.22 (−0.23 to 0.58)	0.04	46.25	0.14 to −0.21	0.983
	S2	0.86±0.22 (−0.24 to 0.55)	0.04	54.24	0.13 to −0.19	0.984
	P	0.26	0.30	<0.01	—	—
	High-order aberration RMS (D)					
	S1	0.23±0.05 (0.11 to 0.34)	0.04	18.29	0.15 to −0.11	0.720
	S2	0.23±0.05 (0.15 to 0.31)	0.03	12.99	0.10 to −0.10	0.776
	P	0.72	0.25	<0.01	—	—
	Low-order aberration RMS (D)					
	S1	0.67±0.40 (0.11 to 1.73)	0.06	12.40	0.20 to −0.22	0.988
	S2	0.66±0.39 (0.08 to 1.75)	0.05	10.78	0.18 to −0.18	0.991
	P	0.53	0.39	<0.01	—	—
Placido-based videokeratography	K flat (D)					
	S1	42.73±1.70 (38.42 to 45.17)	0.21	0.49	0.67 to −0.74	0.993
	S2	42.75±1.76 (38.17 to 45.42)	0.19	0.44	0.61 to −0.61	0.995
	P	0.69	0.63	<0.01	—	—
	K steep (D)					
	S1	43.70±1.89 (39.00 to 46.50)	0.22	0.50	0.66 to −0.75	0.994
	S2	43.75±1.95 (38.75 to 46.17)	0.15	0.34	0.55 to −0.55	0.996
	P	0.27	0.13	<0.01	—	—
	Eccentricity					
	S1	0.70±0.12 (0.47 to 0.96)	0.05	6.92	0.18 to −0.20	0.889
	S2	0.69±0.11 (0.51 to 0.88)	0.05	7.33	0.16 to −0.16	0.912
	P	0.45	0.72	<0.01	—	—
Scheimpflug camera	WTW (mm)					
	S1	12.10±0.60 (11.14 to 13.01)	0.09	0.76	0.30 to −0.33	0.988
	S2	12.19±0.66 (11.18 to 13.18)	0.09	0.73	0.27 to −0.29	0.994
	P	0.25	0.80	<0.01	—	—
	ACD (mm)					
	S1	3.26±0.31 (2.61 to 3.71)	0.03	0.98	0.12 to −0.12	0.994
	S2	3.26±0.30 (2.69 to 3.71)	0.02	0.77	0.08 to −0.08	0.997
	P	0.86	0.74	<0.01	—	—
	Central corneal thickness (μm)					
	S1	547.61±25.63 (504.33 to 616.00)	5.62	1.04	20.39 to −17.22	0.976
	S2	547.24±26.35 (501.33 to 614.33)	6.34	1.16	20.49 to −18.69	0.976
	P	0.84	0.45	<0.01	—	—

ACD, anterior chamber depth; CV, coefficient of variation (CV=Sw/mean×100 [%]); D, diopters; ICC, intraclass correlation coefficient; LoA, limits of agreement lie between 1.96 SD of the mean difference; RMS, root mean square; S1, session 1; S2, session 2; Sw, within-subject SD; WTW, white-to-white.

Instrumentation

The VX120 multidiagnostic unit is a multidiagnostic instrument that combines several functions as follows: autorefraction, keratometry, corneal topography, aberrometry, pachymetry, and noncontact tonometry. This unit incorporates a computerized placido-based videokeratography[11] for keratometry and corneal topography measurements and a Scheimpflug camera[5,11] for anterior chamber visualization that measures pachymetry, white-to-white (WTW), ACD, and lens thickness, and it provides densitometry functions (permitting the opacity to be classified using the Lens Opacity Classification System III).[5] Some devices combine the use of a Scheimpflug camera with a placido disk to complete the measurements of corneal topography; however, this is not the case in this device because the Scheimpflug camera measures only CCT, ACD, and WTW. A Shack–Hartmann sensor[1] provides the power mapping wavefront aberrometry and objective refraction, and finally, a pneumotonometer on the top of the device allows for noninvasive IOP measurements.[4,12,13] The anterior corneal topography is collected by the placido-based videokeratography system, which includes 24 rings that are capable of measuring 6,144 points and evaluating more than 100,000 points. A Shack–Hartmann wavefront sensor has a measuring range from −20D to +20D (spherical values) and plano to −8D (cylinder values) in an area from a minimum of 2 mm to a maximum of 7 mm (categorized in three areas) with 1,500 measured points in 0.2 sec. The Scheimpflug camera works with a blue light (455 nm) in a range from 150 to 1,300 μm with 1-μm resolution and with an angular range of 60° with a 1°

resolution. The pneumatonometer operates in a range from 1 to 50 mm Hg and compensates for the IOP value in relation to the CCT.[14]

