Comparison of OPD-Scan III and Pentacam in Measuring Biological Measurements in Cataract Patients with Corneal Astigmatism

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Research Article

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Abstract

Purpose To assess the accuracy of OPD-Scan III in measuring keratometry, astigmatism, axes and intraocular lens (IOL) power in cataract patients with corneal astigmatism.

Methods Cataract patients with keratometric astigmatism (KA) measurements greater than 0.75 D were included. Measurements were taken with OPD-Scan III and Pentacam devices. The following measurements were obtained via these 2 devices: keratometry in the steepest axis (Ks) and flattest axis (Kf), KA, axis, Jackson crossed cylinder of powers J0 and J45 and IOL power.

Results Seventy eyes of 63 patients were included to analyze the repeatability of the two devices. The ICCs of each index were greater than 0.85 via the OPD-Scan III. Seven hundred thirty-two eyes of 516 patients were included to analyze the differences, correlations and agreements of the two devices. Statistically significant differences between the devices were found in Ks, Kf, axis, J0 and J45 (all $p < 0.01$). There were significant correlations found between the two devices in each index (all $p < 0.01$). The 95% limits of agreement (LOAs) for Ks, Kf, KA, axis, J0, J45 and IOL power 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, (-0.27, 0.35) D and (-0.32, 0.22) D, respectively.

Conclusion OPD-Scan III had high accuracies for measuring keratometry and IOL power, but the accuracies for measuring astigmatism and the axis were poor in eyes with moderate to high astigmatism.

Introduction

Currently, cataract surgery has progressed to the use of refractive surgery, and precise measurements of keratometry, corneal astigmatism and axis are significant in planning refractive cataract surgery (RCS), with preparations including the identification of the location and size of the corneal incision[1–3]. In addition, intraocular lens (IOL) power calculations, especially toric IOLs, also depend on these parameters[4, 5]. At present, there are many devices that are used for measuring keratometry in clinical practice, such as Pentacam, IOL-Master and VERION. OPD-Scan III is a five-in-one true refractive workstation that is combined with a topographer, wavefront aberrometer, keratometer, autorefraction and pupillometer[6–8]. Its multifunctional integration not only provides more comprehensive information for clinicians, but also reduces the examination times of patients and improves the efficiency of diagnoses and treatments. However, there is less clinical research on the accuracy of OPD-Scan III, the findings of which are inconsistent[9, 10]. Moreover, most previous studies have included patients with a low degree of corneal astigmatism, whereas our attention was focused on eyes with astigmatism values greater than 0.75 D, which constitutes the minimum amount of astigmatism that is usually needed to create problems[11].

Pentacam is widely used in clinical practice, and a large number of studies have confirmed its high accuracies in measuring keratometry and astigmatism[12–13]. In this study, we enrolled patients with cataracts and keratometric astigmatism (KA) greater than 0.75 D, and we aimed to assess the

repeatability of OPD-Scan III and its agreement with Pentacam in measuring keratometry, astigmatism, axis and the calculation of IOL power to demonstrate the clinical values of this device.

Subjects And Methods

Subjects

This comparative study was comprised of patients with KA values greater than 0.75 D who received ophthalmologic measurements at the Department of Ophthalmology, Lixiang Eye Hospital of Soochow University, Jiangsu, China, from March 2019 to September 2019. The following inclusion criteria were used: (1) the patient could smoothly complete OPD-Scan III and Pentacam examinations; and (2) the patient had KA measured (as via OPD-Scan III and Pentacam) > 0.75 D. The following exclusion criteria were used: (1) patients with keratoconus, corneal scar and other corneal diseases; and (2) patients with a history of dry eyes, eye trauma and eye surgery, among other conditions. All of the 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 was approved by the ethics committee of the Ideal Ophthalmology Hospital Affiliated of Soochow University.

