

Repeatability of OPD-Scan III and its agreement with Pentacam in measuring keratometry, astigmatism and axis in patients with cataract and moderate to high astigmatism

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Abstract

Purpose

To assess accuracy of OPD-Scan III in measuring keratometry, astigmatism and axis in patients with cataract and moderate to high astigmatism

Materials and Methods

Measurements were taken with OPD-Scan III and Pentacam in cataract patients with keratometric astigmatism (KA) more than 0.75 D. Keratometry in the steepest axis (Ks) and flattest axis (Kf), KA and axis, which are power vector components of astigmatism (J0 and J45), were evaluated. Intraclass correlation coefficients (ICCs) were used to assess repeatability. The Wilcoxon test was used to assess differences, the Spearman correlation was used to assess correlations, and the Bland-Altman method was used to assess agreement.

Results

Seventy eyes of 63 patients were included to analyze the repeatability of the two devices. The ICCs of Ks, Kf, KA, axis, J0 and J45 were 0.991, 0.995, 0.946, 0.883, 0.946 and 0.892, respectively, with OPD-Scan III. Seven hundred and thirty-two eyes of 516 patients were included to analyze the difference, correlation and agreement of the two devices. There were significant differences between the two devices in terms of Ks, Kf, axis, J0 and J45 (all $p < 0.01$). There were significant correlations between the two devices in each parameter (all $p < 0.01$). The 95% limits of agreement (LOAs) for Ks, Kf, KA, astigmatic axis, J0 and J45 were (-0.34, 0.44) D, (-0.24, 0.38) D, (-0.46, 0.48) D, (-10.20, 12.92)°, (-0.24, 0.24) D, and (-0.27, 0.35) D respectively. The 95% LOAs for the degree of IOL calculated according to parameter measured by OPD-Scan III and Pentacam was (-0.32, 0.22) D.

Conclusions

OPD-Scan III has a high accuracy for measuring keratometry, but its accuracy for measuring astigmatism and axis is poor in eyes with moderate to high astigmatism.

Introduction

Currently, cataract surgery has entered the era of refractive surgery, and the intraoperative correction of corneal astigmatism is a necessary requirement for refractive cataract surgery (RCS)[1]. The precise measurement of keratometry, corneal astigmatism and axis is significant in planning RCS, such as identifying the location and with of the clear corneal incision(CCI)[2, 3],and calculating the type and axis of Toric intraocular lens (IOL)[4, 5]. In addition, calculating the power of IOL power also depend on

keratometry[6] .At present, there are many devices for measuring keratometry in clinical practice, such as Pentacam, IOL-Master, VERION and so on. OPD-Scan III is a five-in-one true refractive workstation, combined with a topographer, wavefront aberrometer, keratometer, auto-refraction and pupillometer[7–10]. Its characteristic of multi-functional integration not only provides more comprehensive information for clinicians but also reduces the examination time of patients and improves the efficiency of diagnosis and treatment. However, there is less clinical research on the accuracy of OPD-Scan III and some results are inconsistent[11, 12]. Moreover, most previous studies included patients with healthy eyes and not further grouped according to the degree of astigmatism. whereas our attention is focused on eyes with moderate to high astigmatism, that is, the minimum amount of astigmatism that is usually needed to correct. Pentacam is widely used in clinical practice, and a large number of studies have confirmed its high accuracy in measuring keratometry and astigmatism[13–15]. In this study, we enrolled patients with cataract and moderate to high corneal astigmatism (more than 0.750 D) and aimed at assessing the repeatability of OPD-Scan III and its agreement with Pentacam in measuring keratometry, astigmatism and axis in order to demonstrate the clinical value of this device.

Patients And Methods

This cross-sectional study comprised patients with cataract and moderate to high astigmatism who received ophthalmologic measurement at the Department of Ophthalmology, Lixiang Eye Hospital of Soochow University, Jiangsu, China, from May 2018 to September 2019. The inclusion criteria included the following: (1) the patient could smoothly complete OPD-Scan III and Pentacam examinations; (2) regular astigmatism of more than 0.75 D;. The exclusion criteria included the following: (1) keratoconus, corneal scar and other corneal diseases; and (2) history of dry eyes, eye trauma, eye surgery, etc. All patients agreed to participate, met the inclusion criteria, and signed an informed consent agreement before undergoing any procedure. The study was performed in accordance with the ethical principles of the Declaration of Helsinki and approved by the Ideal Ophthalmology Hospital Affiliated of Soochow University University's ethics committee.