Measurement Procedure

Using the VX120 multidiagnostic unit, three consecutive measurements were obtained in the undilated right eye of all volunteers between 11 AM and 3 PM to minimize the effects of diurnal variation on the anterior segment shape in both study sessions. The time between repeated measurements by the operator was the minimum possible (usually <5 min). Volunteers were repositioned automatically by the device between each of the three measurements to ensure the correct alignment of the eye with the optical axis of the measuring device. The three measurements were repeated in the second session that was scheduled 1-week later, at the same time as the first session, by the same examiner using the same protocol and after the manufacturer's guidelines. The same experienced operator performed all measurements and deleted the poor-quality values including eye movements, eyelid shadows, blinking, or artifacts from the tear film.

Measurement Obtained

The values of sphere, cylinder, axis, anterior corneal powers (K flat and K steep; 3-mm zone diameter), total ocular high- and low-order aberration root mean square (HOA-RMS and LOA-RMS in 3-mm zone diameter), eccentricity, WTW diameter, ACD, and CCT (measured in 2-mm central) of each eye examination were collected from VX120 multidiagnostic unit in an automatic sequence in both sessions. The repeatability of IOP measurement was not assessed to avoid the effect of corneal deformation in posterior anterior eye measurements.

The corneal astigmatism was converted into a vector representation, J0 (cylinder at 0° meridian), and J45 (cylinder at 45° meridian), which were calculated according to the following formulas[11,15]: $J0=(-\text{cylinder}/2)\cos(2\times\text{axis})$ and $J45=(-\text{cylinder}/2)\sin(2\times\text{axis})$.

Statistical Analysis

Statistical analysis was performed using SPSS for Windows software (version 15.0; SPSS, Inc, Chicago, IL). Nonparametric data distribution of variables were verified using the Kolmogorov–Smirnov test ($P<0.05$ indicated that the data were not normally distributed). Description of the collected variables (sphere, cylinder, J0, J45, HOA-RMS, LOA-RMS, K flat, K steep, eccentricity, WTW distance, ACD, and CCT) was summarized with mean, SD, and range (maximum to minimum value).

The mean of the three measurements of each session was calculated for each parameter collected by VX120 multidiagnostic unit. This study followed the definitions of reproducibility, repeatability, and agreement according to the British Standards Institute and the International Organization for Standardization.[16] The intrasession repeatability of the set of three consecutive measurements of each parameter was calculated using the following five parameters in the two sessions: within-subject SD (Sw),[17] intrasubject precision could be calculated as 1.96×Sw, which shows the error range for 95% of the repeated measurements and the true value,[17] and repeatability as 2.77×Sw, which defines the difference between 2 measurements of the same volunteer for 95% of pairs of observation.[17] Coefficient of variation {CV; percentage value of the measurement's variation and defined as the ratio of the Sw to the overall mean (CV=Sw/mean×100 [%])}[17] and the intraclass correlation coefficient (ICC; classified as follows: less than 0.75=poor agreement; 0.75 to less than 0.90=moderate agreement; and 0.90 or greater=high agreement).[18]

Intersession reproducibility was assessed after Bland and Altman recommendations, whereby 95% of the differences or limits of agreement, lie between 1.96 SD of the mean difference.[16,19]

Different intersessions in parameters and all calculated repeatability coefficients (Sw, precision, repeatability, CV, and ICC) were compared with Wilcoxon nonparametric paired test ($P<0.05$ was considered significant).

RESULTS

This study involving 25 healthy volunteers (9 men and 16 women) with 22.04±3.80 years old (range 20–29 years) and spherical equivalent refractive error −2.45±2.14 D (range −0.50 to −7.25 D).

