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Original research

Repeatability of curvature measurements in central and paracentral corneal areas of keratoconus patients using Orbscan and Pentacam

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Abstract

Purpose: To determine the repeatability of curvature measurements in 5 corneal rings (1−5 mm from the corneal center) in keratoconus (KCN) patients using the Orbscan and Pentacam and to compare the values of these devices.
Methods: Forty-eight patients with a definite diagnosis of KCN were included in the study. Patients with any corneal scar or active disease or a history of ocular surgery were excluded from the study. The right eye of the patients was studied three times with the Orbscan and Pentacam. The repeatability of the curvatures of 5 corneal rings (1−5 mm from the corneal center) was evaluated using the Orbscan and Pentacam, and the agreement of their values was analyzed.
Results: The intraclass correlation coefficient (ICC) of three measurements was at least 0.94 ($P < 0.0001$) for the Orbscan and at least 0.88 ($P < 0.0001$) for the Pentacam in all corneal rings. According to the grade of KCN, the Orbscan had a low ICC in the 2 mm ring in grades 2 and 3 (ICC = 0.750 and 0.298, respectively). Repeated measures ANOVA showed no significant difference between the repeated measurements of the Orbscan and Pentacam in all corneal rings. The paired *t*-test showed a significant difference in curvature measurements in all rings except for the 5-mm ring between the two devices ($P < 0.0001$). The Bland-Altman plot showed a week agreement between these two devices in 1−4 mm corneal rings in curvatures more than 45 D.
Conclusions: According to the results of this study, keratometry readings are highly repeatable in Pentacam and Orbscan devices in all corneal rings. Despite the high correlation between curvature measurements of the Orbscan and Pentacam, there was a significant statistical and clinical difference between the results of two devices in all corneal rings (except the 5-mm ring), and the curvature measurements of the Pentacam were steeper than Orbscan measurements.

Keywords: Repeatability; Keratoconus; Keratometric values; Orbscan; Pentacam

Introduction

Keratoconus (KCN) is a bilateral non-inflammatory corneal ectasia.[1] Its prevalence varies from 0.086 to 2.5% in different studies depending on the geographical region, ethnicity, age, and diagnostic criteria.[2,3] The clinical signs and symptoms of this disease depend on its severity.[4] This disease is only diagnosed with corneal topography in early

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stages.[5] Disease progression results in decreased visual acuity not correctable with glasses.[4,5] Most clinical signs that can be detected with devices are seen in later stages of KCN when the chance of controlling disease progression with method like cross-link surgery is markedly decreased.[6] Topography has an important role in early detection of KCN (grade one),[7] increasing the odds of treatment before progression to higher grades. Different devices are available for topography, among which the Orbscan and Pentacam are widely used in hospitals. These devices benefit from different technologies. The Pentacam uses a rotating Scheimpflug camera,[8] and the Orbscan uses the slit-scan technology[9] to assess the corneal surface. Use of different technologies in these devices may result in measurement differences, and since treatment centers use different topographic devices, this disparity in measurements may lead to diagnostic or treatment differences between different centers. For this reason, we assessed the agreement between measurements of these two devices to find out if they can be used interchangeably. On the other hand, the data provided by each device should be consistent in different measurements to use the results in the diagnosis and treatment of KCN. For this reason, we assessed the repeatability of the measurements of these devices to determine their validity. A number of studies have compared the Pentacam and Orbscan in KCN patients. Although these studies have assessed parameters like best-fitting spherical curvature radius, corneal thickness, and corneal height between these two devices,[10,11] no study has compared corneal curvature values. For this reason, considering the importance of curvature values in the diagnosis and treatment of KCN progression and since these parameters were not investigated in previous studies, we compared these values in five corneal rings (1–5 mm of the corneal center).

Methods

In this study, 48 KCN patients were selected among subjects visiting Noor Eye Hospital using convenience sampling. The tenets of the Declaration of Helsinki were observed in all stages of the study. The objectives of the study and the tests used in the study were explained to the participants and informed consent was obtained from the participants. The protocol of the study was approved by the Ethics Committee of the Faculty of Rehabilitation Sciences of Iran University of Medical Sciences.