Ophthalmologic Measurement

All patients underwent complete ophthalmologic measurement. Slit-lamp microscopy (iec601-1, TOPCON, Japan) was used for general examination to examine the anterior segment and eliminate corneal scarring. Pentacam (70900, Oculus, Wetzlar, Germany) was used to examine the corneal topography and exclude keratoconus. The Schirmer test was used to check the amount of tear secretion and exclude patients whose amount of tear secretion was less than 5 mm/5 min.

All enrolled patients underwent corneal topography with two devices: OPD-Scan III (Nidek Inc., Tokyo, Japan) and Pentacam (70900, Oculus, Wetzlar, Germany). The following parameters of the 3-mm central zone were analyzed for the two devices: keratometry in the steepest axis (Ks), keratometry in the flattest axis (Kf), keratometric astigmatism (KA, the keratometric refractive index is typically 1.3375) and axis. KA and axis, power vectors were computed at axis 0 according to the Jackson coefficient orthogonal

coordinate system (J0) and at axis 45 according to the Jackson coefficient orthogonal coordinate system (J45) [16]:

J0: astigmatism at axis 0° (or 180°) = $(KA/2) \cos(2 \text{ axis})$;

J45: astigmatism at axis 45° = $(KA/2) \sin(2 \text{ axis})$

Repeatability measurements

To examine the repeatability of the OPD-Scan III and Pentacam measurements, three successive measurements were performed with each device in random order. 70 eyes were examined 3 times half an hour apart by the same optometrist. During this time, the participant remained in the examination room and was then asked to return to the seat at the device. The device was realigned before each imaging examination. For each participant, the seat height was adjusted, their head and chin were placed properly, and they were asked to blink a couple of times right before each acquisition.

Agreement measurements

To examine the agreement of the OPD-Scan III and Pentacam measurements, the other 732 eyes received three successive measurements with each device in a random order. We analyzed the measurement results, in which axis was in the median of the three successive measurements. The degree of IOL calculated according to the following SRK regression formula: $P = A - 2.5L - 0.9K$ (P: the degree of intraocular lens to be implanted, A: constant, L: axial length, and K: keratometry).[17]

Statistical analysis

Statistical analysis was performed using SPSS for Windows software (version 22, SPSS, Inc). Intraclass correlation coefficients (ICCs) were used to assess repeatability. The Wilcoxon test result was used to assess differences. The Spearman correlation was used to assess correlations. The Bland-Altman method was used to assess agreement in variables between the two devices, and 95% limits of agreement (LOAs) were calculated. The level of statistical significance was $p < 0.05$.

Results

Repeatability of parameters measured by OPD-Scan III and Pentacam

Seventy eyes (33 right and 37 left) of 63 patients (46 men and 17 women) were included to analyze the repeatability of OPD-Scan III and Pentacam for measuring keratometry and astigmatism in eyes with cataract and moderate to high corneal astigmatism. The mean age was 62.95 ± 5.79 years. The mean Ks, Kf, KA, astigmatic axis, J0 and J45 were 43.76 (42.42, 44.77) D, 42.41 (41.27, 43.26) D, 1.23 (1.02, 1.55) D, 92.00 (86.58, 95.75)°, 0.60 (0.48, 0.76) D, and 0.04 (-0.07, 0.14) D, as measured by OPD-Scan III, and 43.69 (42.25, 44.60) D, 42.55 (41.20, 43.26), 1.11 (0.97, 1.41) D, 89.01 (82.89, 94.68)°, 0.53 (0.44, 0.70) D,

and - 0.02 (-0.14,0.09) D, as measured by Pentacam. Table 1 shows the ICC of each parameter obtained with OPD-Scan III and Pentacam. The ICCs of Ks, Kf, KA, astigmatic axis, J0 and J45 were 0.991, 0.995, 0.946, 0.883, 0.946 and 0.892, respectively, with OPD-Scan III and were greater than 0.9 with Pentacam.