The intrasession repeatability of the values for sphere, cylinder, anterior corneal powers (K flat and K steep), HOA-RMS and LOA-RMS, eccentricity, WTW, ACD, and CCT that were measured using the VX120 multidiagnostic unit is summarized in Table 1. The CV was low for K flat and K steep, WTW, ACD, and CCT with a range from 0.34% to 1.16%. The CV was higher for sphere, cylinder, HOA-RMS and LOA-RMS, and eccentricity with a range

TABLE 2. *Intersession Reproducibility for All Parameters Measured With VX120*

Intersession Parameter	Mean±SD	Range	Mean Diff±SD	LoA
Sphere (D)	−2.43±2.18	−6.46 to 2.67	−0.02±0.20	0.38 to −0.42
Cylinder (D)	−0.81±0.62	−2.75 to −0.08	0.03±0.12	0.26 to −0.20
J0 (D)	−0.20±0.41	−1.27 to 0.46	−0.02±0.07	0.15 to −0.23
J45 (D)	0.09±0.22	−0.23 to 0.56	0.01±0.04	0.07 to −0.09
K flat (D)	42.74±1.72	38.29 to 45.29	−0.02±0.24	0.46 to −0.49
K steep (D)	43.73±1.92	38.88 to 46.33	−0.04±0.25	0.44 to −0.53
HOA-RMS (D)	0.23±0.05	0.14 to 0.33	0.00±0.04	0.07 to −0.07
LOA-RMS (D)	0.67±0.39	0.10 to 1.74	0.00±0.09	0.17 to −0.16
Eccentricity	0.70±0.11	0.49 to 0.91	0.01±0.06	0.14 to −0.11
WTW (mm)	12.15±0.61	11.16 to 13.05	−0.08±0.27	0.44 to −0.60
ACD (mm)	3.26±0.30	2.67 to 3.71	0.00±0.05	0.11 to −0.10
CCT (μm)	547.42±25.64	502.83 to 615.17	0.38±8.59	17.21 to −16.46

ACD, anterior chamber depth; CCT, central corneal thickness; D, diopters; HOA-RMS, high-order aberration root mean square; LoA, limits of agreement lie between 1.96 SD of the mean difference; LOA-RMS, Low-order aberration root mean square; WTW, white-to-white.