In this study, KCN was defined as the presence of a scissor reflex on retinoscopy and either a max anterior elevation above 15 μm or a max posterior elevation above 20 μm.[12,13]

Exclusion criteria were any history of ocular surgery or trauma, corneal disease, or infection.

After selecting the patients using inclusion criteria, three Orbscan and three Pentacam images were obtained from the right eye of each participant. Before imaging, the examination method was fully explained to the participants. Soft and hard contact lenses were asked to stop using their lenses 1 and 3 weeks before the study, respectively. After imaging with both devices, the sagittal maps of the devices were used to determine five corneal rings 1–5 mm from the central cornea. In each ring, four points were considered at 45°, 135°, 225°, and 315° and corneal curvature in these points was assessed. The mean curvature of these points was considered the ring curvature.

All images were taken by one experienced optometrist and had an acceptable quality score. Moreover, if the patient had dry eyes, to prevent any imaging errors and artifacts, one drop of preservative-free artificial tears was instilled before imaging.

Error-free Orbscan images were also selected at the discretion of the optometrist. In this study, the severity of KCN was categorized according to maximum keratometry of the Pentacam (maximum keratometry < 50: mild, 50–55: moderate, and >55: severe).[14]

The Pentacam marks high quality images, which was our basis for selecting quality images (OK). As for the Orbscan, the quality of the images was assessed and confirmed based on the optometrist's experience.

SPSS version 16 was used for statistical analysis. Intraclass correlation coefficient (ICC) and repeated measures ANOVA were used to assess the repeatability of the devices. Pearson's correlation coefficient, paired *t*-test, and Bland-Altman plots were used to compare the two devices.

The Ethics Committee of Iran University of Medical Sciences approved the study protocol, which was conducted in accord with the tenets of the Declaration of Helsinki. All participants signed a written informed consent.

Table 1
Mean, standard deviation (SD), and intraclass correlation coefficient (ICC) of curvature readings by Pentacam in 5 corneal rings [curvature unit: diopter (D)].

Pentacam	First measurement	Second measurement	Third measurement	ICC	*P*-value[a]
	Mean ± SD	Mean ± SD	Mean ± SD		
1 mm ring	5.08 ± 49.55	5.30 ± 49.64	5.18 ± 49.60	0.99	0.62
2 mm ring	4.76 ± 49.01	4.93 ± 49.16	4.87 ± 49.08	0.99	0.34
3 mm ring	4.29 ± 48.29	4.45 ± 48.35	4.34 ± 48.36	0.99	0.70
4 mm ring	3.74 ± 47.38	3.69 ± 47.41	3.71 ± 47.42	0.99	0.94
5 mm ring	2.94 ± 46.46	4.60 ± 46.05	3.00 ± 46.49	0.89	0.43

ICC: Intraclass correlation coefficient; SD: Standard deviation.
[a] The *P*-value was calculated by Repeated Measures ANOVA.

Table 2
Mean, standard deviation (SD), and intraclass correlation coefficient (ICC) of curvature readings by Orbscan in 5 corneal rings [curvature unit: diopter (D)].

	First measurement	Second measurement	Third measurement	ICC	*P*-value[a]
	Mean ± SD	Mean ± SD	Mean ± SD		
1 mm ring	3.19 ± 47.59	3.21 ± 47.63	3.26 ± 47.52	0.99	0.30
2 mm ring	3.05 ± 47.40	3.04 ± 47.40	3.12 ± 47.29	0.99	0.27
3 mm ring	2.87 ± 47.00	2.89 ± 47.02	2.91 ± 46.92	0.99	0.26
4 mm ring	2.67 ± 46.52	2.69 ± 46.51	2.73 ± 46.46	0.95	0.56
5 mm ring	2.50 ± 45.97	2.55 ± 46.04	2.63 ± 46.01	0.99	0.67

ICC: Intraclass correlation coefficient; SD: Standard deviation.
[a] The *P*-value was calculated by Repeated Measures ANOVA.