Table 1
 ICCs and 95%CI of keratometric parameters obtained with OPD-Scan III and Pentacam (n = 70)

	OPD-Scan III		Pentacam	
	ICC	95%CI	ICC	95%CI
Ks (D)	0.991	0.995 ~ 0.998	0.988	0.983 ~ 0.992
Kf (D)	0.995	0.998 ~ 0.999	0.988	0.982 ~ 0.992
KA (D)	0.946	0.921 ~ 0.964	0.951	0.928 ~ 0.968
Axis (°)	0.883	0.833 ~ 0.922	0.943	0.917 ~ 0.962
J0	0.946	0.921 ~ 0.964	0.948	0.923 ~ 0.965
J45	0.892	0.845 ~ 0.928	0.946	0.9231 ~ 0.964

ICC: Intraclass correlation coefficients;CI:confidence interval; Ks: Keratometric value at the steepest corneal meridian for the 3-mm central zone; Kf: Keratometric value at the flattest corneal meridian for the 3-mm central zone; KA: Keratometric astigmatism; J0: Power vectors were computed at axis 0 according to the Jackson coefficient orthogonal coordinate system; J45: Power vectors were computed at axis 45 according to the Jackson coefficient orthogonal coordinate

Agreement of parameters measured by OPD-Scan III and Pentacam

Seven hundred and thirty-two eyes (362 right and 370 left) of 516 patients (299 men and 217 women) were included to analyze the agreement of OPD-Scan III and Pentacam for measuring keratometry and astigmatism in eyes with cataract and moderate to high corneal astigmatism.. The mean age was 63.98 ± 6.22 years.

Table 2 displays each parameter as measured by the two devices. The Ks, Kf, KA, astigmatic axis, J0 and J45 were 44.00 (42.95, 45.06) D, 42.48 (41.56, 43.38) D, 1.33 (1.06, 1.82) D, 92.00 (86.00, 97.00), 0.63 (0.49, 0.88) D, and 0.04 (-0.09, 0.16) D, as measured with OPD-Scan III, and 44.00 (42.90, 44.90) D, 42.40 (41.60, 43.40)

Table 2

Difference in and correlation of keratometric parameters obtained with OPD-Scan III and Pentacam (n = 732)

	OPD-Scan III	Pentacam	Wilcoxon test		Spearman analysis	
			Z	P	r	P
Ks (D)	44.00(42.95,45.06)	44.00(42.90,44.90)	-7.249	≤ 0.001	0.990	≤ 0.001
Kf (D)	42.48(41.56,43.38)	42.40(41.60,43.40)	-9.273	≤ 0.001	0.992	≤ 0.001
KA (D)	1.33(1.06,1.82)	1.33(1.10,1.80)	-0.002	0.998	0.920	≤ 0.001
Axis (°)	92.00(86.00,97.00)	90.20(84.23,95.90)	-5.808	≤ 0.001	0.841	≤ 0.001
J0	0.63(0.49,0.88)	0.64(0.50,0.85)	-0.192	≤ 0.001	0.925	≤ 0.001
J45	0.04(-0.09,0.16)	0.01(-0.14,0.14)	-6.406	≤ 0.001	0.734	≤ 0.001

III and Pentacam (n=732)

Ks: Keratometric value at the steepest corneal meridian for the 3-mm central zone; Kf: Keratometric value at the flattest corneal meridian for the 3-mm central zone; KA: Keratometric astigmatism; J0: Power vectors were computed at axis 0 according to the Jackson coefficient orthogonal coordinate system; J45: Power vectors were computed at axis 45 according to the Jackson coefficient orthogonal coordinate system

1.33 (1.10, 1.80) D, 90.20 (84.23, 95.90)°, 0.64 (0.50, 0.85) D, and 0.01 (-0.14, 0.14) D, as measured with Pentacam. The Wilcoxon test showed that there were significant differences between the two devices in these parameters (all $p \leq 0.01$) except KA ($p = 0.998$). The Spearman analysis showed that a significant correlation existed between OPD-Scan III and Pentacam in the measurements of Ks, Kf, KA, astigmatic axis, J0 and J45 ($r = 0.990, 0.992, 0.920, 0.841, 0.925, 0.734$; all $p < 0.001$) (Fig. 1).

Table 3 shows that the 95% LOAs for Ks, Kf, KA, astigmatic axis, J0 and J45 were (-0.34, 0.44) D, (-0.24, 0.38) D, (-0.46, 0.48) D, (-10.20, 12.92)°, (-0.24, 0.24) D, and (-0.27, 0.35) D; the width of agreement (WOA) was 0.78 D, 0.62 D, 0.94 D, 23.12°, 0.48 D and 0.62 D, and the percentage of out-of 95% limits of agreement (LOA) points was 4.51%, 4.37%, 4.51%, 3.83%, 4.51%, and 4.64%, respectively, for the differences between OPD-Scan III and Pentacam (Fig. 2).