Ophthalmologic Measurement

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

All of the enrolled patients underwent corneal topography with the use of 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), KA (with the keratometric refractive index typically being 1.3375) and aix. KA and aix were decomposed into J0 (Jackson cross cylinder at 0° or 180°) and J45 (Jackson cross cylinder at 45°), according to a Jackson crossed cylinder (JCC) [17]:

$$J0=(-KA/2)\cos(2\,aix)$$

$$J45=(-KA/2)\sin(2\,aix)$$

Repeatability measurements To examine the repeatability, 70 eyes received measurements by the same optometrist, wherein Pentacam was first used for the measurements, followed by the use of OPD-Scan III. Each individual was examined three times at intervals of 30 min by the same optometrist. During this time, each 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. For each participant, the seat height was adjusted,

their head and chin were properly placed, after which they were asked to blink several times immediately before each acquisition. If an examination was considered to be unsatisfactory because of excessive eye movement or eyelid blinking, it was performed again.

Agreement measurements To examine the agreement of the OPD-Scan III and Pentacam measurements, the other 732 eyes received three successive measurements started, wherein Pentacam was first used for the measurements, followed by the use of OPD-Scan III by the same optometrist. We then recorded the most high-quality image. Axial length was obtained via ultrasound pachymetry (NIDEK, US-500, Japan). The degree of IOL was calculated according to the SRK/T formula.

Statistical analysis

Statistical analyses were performed by using SPSS for Windows software (version 22, SPSS, Inc.). Intraclass correlation coefficients (ICCs) were used to assess repeatability. In this study, the measurement data did not conform to a normal distribution based on the Kolmogorov-Smirnov test, and the Wilcoxon test result was used to assess differences and is represented as M [Q_1,Q_3]. Spearman correlations were used to assess the correlations. The Bland-Altman method was used to assess the 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

Seventy eyes (33 right and 37 left eyes) 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 cataracts and corneal astigmatism. The mean age was 62.95 ± 5.79 years. The Ks, Kf, KA, astigmatic axis, J0 and J45 were 43.76 (43.02, 44.77) D, 42.41 (41.57, 43.26) D, 1.30 (1.09, 1.78) D, 92.00 (86.58, 95.75)°, 0.60 (0.48, 0.86) D and 0.04 (-0.09, 0.14) D, as measured by the OPD-Scan III, as well as 43.69 (42.92, 44.60) D, 42.55 (41.60, 43.28), 1.28 (1.12,1.68) D, 89.01(86.89,94.68)°, 0.62 (0.51,0.70) D, and −0.02 (-0.14,0.09) D, as measured by Pentacam. Table 1 shows the ICCs of each parameter that were 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 the OPD-Scan III; in addition, all of these values were greater than 0.9 with Pentacam.

Table 1
Repeatability of measurements between OPD-Scan III and Pentacam

	OPD-Scan III (n = 70)		Pentacam (n = 70)	
	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
Aix (°)	0.883	0.833 ~ 0.922	0.943	0.917 ~ 0.962
J0 (D)	0.946	0.921 ~ 0.964	0.948	0.923 ~ 0.965
J45 (D)	0.892	0.845 ~ 0.928	0.946	0.9231 ~ 0.964

Agreement

Seven hundred thirty-two eyes (362 right and 370 left eyes) 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 cataracts and corneal astigmatism. The mean age was 63.98 ± 6.22 years.

Table 2 displays each parameter as measured by the two devices. The Wilcoxon test showed that there were significant differences between the two devices in these parameters (all $p \leq 0.01$), except for KA ($p = 0.998$).

Table 2
Differences in measurements between OPD-Scan III and Pentacam (M [Q_1, Q_3])

	OPD-Scan III (n = 732)	Pentacam (n = 732)	Wilcoxon test	
			Z	P
Ks (D)	44.00(42.95,45.06)	44.00(42.90,44.90)	-7.249	≤ 0.001
Kf (D)	42.48(41.56,43.38)	42.40(41.60,43.40)	-9.273	≤ 0.001
KA (D)	1.33(1.06,1.82)	1.33(1.10,1.80)	-0.002	0.998
Aix (°)	92.00(86.00,97.00)	90.20(84.23,95.90)	-5.808	≤ 0.001
J0 (D)	0.63(0.49,0.88)	0.64(0.50,0.85)	-0.192	≤ 0.001
J45 (D)	0.04(-0.09,0.16)	0.01(-0.14,0.14)	-6.406	≤ 0.001

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 and 0.734; all $p < 0.001$) (Fig. 1).