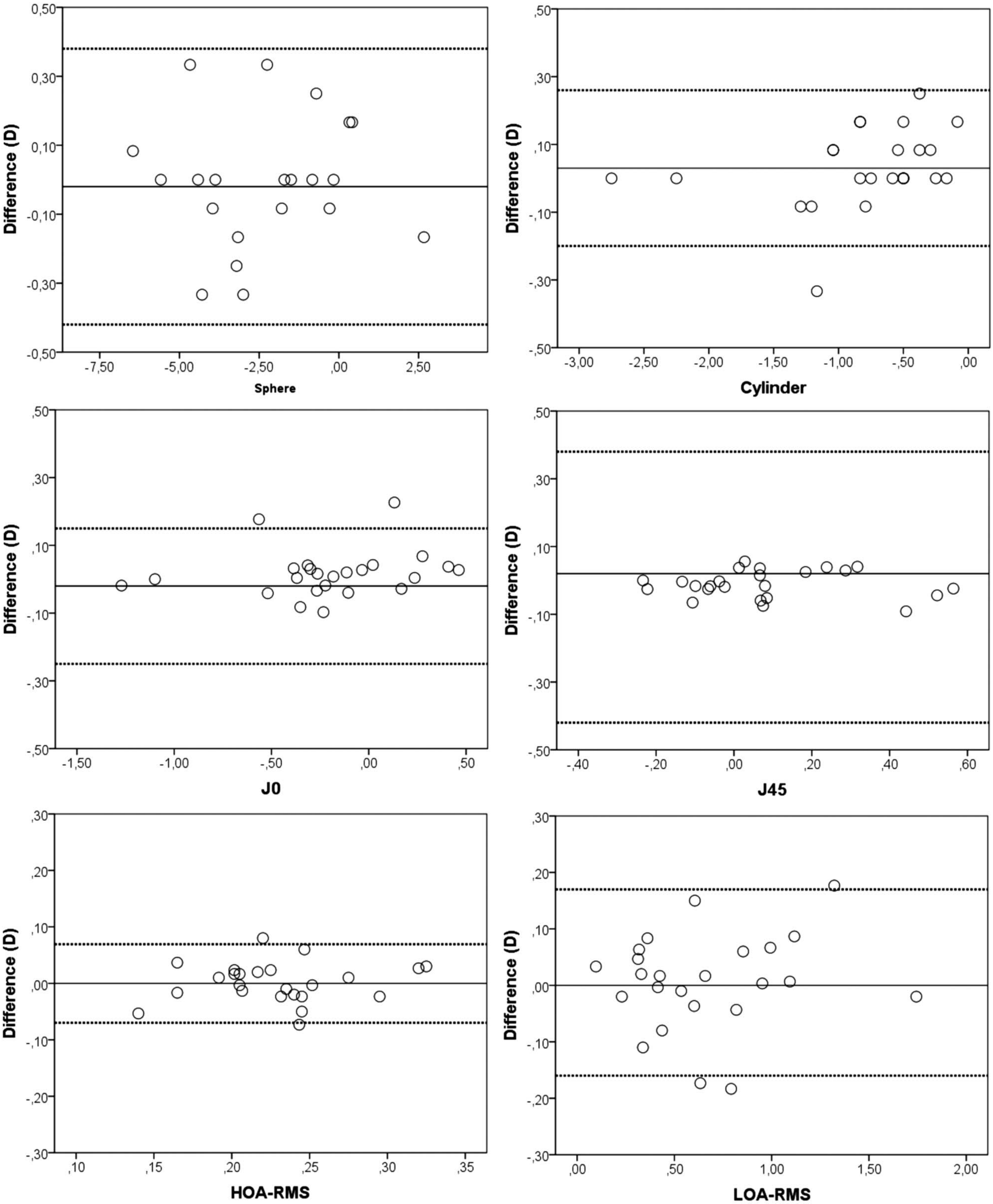

FIG. 1. Bland–Altman plot showing the sphere, cylinder, J0, J45, HOA-RMS, and LOA-RMS reproducibility. The mean difference (solid line) and limits of agreement (discontinuous line) were represented for the parameters measured with Shack–Hartmann wavefront sensor.

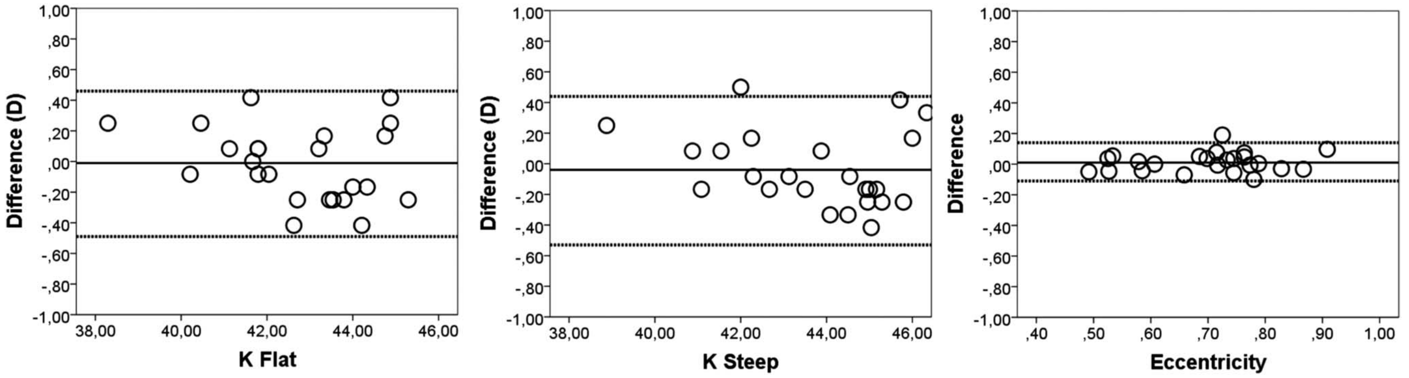

FIG. 2. Bland–Altman plot showing the K flat, K steep, and eccentricity reproducibility. The mean difference (solid line) and limits of agreement (discontinuous line) were represented for the parameters measured with placido-based videokeratography.

between 6.92% and 54.24%. The ICC showed high values in all parameters except the HOA-RMS (0.720–0.776) and eccentricity (0.889) in the first session with moderate agreement.