Table 3
Paired *t*-test results and correlation of Orbscan and Pentacam in curvature readings in 5 corneal rings.

Orbscan and Pentacam	1 mm ring	2 mm ring	3 mm ring	4 mm ring	5 mm ring
Mean difference ± SD	−2.01 ± 2.70	−1.72 ± 2.43	−1.34 ± 2.04	−0.90 ± 1.50	−0.32 ± 1.46
P-value[a]	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	0.12
Correlation (Pearson's coefficient)	0.89	0.90	0.91	0.93	0.90
P-value[b]	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$	$P < 0.0001$

SD: Standard deviation.
[a] The *P*-value was calculated by paired *t*-test.
[b] The *P*-value for correlation coefficient.

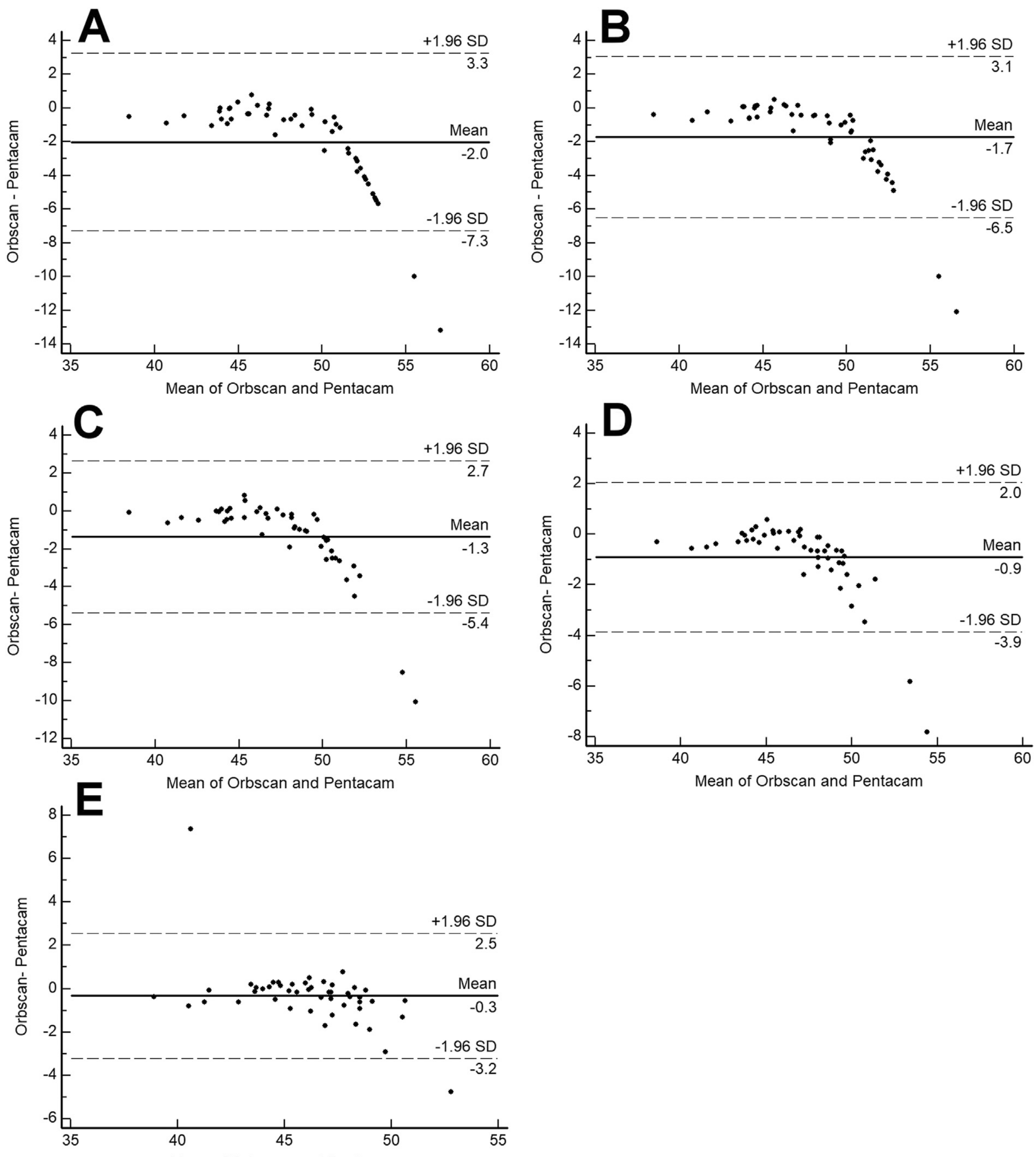

Fig. 1. Bland-Altman plots demonstrating 95% limits of agreement (LOA) between Pentacam and Orbscan in measuring the curvature readings in 5 corneal rings; 1 mm ring (A), 2 mm ring (B), 3 mm ring (C), 4 mm ring (D), 5 mm ring (E).

Table 4
Intraclass correlation coefficient (ICC) for curvature readings in Pentacam and Orbscan by keratoconus grades.

	Grade 1	Grade 2	Grade 3
Pentacam			
1 mm ring	0.989	0.985	0.902
2 mm ring	0.990	0.978	0.890
3 mm ring	0.993	0.983	0.863
4 mm ring	0.993	0.958	0.851
5 mm ring	0.979	0.969	0.866
Orbscan			
1 mm ring	0.972	0.900	0.821
2 mm ring	0.969	0.750	0.298
3 mm ring	0.970	0.828	0.888
4 mm ring	0.973	0.907	0.941
5 mm ring	0.958	0.887	0.929

Results

In this study, the corneal curvature of the right eye of 48 KCN patients including 14 women (29.16%) and 34 men (70.84%) was assessed in 5 corneal rings 1—5 mm from the central cornea using the Orbscan and Pentacam. As for the severity of KCN, 24, 18, and 6 eyes had mild, moderate, and severe KCN, respectively.

The mean Kmax was 46.76 ± 1.77 D, 52.83 ± 1.53 D, and 58.53 ± 3.63 D in mild, moderate, and severe KCN. Tables 1 and 2 show the measurements.

The ICC of three measurements was at least 0.94 ($P < 0.0001$) for the Orbscan and at least 0.88 ($P < 0.0001$) for the Pentacam in all corneal rings. Repeated measures ANOVA showed no significant difference between three measurements of the Orbscan and Pentacam in all corneal rings (Tables 1 and 2).