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, respectively; the widths of agreement (WOA) were 0.78 D, 0.62 D, 0.94 D, 23.12°, 0.48 D and 0.62 D, respectively, and the percentages of the out-of 95% limits of agreement (LOA) points were 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).

The IOL power that was calculated according to the parameters 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 that there were significant differences between the two devices (Z=-9.316, $p < 0.001$).The Spearman analysis showed that there were significant differences between the two devices in IOL power (r = 0.994, $p < 0.001$). The 95% LOAs for the IOL power were (-0.32, 0.22) D, the WOA was 0.64 D and the percentage of the out-of 95% LOA points was 4.91% (Fig. 3).

Discussion

The OPD-Scan III is a new, multifunctional device that integrates the corneal topographic map system (based on the placidido disc) and the subjective aberrometer (based on dynamic retinoscopy) [9, 10]. In this study, we compared OPD-Scan III to Pentacam for measuring biological measurements before cataract surgery to assess the accuracy of the OPD-Scan III. We intentionally excluded eyes with lower degrees of astigmatism because such eyes do not usually have surgical corrections of astigmatism. Moreover, the vector parameters J0 and J45 of KA, as well as the degree of intraocular lens, were added, and the analysis was more comprehensive.

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 values in terms of the measurement of Ks, Kf and KA (all ICCs greater than 0.9). However, the repeatability of axis measurements with OPD-Scan III (ICC = 0.883) was slightly lower than that with Pentacam (ICC = 0.943), and its repeatability of vector values (J0 and J45) was lower than that with Pentacam. Guilbert et al.[15] found that the OPD-Scan III had high repeatability for the measurement of keratometry in both normal people and keratoconus patients (ICC greater than 0.9). Asgari et al.[9]also reported that high repeatability of keratometry was obtained in emmetropia and ametropia. These findings were in accordance with our results. However, they did not analyze the repeatability of the axis. According to our results, we concluded that the OPD-Scan III was a reliable device and that a single measurement appeared to be sufficient for measuring keratometry, KA and axis in eyes with moderate-to-high degrees of corneal astigmatism.

Agreement refers to the comparison of the measurement results of two or more devices. At present, most of them are evaluated in combination with differences, correlations and Bland-Altman analyses. In this study, we found that the differences in keratometry between OPD-Scan III and Pentacam were statistically

significant (all $p < 0.001$). We analyzed the reasons for these differences, mainly due to the differences in the measurement principles and measurement points of the two devices (12960 measurement point data points obtained by OPD-Scan III and 25000 measurement point data points generated by Pentacam). Eibschitz-Tsimhoni et al16 reported that a 1.00 D error in keratometry measurement changed the calculated implant intraocular lens (IOLs) power by -0.9D; in our study, the mean difference of the Ks measured between OPD-scan III and Pentacam was (0.05 ± 0.20) D and that of Kf was (0.05 ± 0.17) D. Moreover, the influence of this difference on the degree of IOL was approximately only 0.09 D. We concluded that the difference in keratometry between the two measurements was small and had no clinical significance. Gharieb et al.10 enrolled 660 healthy right eyes, in which the patient ages ranged from 19–48 years. The percentages of the myopes and hyperopes in this sample were 93.63% (618 eyes) and 4.84% (32 eyes), respectively, whereas 10 eyes had near emmetropia. They found that there were no significant differences in keratometry between OPD-scan III and Pentacam; however, the WOA was 1.60 D for K and 1.06 D for Kf, thus negating the accuracy of the use of devices that interchangeably regard keratometry. Asgari et al.9 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. Moreover, 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, which was in accordance with our results.