Comparing the intrasession repeatability of first and second session, statistically significant differences ($P<0.01$) were found between both sessions just to the CV for all parameters (except cylinder values) measured with VX120 multidiagnostic unit. However, nonstatistically significant differences ($P>0.13$) were found for Sw, precision, and repeatability values. Intersession reproducibility was represented in Table 2 with Bland and Altman plots in Figures 1–3.

DISCUSSION

To our knowledge, no previous reports have described the reproducibility or repeatability of all parameters that can be measured using the VX120 multidiagnostic unit. Piñero et al.[10] reported the intrasession repeatability of corneal geometric and aberrometric outcomes with this device in a larger sample of healthy eyes. We found a high repeatability and reproducibility in the corneal parameters measured with the Scheimpflug camera of the VX120 multidiagnostic unit. The corneal power was measured with placido-based videokeratography, and according to the results of Piñero et al.,[10] close values for the Sw and ICC were achieved, except in the HOA-RMS, which had a moderate agreement for ICC in our study (0.776) versus an ICC of 0.901. The CV would help to assess the reliability of the device; however, it was not reported by Piñero et al.

To analyze the differences, it is necessary to compare repeatability values of all the parameters measured using the VX120 multidiagnostic unit with other devices that only include a few parameters.

Repeatability of Shack–Hartmann Sensor

Piñero et al.[10] found a slightly worse value of Sw than our study for HOA-RMS with better ICC (0.901). These differences could be related with the differences in sample size of both studies.

Prakash et al.[7] reported the repeatability of a new generation of Shack–Hartmann wavefront sensor finding good CV values for sphere (0.07%), cylinder (0.08%), WTW (0.01%), and HOA-RMS (0.49%); Sw value for sphere (0.25D), cylinder (0.08D), WTW (0.11 mm), and HOA-RMS (0.18D); and ICC values in sphere (0.998), cylinder (0.994), WTW (0.940), and HOA-RMS (0.889) similar to our results.

Repeatability of Placido-Based Videokeratography

Piñero et al.[10] found a slightly worse values of Sw than our study for K steep (0.20D), eccentricity (0.07), and similar values for K flat in Sw and ICC. However, ICC values are better than our study 0.957 for eccentricity and worse for K steep (0.993).

Comparing with the results of Mao et al.,[15] who used a Keratograph 4 (OCULUS), the VX120 multidiagnostic unit showed worse repeatability. Mao reported better intrasession repeatability for K flat