Table 3

Inter-device agreement of keratometric parameters obtained with OPD-Scan III and Pentacam (n = 732)

	Ks	Kf	KA	Axis	J0	J45
Mean difference \pm SD	(0.05 \pm 0.20) D	(0.05 \pm 0.17) D	(0.01 \pm 0.24) D	(1.36 \pm 5.90) $^{\circ}$	(0.00 \pm 0.12) D	(0.04 \pm 0.16) D
95% LOA	(-0.34,0.44) D	(-0.24,0.38) D	(-0.46,0.48) D	(-10.20, 12.92) $^{\circ}$	(-0.24,0.24) D	(-0.27,0.35) D
WOA	0.78D	0.62D	0.94D	23.12 $^{\circ}$	0.48D	0.62D
Point out of 95% LOA	4.51%	4.37%	4.51%	3.83%	4.51%	4.64%

Ks: Keratometric value at the steepest corneal meridian for the 3-mm central zone; Kf: Keratometric value at the flattest corneal meridian for the 3-mm central zone; KA: Keratometric astigmatism; J0: Power vectors were computed at axis 0 according to the Jackson coefficient orthogonal coordinate system; J45: Power vectors were computed at axis 45 according to the Jackson coefficient orthogonal coordinate system; LOA: limit of agreement; WOA: width of agreement

The mean dioptric power of IOL calculated according to parameter measured by OPD-Scan III and Pentacam were 19.08(18.24,11.98) D and 19.17(18.31,19.93) D respectively. The Wilcoxon test showed significant differences ($Z=-9.550$, $p < 0.001$). The Spearman analysis showed significant correlation ($r = 0.994$, $p < 0.001$). The 95% LOAs for the dioptric power of IOL was (-0.32, 0.22) D, the WOA was 0.64 D, and the percentage of out-of 95% LOA points was 4.91% (Fig. 3).

Discussion

At present, the clinical devices used for measuring keratometry, astigmatism and axis are mainly based on the following principles: Placido rings, Scheimpflug imaging, the Scheiner principle, the scanning slit method, or a combination of several principles. OPD-Scan III is a new, multi-functional device that integrates the corneal topographic map system based on the placido disc and the subjective aberrometer based on dynamic retinoscopy[7–9]. Pentacam is widely used in clinics, and a large number of studies have confirmed its high accuracy in measuring keratometry and astigmatism[13–15]. In this study, we compared OPD-Scan III to Pentacam for measuring keratometry and astigmatism in order to assess the accuracy of OPD-Scan III in patients with cataract and moderate to high astigmatism. We intentionally excluded eyes with lower astigmatism for several reasons. First, such eyes do not usually have surgical correction of astigmatism; second, their data may generate noise; and third, they have been evaluated in previous studies.

Repeatability refers to the ability of the device to repeat its own measurements. In this study, we found that both OPD-Scan III and Pentacam had high repeatability in terms of the measurement of Ks, Kf and

astigmatism (all ICC greater than 0.9); However, the repeatability of axial measurements with OPD-Scan III (ICC = 0.883) was slightly lower than that with Pentacam (ICC = 0.943), and its repeatability of vectors values (J0 and J45) was lower than that with Pentacam. Guilbert et al. [18] found that OPD-Scan III had high repeatability for the measurement of keratometry in normal people and keratoconus patients (ICC greater than 0.9). Asgari et al.[12] also reported that high repeatability of keratometry was obtained in emmetropia and ametropia. These findings were accordance with our results. However, they did not analyze the repeatability of axis. In Guilbert's study¹⁸, the repeatability of the AcuTarget measurements was found to be good (with the ICC ranging from 0.773 to 0.780). Therefore, they believed that the AcuTarget was a reliable device and that a single measurement appeared to be sufficient. According to our results, we concluded that OPD-Scan III was a reliable device and that a single measurement appeared to be sufficient for measuring keratometry, astigmatism and axis in patients with cataract and moderate to high astigmatism.

Agreement refers to comparing the measurement results of two or more devices. At present, most of them are evaluated in combination with differences, correlations and Bland-Altman analyses. We analyzed the measurement results with axis in the median three successive measurements because the ICC of axis was lower than that of the other parameters.