In this study, we found that the differences in KA between OPD-scan III and Pentacam were not statistically significant ($p = 0.998$). The KA that was measured with the OPD scan III was 0.01 ± 0.24 D higher than that measured with Pentacam. Piñero et al.17 reported that the difference between the IOL Master and Sirius systems in the measurement of corneal astigmatism diopter was 0.10 ± 0.25 D, and he considered that the two could replace each other in the measurement of corneal astigmatism diopter. According to the viewpoint of Piñero[17], OPD-scan III and Pentacam can replace each other for the measurement of corneal astigmatism. However, the Bland-Altman analysis revealed poor agreements in KA, J0 and J45 (with WOA values being 0.94 D, 0.48 D and 0.62 D, respectively) between the two devices in our study. In the Molina-Martín study18, 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 values of corneal astigmatism, J0 and J45 were 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 degrees of corneal astigmatism.

In this study, the differences and correlations in the 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 the axis. The maximum difference in the axis between OPD-Scan III and Pentacam was 26°, the 95% LOA was (-10.20, 12.92) ° and the WOA was 23.12°. These axis errors cannot be considered to be acceptable when planning the alignment of a toric IOL when considering the axis of corneal astigmatism.

According to Viestenz et al.19, 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.20 demonstrated that toric IOL rotations of less than 10° were able to change eye refraction by less than 0.50 D. In the study by Lin HY[21], a 95% LOA of the axis between OPD-Scan III and VERION was (-27.85°, 65.17°). This difference was more widespread than in our results. In addition to the difference in the measurement principle, this discrepancy between the Lin HY study and our study is mainly due to the difference in the measurement range. In the Lin HY study[21], VERION measured corneal data within 2.8 mm, whereas OPD-Scan III and Pentacam measured corneal data within 3.0 mm in our study.

After cataract surgery, the refractive state mainly depends on the precise calculation of the IOL power. To avoid errors, ultrasound pachymetry was used to measure the axial lengths of all of the patients, and the difference in the calculation of the IOL power in this study can only be derived from the measurement of the keratometry. A difference within 1 D in IOL power corresponds to cases wherein patients can generally see well without corrective glasses[22]. In our study, the 95% LOA for IOL power was (-0.32, 0.22) D. Thus, we concluded that OPD-Scan III and Pentacam were in good agreement for the measurements of IOL power, and we further verified that there was no clinical significance in the difference in keratometry between the two devices.

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 aix is poor in eyes with moderate-to-high degrees of corneal astigmatism.

Declarations

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Conflicts of interest/Competing interests The authors report no conflflicts of interest and have no proprietary interest in any of the materials mentioned in

this article.

Availability of data and material The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable

Authors' contributions Study concept and design (Li PP); data collection (Li PP, Tuan YY); analysis and interpretation of data (Li PP, Tuan YY,) manuscript (Li PP); administrative, technical, or material support (Song Y, Yuan Y); supervision (Song Y, Yuan Y).

Additional declarations for articles in life science journals that report the results of studies involving humans and/or animals Not applicable

Ethics approval The study was performed in accordance with the ethical principles of the Declaration of Helsinki and was approved by the ethics committee of the Ideal Ophthalmology Hospital Affiliated of Soochow University.

Consent for participate and publication The authors declare they have participated in this work, and they have reviewed the final version of the work, believe it represents valid work, and approve it for publication.