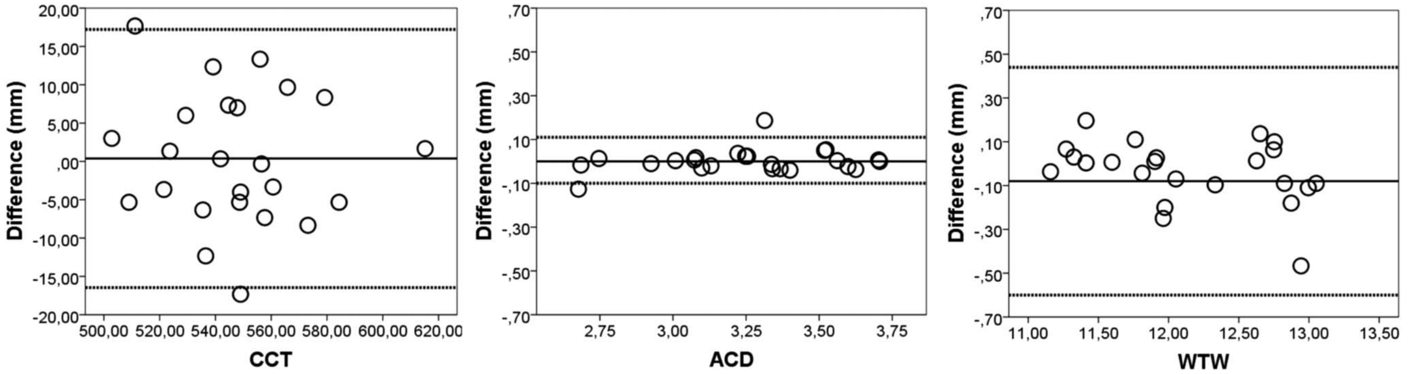

FIG. 3. Bland–Altman plot showing the WTW, ACD, and CCT reproducibility. The mean difference (solid line) and limits of agreement (discontinuous line) were represented for the parameters measured with Scheimpflug camera.

(Sw=0.06D, CV=0.15%), K steep (Sw=0.06D, CV=0.14%), J0, and J45 (Sw=0.02D). The same device Allegro Topolyzer (WaveLight Technologie AG, Alcon Laboratories, Erlangen, Germany) showed better repeatability than did the VX120 multidiagnostic unit in healthy subjects in K flat (Sw=0.11D, CV=0.25%, ICC=0.997), K steep (Sw=0.13D, CV=0.29%, ICC=0.996), WTW (Sw=0.11D, CV=0.25%, ICC=0.997), and eccentricity (CV=5.79%, ICC=0.96); however, for the HOA-RMS, the ICC values were better (0.865), and repeatability values were worse for Sw (0.10D). Similar values for CV (16.23%) were observed, according to Ortiz-Toquero et al.[2,20]

The KR-1W marketed by Topcon is an integrated placido disk topography and Hartmann–Shack device with worse repeatability and low ICC values than VX120 multidiagnostic unit in J0 (Sw=0.37D, ICC=0.374) and J45 (Sw=0.34D, ICC=0.363). However, better repeatability in K flat (Sw=0.14D, CV=0.19, ICC=0.996) and K steep (Sw=0.15D, CV=0.23, ICC=0.997) has been reported.[21] Total ocular HOA-RMS measured in 6-mm central with Topcon KR-1W[22] showed similar repeatability (Sw=0.038D) and better ICC value (0.902).

Repeatability of Scheimpflug Camera

The repeatability of the ACD measurements obtained with the Scheimpflug camera was analyzed by Wang et al.[6] who compared the Oculus Pentacam with other devices, including the Sirius, Galilei G2, and Visante, and found nonstatistically significant differences among all devices. The Pentacam was the only device that provided measurements using the Scheimpflug camera and showed similar values of repeatability (Sw=0.02 mm) with better CV (0.71%) but worse ICC values (0.988) than did the VX120 multidiagnostic unit. Xu et al.[23] reported the repeatability values for the CCT measurements using the Pentacam device and found a CV of 0.8% and an ICC of 0.994 with a small limit of agreement (LoA) (−9.3 to 8.2 μm), which were lower than those of the VX120 multidiagnostic unit. Moreover, Yu et al.[24] reported good repeatability of the CCT measured using the Corvis ST with an Sw of 4.7 μm, a CV of 0.87%, and an ICC of 0.972; however, the VX120 multidiagnostic unit showed better repeatability.

Intersession Reproducibility

Nonprevious reproducibility reports of VX120 device have been published. However, reproducibility is of paramount importance in clinical practice, for example, in follow-up assessment. VX120 showed good reproducibility results, with small LoA that suggest that this device will be useful to patients' follow-up because reproducibility outcomes show differences between sessions less than 0.04 D for sphere, cylinder, J0, J45, HOA-RMS, LOA-RMS, K flat, and K steep taking into account that in clinical practice, the minimum difference clinically significant is 0.25D (Figs. 1 and 2).[25]

Clinical Implications

The repeatability values found in this study are clinically acceptable and provide consistent measurements for many parameters. The main advantage of the VX120 multidiagnostic unit is that it combines several functions (autorefraction, keratometry, corneal topography, aberrometry, pachymetry, and noncontact tonometry) into one instrument, which saves cost, space, and time in conducting an eye examination. At this moment, VX120 multidiagnostic unit and VX130 multidiagnostic unit (the new version) are compact, easily transportable, and the only devices with these characteristics; for this reason, they could be used in screening campaigns, telemedicine practice, etc.