In this study, we found that the differences and correction of keratometry between OPD-scan III and Pentacam were statistically significant (all $p < 0.001$). We analyzed the reasons for the above differences mainly because of the differences in the measurement principles and measurement points of the two devices (12960 measurement point data obtained by OPD-Scan III and 25000 measurement point data generated by Pentacam). Eibschitz-Tsimhoni et al.[19] reported that a 1.00 D error in keratometry measurement changed the calculated implant intraocular lens (IOLs) power by -0.9 D. In our study, the mean difference of Ks measured between OPD-scan III and Pentacam was (0.05 ± 0.20) D and that of Kf was (0.05 ± 0.17) D, according to the following SRK regression formula: $P = A - 2.5L - 0.9K$ (P: the degree of intraocular lens to be implanted, A: constant, L: axial length, and K: keratometry). The influence of this difference on the dioptric power of IOL was approximately 0.09 D, while the dioptric power of IOL in the clinic was increased by 0.5 D, In addition, we assessed the agreement of dioptric power of IOL calculated according to parameter measured by OPD-Scan III and Pentacam and found that the 95% LOAs for the dioptric power of IOL was $(-0.32, 0.22)$ D, and the percentage of out-of 95% LOA points was 4.91%. so we concluded that the difference in keratometry between the two measurements was small and had no clinical significance especially about calculating the degree of IOL. Gharieb et al¹¹ enrolled 660 healthy right eyes, they found that there was no significant differences in keratometry between OPD-scan III and Pentacam, but the WOA was 1.60 D for K and 1.06 D for Kf, negating the accuracy of the use of devices interchangeably regarding keratometry. Asgari et al.¹² reported that in the ametropia group, the WOAs were 0.24 D for Ks, 0.31 D for Kf and 0.63 D for Ks, as well as 0.67 D for Kf in the emmetropia group, while the WOA was 0.63 D for Ks and 0.67 D for Kf. He concluded that OPD-Scan III and Pentacam were in good agreement for the measurements of keratometry in cases of emmetropia and ametropia. In our study, the WOA was 0.78 D for Ks and 0.62 D for Kf. We found that OPD-Scan III and Pentacam were in good agreement for the measurement of keratometry, which was in accordance with Asgari^[12].

In this study, we found that the differences in KA between OPD-scan III and Pentacam were not statistically significant ($p = 0.998$). KA measured with OPD scan III was (0.01 ± 0.24) D higher than that measured with Pentacam. Piñero et al.¹⁹ reported that the difference between the IOL Master and Sirius system in the measurement of corneal astigmatism was (0.10 ± 0.25) D, and he considered that the two could replace each other in the measurement of corneal astigmatism. According to the viewpoint of Piñero^[20], OPD-scan III and Pentacam can replace each other for the measurement of corneal astigmatism. However, the Bland-Altman analysis revealed poor agreement in KA, J0 and J45 (WOA was 0.94 D, 0.48 D and 0.62 D, respectively) between the two devices in our study. In the Molina-Martín study²¹, the differences between Cassini and Pentacam in measuring corneal astigmatism did not reach statistical significance. However, for the Bland-Altman analysis of Cassini versus Pentacam, the WOA of corneal astigmatism, J0 and J45 was 0.739 D, 0.390 D, and 0.374 D, respectively. These results suggest that the differences between these two devices are clinically relevant and, consequently, that the two devices cannot be used as interchangeable systems for measuring corneal astigmatism. After comprehensive consideration, we concluded that OPD-Scan III and Pentacam cannot be used as interchangeable systems for measuring KA in eyes with moderate to high astigmatism.

In this study, the differences and correlations in axis reached statistical significance. In the Bland-Altman analysis, we found that OPD-Scan III and Pentacam were in poor agreement for the measurement of axis. The maximum difference in axis between OPD-Scan III and Pentacam was 26° , the 95% LOA was $(-10.20, 12.92)^\circ$, and the WOA was 23.12° . These axis errors cannot be considered as acceptable when planning the alignment of a toric IOL, considering the axis of corneal astigmatism. According to Viestenz et al.²², 11.5° of toric IOL rotation would lead to residual astigmatism that is 40% of the initial astigmatic power and 3° , or 10%, of the initial power. Likewise, Felipe et al.^[23] demonstrated that toric IOL rotations of less than 10° were able to change the eye's refraction less than 0.50 D. In Lin HY's^[24] study, a 95% LOA of axis between OPD-Scan III and VERION was $(-27.85^\circ, 65.17^\circ)$. This difference was wider than our results. In addition to the difference in measurement principle, this discrepancy between Lin HY's study and our own is mainly due to the difference in measurement range. In Lin HY's study, VERION measured corneal data within 2.8 mm, while OPD-Scan III and Pentacam measured within 3.0 mm in our study.

Conclusions

In conclusion, our results indicate that OPD-Scan III, as a new multifunctional device, has a high accuracy for measuring keratometry, but its accuracy for measuring astigmatism and axis is poor in patients with cataract and moderate to high astigmatism.