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Figures

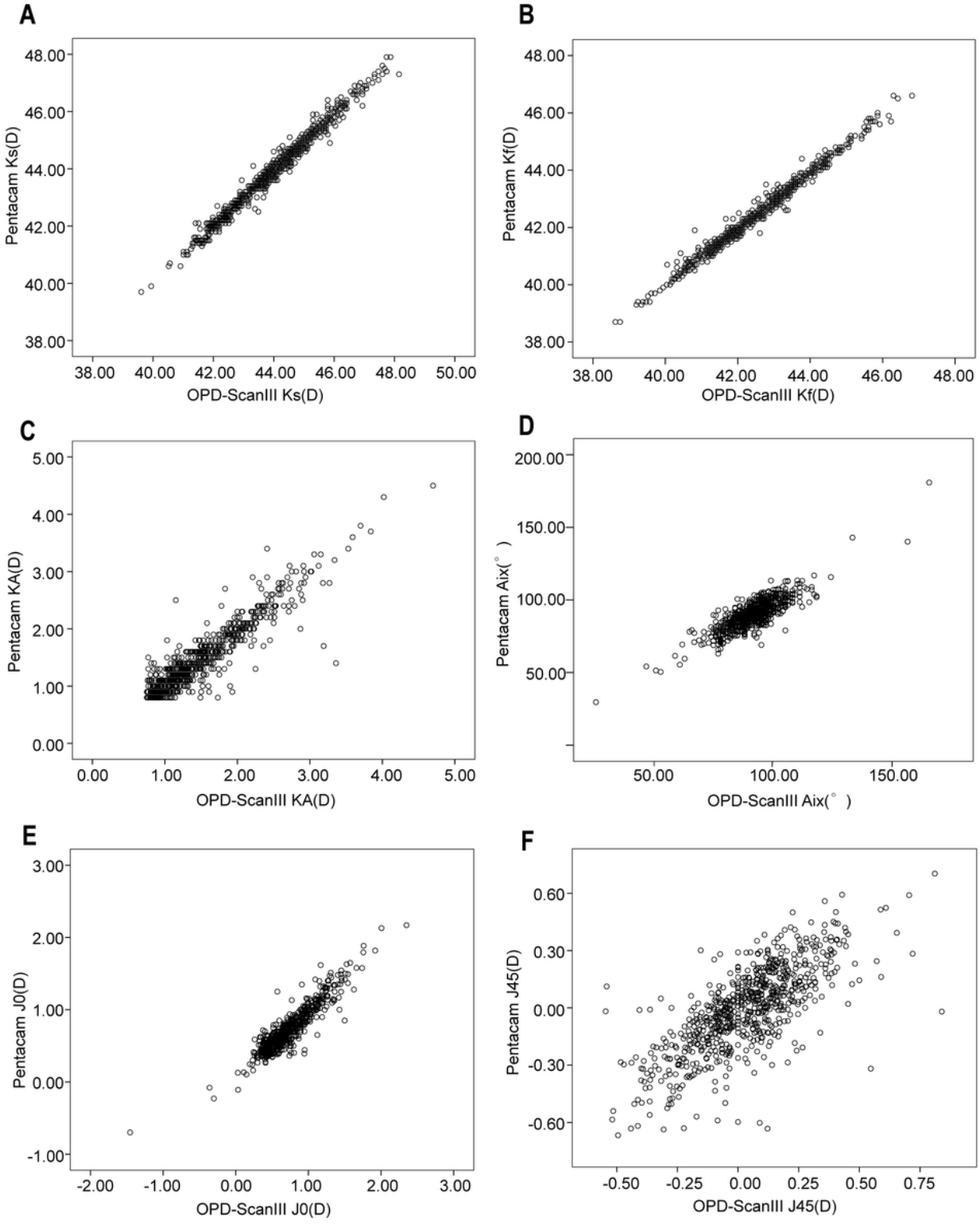

Figure 1

Correlation analysis of parameters that were measured by OPD-Scan III and Pentacam (Spearman correlation analysis, n=732) Ks, Kf, KA, astigmatic axis, J0 and J45 measured by OPD-Scan III and Pentacam were positively correlated (r=0.990, 0.992, 0.920, 0.841, 0.925 and 0.734; all p<0.001). A-F: The correlation analysis of Ks, Kf, KA, astigmatic axis, J0 and J45; Ks Keratometry at the steepest axis; Kf