Study Limitations

This study has some limitations, such as a small sample size of young volunteers; however, some authors used a similar sample size[26] or a smaller sample size,[7,20] and others had a large sample size.[10] However, our results are comparable to those of Piñero et al., whose study involved a large sample of healthy patients; thus, the effect of the sample size could have a limiting effect on our results and conclusions. The intraobserver repeatability was not possible with the VX120 multidiagnostic unit because the patient alignment, focus, and measurement moment were determined automatically. The automatic sequence of the VX120 multidiagnostic unit was interrupted, which caused the last test, namely, the IOP measurement, not to be performed because this test would disturb the posterior corneal measurements and change the ocular surface properties. In addition, this study included only young and healthy people and excluded patients who were affected by corneal deformation (postlasik surgery and keratoconus) or other pathologies (dry eye syndrome, lens opacities, and pathological myopia). Thus, it would be necessary to assess the repeatability and reproducibility of the VX120 multidiagnostic unit in nonhealthy patients in future studies.

Corneal geometric and aberrometric measurements had some limitations such as eye movements (i.e., microsaccades, fixation instability, and tremors) and tear film status, which could have affected the accuracy and repeatability of the placido disk and measurements using the Shack–Hartmann wavefront sensor.[15,27] In the study of Prakash et al.[7] the patient rested with closed eyes for 5 min between measurements, which may have improved their results because their outcomes were better than those of many other studies.

Another limitation is the heterogeneous statistical analysis conducted in different studies taking into account that the CV is the only repeatability value that was expressed as a percentage, which made it easier to compare the outcomes across different studies; absolute values could not always be compared (depending on the assessed patients' characteristics). However, a small CV is too sensitive when the mean value is near zero, which limits its usefulness; the mean values could be close to zero, as occurs for the HOA values.[11] Moreover, the better option for analyzing corneal astigmatism is the decomposition in J0 and J45 vector components; however, the clinical interpretation of these data in clinical practice is difficult.[8,26]

CONCLUSIONS

The VX120 multidiagnostic unit provides repeatable measurements in anterior corneal power (K flat and K steep), WTW diameter, ACD, and CCT. However, sphere, cylinder, total ocular HOA-RMS, LOA-RMS, and eccentricity showed worse repeatability in healthy subjects. Our results expand and raise previous report about VX120 repeatability. Intersession reproducibility showed good results with little differences between sessions in healthy subjects.