Declarations

Funding

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Availability of data and materials

The data have not been placed in any online data storage. The datasets generated and analyzed during the study are available upon request from the first author.

Authors' contributions

Study concept and design (LPP, WY); collection, management, analysis, and interpretation of data (LPP, TYY, HLL); and preparation, review, or approval of the manuscript (SY,YY). All authors read and approved the final manuscript.

Ethics approval and consent to participate

This study followed the tenets of the Declaration of Helsinki and approved by the ethics committee of the Lixiang Eye Hospital of Soochow University. Informed written consent was obtained from all participants.

Competing interests

The authors declare that they have no competing interests

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Figures

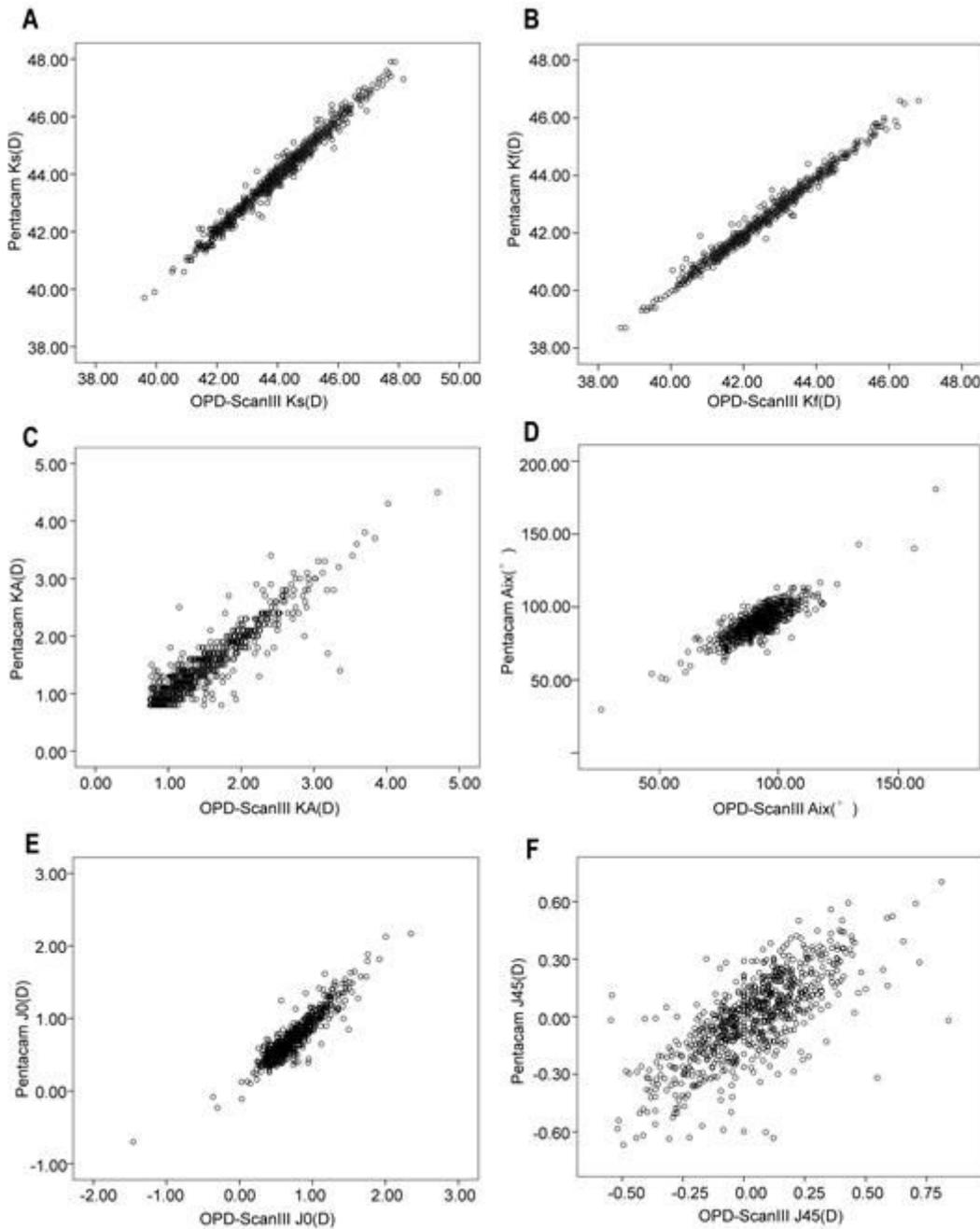


Figure 1

Spearman correlation scatterplots of keratometry, KA and axis obtained using OPD-Scan III and Pentacam (n=732) A:Spearman correlation scatterplot of Ks obtained using OPD-Scan III and Pentacam ($r=0.990$, $p<0.001$); B: Spearman correlation scatterplot of Kf obtained using OPD-Scan III and Pentacam ($r=0.992$, $p<0.001$); C: Spearman correlation scatterplot of KA obtained using OPD-Scan III and Pentacam ($r=0.920$, $p<0.001$); D: Spearman correlation scatterplot of axis obtained using OPD-Scan III and Pentacam ($r=0.841$, $p<0.001$); E:Spearman correlation scatterplot of J0 obtained using OPD-Scan III and Pentacam ($r=0.925$, $p<0.001$); F: Spearman correlation scatterplot of J45 obtained using OPD-Scan III and Pentacam ($r=0.734$, $p<0.001$)