Keratometry at the flattest axis; KA Keratometric astigmatism; J0 Jackson cross cylinder at 0° or 180°; J45 Jackson cross cylinder at 45°

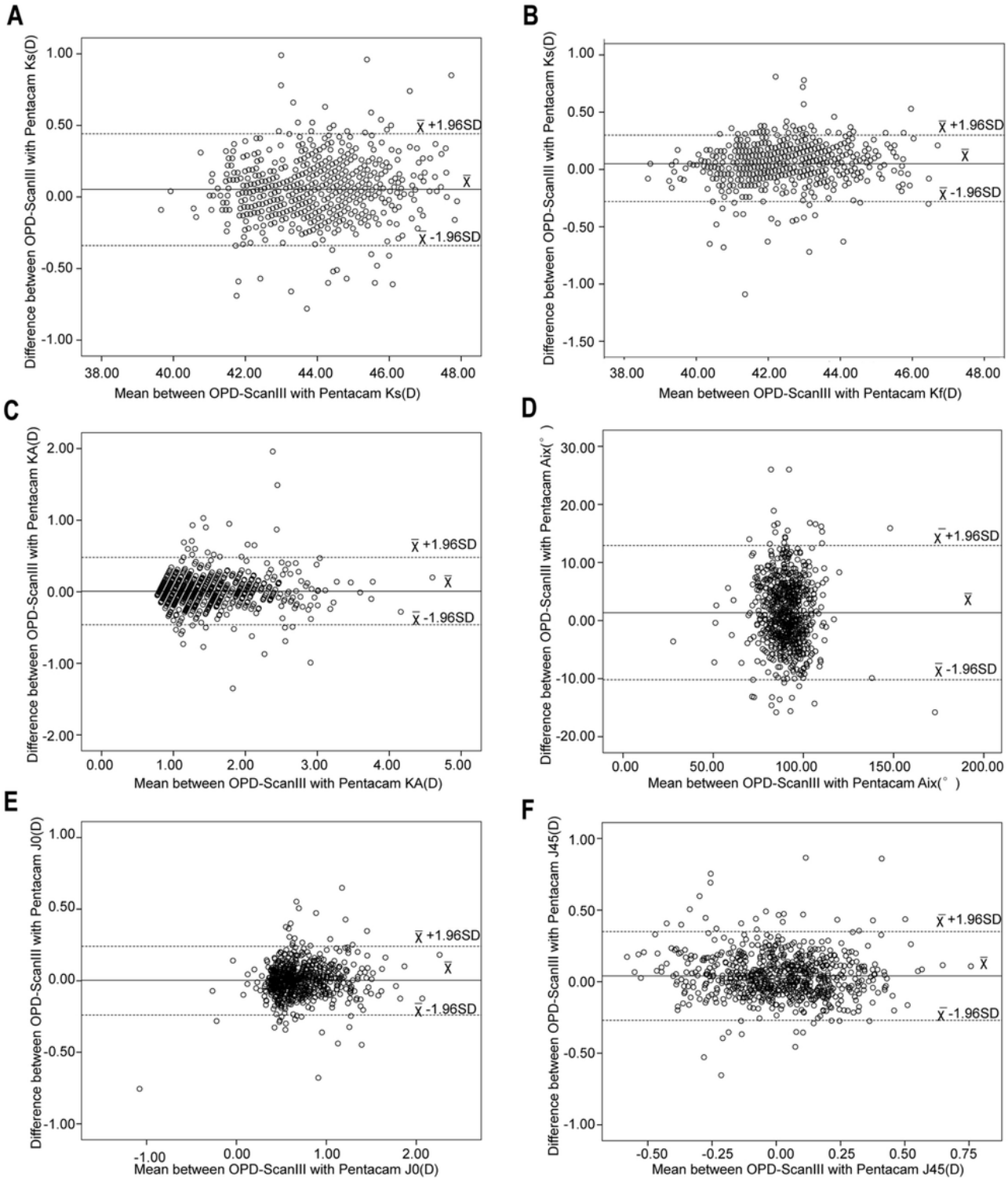

Figure 2

Bland-Altman plots of the parameters that exhibited differences between OPD-Scan III and Pentacam (n=732). The 95% LOAs of 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. A-F: The agreement analysis of Ks, Kf,