REFERENCES

1. Wu Y, He JC, Zhou XT, et al. A limitation of Hartmann-Shack system in measuring wavefront aberrations for patients received laser refractive surgery. *PLoS One* 2015;10:e0117256.
2. Ortiz-Toquero S, Rodriguez G, de Juan V, et al. Repeatability of placido-based corneal topography in keratoconus. *Optom Vis Sci* 2014;91:1467–1473.
3. Shinto H, Saita Y, Nomura T. Shack-Hartmann wavefront sensor with large dynamic range by adaptive spot search method. *Appl Opt* 2016;55:5413–5418.
4. Yaoeda K, Fukushima A, Shirakashi M, et al. Comparison of intraocular pressure adjusted by central corneal thickness or corneal biomechanical properties as measured in glaucomatous eyes using noncontact tonometers and the Goldmann applanation tonometer. *Clin Ophthalmol* 2016;10:829–834.
5. Grewal DS, Grewal SP. Clinical applications of Scheimpflug imaging in cataract surgery. *Saudi J Ophthalmol* 2012;26:25–32.
6. Wang Q, Ding X, Savini G, et al. Anterior chamber depth measurements using Scheimpflug imaging and optical coherence tomography: Repeatability, reproducibility, and agreement. *J Cataract Refract Surg* 2015;41:178–185.
7. Prakash G, Jhanji V, Srivastava D, et al. Single session, intra-observer repeatability of an advanced new generation Hartmann-Shack aberrometer in refractive surgery candidates. *J Ophthalmic Vis Res* 2015;10:498–501.
8. Ortiz-Toquero S, Zuñiga V, Rodriguez G, et al. Agreement of corneal measurements between dual rotating Scheimpflug-Placido system and Placido-based topography device in normal and keratoconus eyes. *J Cataract Refract Surg* 2016;42:1198–1206.
9. Visser N, Berendschot TT, Verbakel F, et al. Evaluation of the comparability and repeatability of four wavefront aberrometers. *Invest Ophthalmol Vis Sci* 2011;52:1302–1311.
10. Piñero DP, López-Navarro A, Cabezos I, et al. Corneal topographic and aberrometric measurements obtained with a multidiagnostic device in healthy eyes: Intrasession repeatability. *J Ophthalmol* 2017;2017:2149145.
11. Wang Q, Savini G, Hoffer KJ, et al. A comprehensive assessment of the precision and agreement of anterior corneal power measurements obtained using 8 different devices. *PLoS One* 2012;7:e45607.
12. Bayraktar S, Bayraktar Z. Central corneal thickness and intraocular pressure relationship in eyes with and without previous LASIK: Comparison of Goldmann applanation tonometer with pneumatonometer. *Eur J Ophthalmol* 2005;15:81–88.
13. Cacho I, Sanchez-Naves J, Batres L, et al. Comparison of intraocular pressure before and after laser in situ keratomileusis refractive surgery measured with perkins tonometry, noncontact tonometry, and transpalpebral tonometry. *J Ophthalmol* 2015;2015:683895.
14. Technical specifications of the instrument. Available at: http://visionix-vx120.com/es/lo-que-hace-el-vx120/caracteristicas-tecnicas. Accessed November 14, 2017
15. Mao X, Savini G, Zhuo Z, et al. Repeatability, reproducibility, and agreement of corneal power measurements obtained with a new corneal topographer. *J Cataract Refract Surg* 2013;39:1561–1569.
16. McAlinden C, Khadka J, Pesudovs K. Statistical methods for conducting agreement (comparison of clinical tests) and precision (repeatability or reproducibility) studies in optometry and ophthalmology. *Ophthalmic Physiol Opt* 2011;31:330–338.
17. Bland M. *An Introduction to Medical Statistics*. 3rd ed. Oxford, United Kingdom, Oxford University Press, 2000, pp 268–275.
18. McGraw KO, Wong SP. Forming inferences about some intraclass correlation coefficients. *Psychol Meth* 1996;1:30–46.
19. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet* 1986;1:307–310.
20. Ortiz-Toquero S, Rodriguez G, de Juan V, et al. Repeatability of wavefront aberration measurements with a placido-based topographer in normal and keratoconic eyes. *J Refract Surg* 2016;32:338–344.
21. Hua Y, Xu Z, Qiu W, et al. Precision (repeatability and reproducibility) and agreement of corneal power measurements obtained by Topcon KR-1W and iTrace. *PLoS One* 2016;11:e0147086.
22. López-Miguel A, Martínez-Almeida L, González-García MJ, et al. Precision of higher-order aberration measurements with a new Placido-disk topographer and Hartmann-Shack wavefront sensor. *J Cataract Refract Surg* 2013;39:242–249.
23. Xu Z, Peng M, Jiang J, et al. Reliability of Pentacam HR thickness maps of the entire cornea in normal, post-laser in situ keratomileusis, and keratoconus eyes. *Am J Ophthalmol* 2016;162:74–82.e71.
24. Yu A, Zhao W, Savini G, et al. Evaluation of central corneal thickness using corneal dynamic Scheimpflug analyzer Corvis ST and comparison with pentacam rotating Scheimpflug system and ultrasound pachymetry in normal eyes. *J Ophthalmol* 2015;2015:767012.
25. Perches S, Collados MV, Ares J. Repeatability and reproducibility of virtual subjective refraction. *Optom Vis Sci* 2016;93:1243–1253.
26. Delrivo M, Ruiseñor Vázquez PR, Galletti JD, et al. Agreement between placido topography and Scheimpflug tomography for corneal astigmatism assessment. *J Refract Surg* 2014;30:49–53.
27. González-Méijome JM, Queirós A, Jorge J, et al. External factors affecting data acquisition during corneal topography examination. *Eye Contact Lens* 2007;33:91–97.