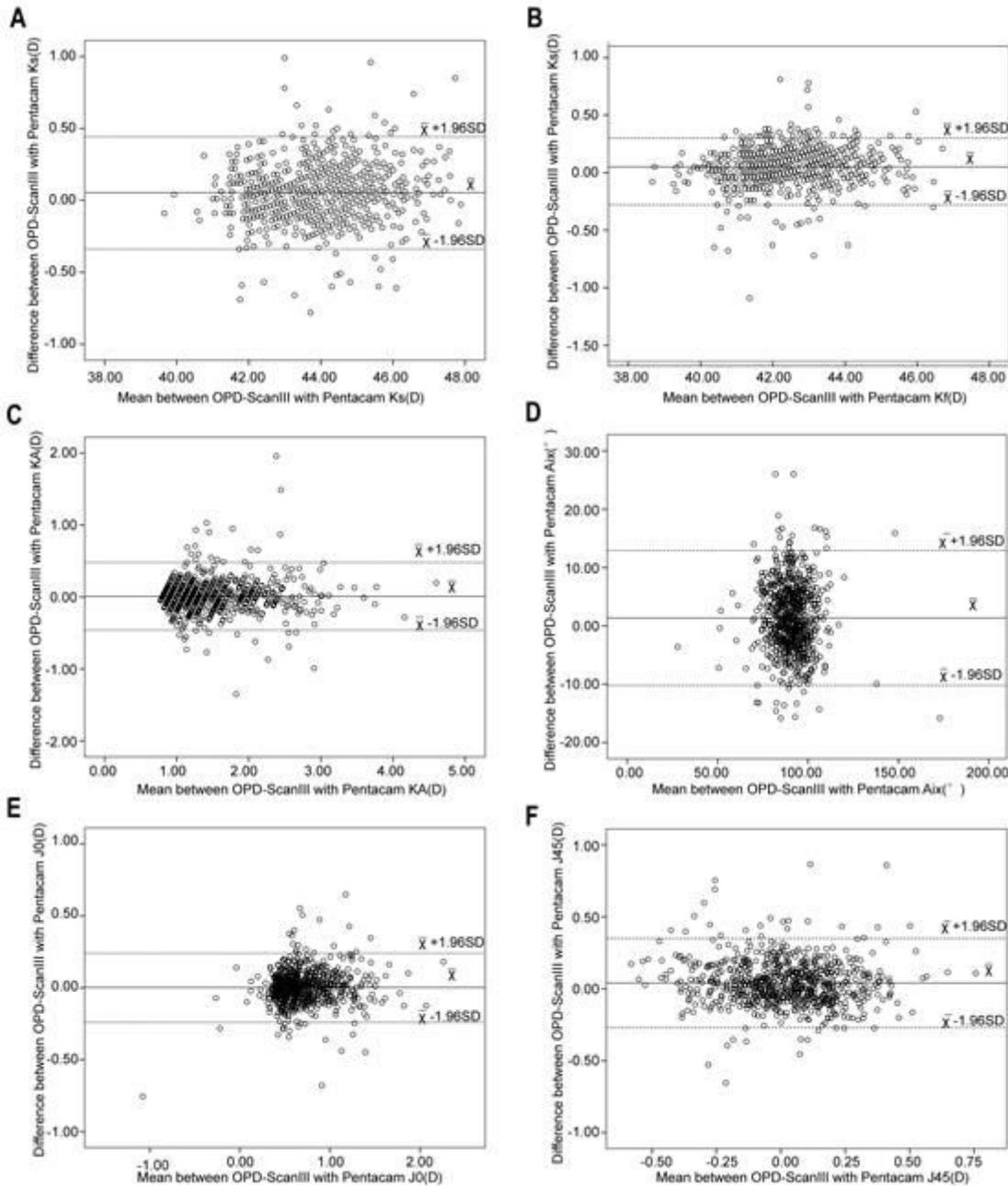


Figure 2

Bland-Altman scatterplots of keratometry, KA and axis obtained using OPD-Scan III and Pentacam (n=732). A: Bland-Altman scatterplot of Ks obtained using OPD-Scan III and Pentacam, 95% LOA was (-0.34,0.44) D; B: Bland-Altman scatterplot of Kf obtained using OPD-Scan III and Pentacam, 95% LOA was (-0.24,0.38) D; C: Bland-Altman scatterplot of KA obtained using OPD-Scan III and Pentacam, 95% LOA was (-0.46,0.48); D: Bland-Altman scatterplot of axis obtained using OPD-Scan III and Pentacam, 95% LOA was (-10.20 ,12.92)°; E: Bland-Altman scatterplot of J0 obtained using