KA, astigmatic axis, J0 and J45; Ks Keratometry at the steepest axis; Kf Keratometry at the flattest axis; KA Keratometric astigmatism; J0 Jackson cross cylinder at 0° or 180°; J45 Jackson cross cylinder at 45°

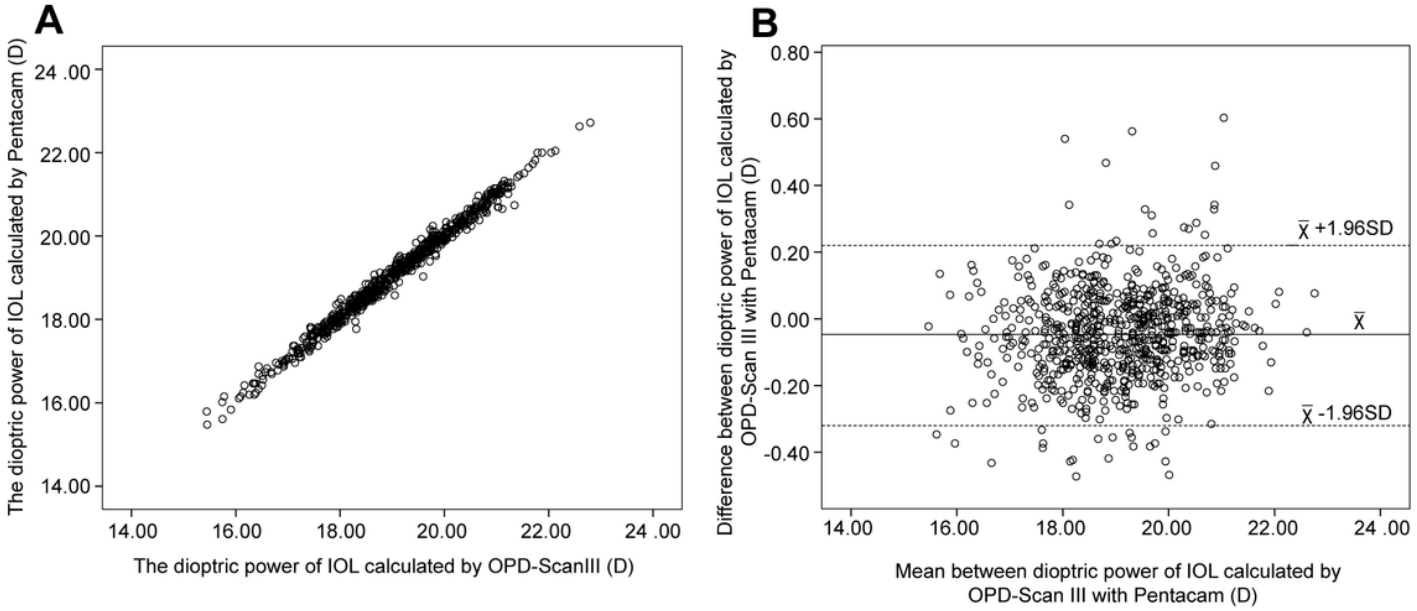

Figure 3

Correlation analysis and Bland-Altman plots of the degree of IOL that were calculated according to the parameters measured via OPD-Scan III and Pentacam (n=732). A: The correlation analysis of the degree of IOL that was calculated according to parameters measured via OPD-Scan III and Pentacam (r=0.994, p<0.001); B: Bland-Altman plots of the degree of IOL that was calculated according to the parameters that were measured via OPD-Scan III and Pentacam, with 95% LOAs for the degree of IOL being (-0.32, 0.22) D.