OPD-Scan III and Pentacam, 95% LOA was (-0.24,0.24) D; F: Bland-Altman scatterplot of J45 obtained using OPD-Scan III and Pentacam, 95% LOA was (-0.27,0.35) D

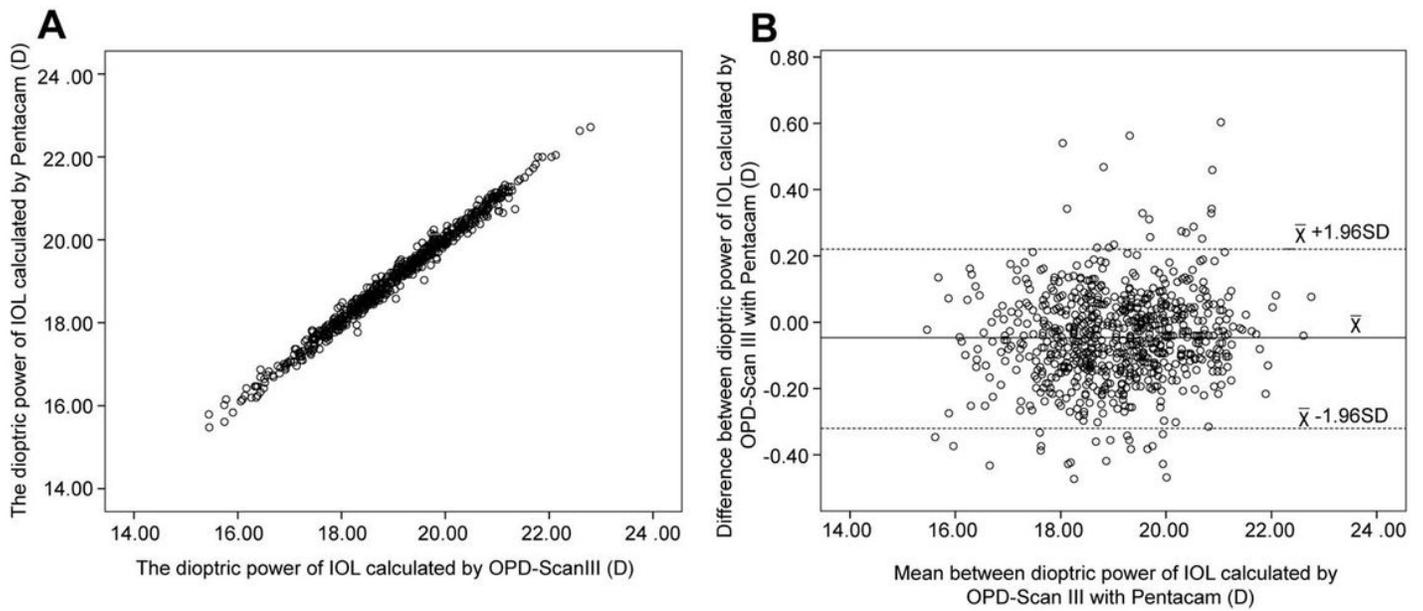


Figure 3

Spearman correlation and Bland-Altman scatterplots of the dioptric power of IOL calculated by OPD-Scan III and Pentacam (n=732). A: Spearman correlation scatterplot of dioptric power of IOL calculated by OPD-Scan III and Pentacam ($r=0.994$, $p<0.001$); B: Bland-Altman scatterplots of the dioptric power of IOL calculated by OPD-Scan III and Pentacam, 95% LOAs for the dioptric power of IOL was (-0.32, 0.22) D.