Table 3 shows the results of Pearson's correlation coefficient and paired *t*-test for comparison of curvature measurements between the Orbscan and Pentacam. Fig. 1 demonstrates the Bland-Altman plots for assessment of agreement between the two devices. Paired *t*-test showed a significant difference in curvature measurements in all rings except for the 5-mm ring between the two devices ($P < 0.0001$) (Table 3) as the Pentacam measurements were steeper than the Orbscan readings. The Pearson's correlation coefficient showed a significant correlation between curvature measurements of the Orbscan and Pentacam in all rings ($r \geq 0.89$, $P < 0.0001$). According to the Bland-Altman plots, the steeper the corneal curvature in rings 1—4, the greater the difference between the two devices, and the closer the corneal curvature to the normal corneal curvature, the smaller the difference.

Table 4 shows curvature repeatability of the two devices at 5 points according to the severity of KCN.

According to the grade of KCN, the Orbscan had a low ICC in the 2 mm ring in grades 2 and 3 (ICC = 0.750 and 0.298, respectively). Repeatability was higher at all points in mild cases compared to severe cases. Table 5 shows agreement between the Orbscan and Pentacam in reading 5 points of the corneal curvature according to the KCN severity.

Discussion

In this study, we assessed the corneal curvature data of the central and paracentral cornea obtained by the Orbscan and Pentacam and evaluated their repeatability. The results of this study can be used for a better diagnosis of KCN using topography. According to the results, the curvature measurements of each device had a high repeatability in all rings. The results of some previous studies showed the repeatability of keratometry readings in the 3-mm ring[15—17]; our study also confirmed the high repeatability of the measurements of each device in the 3-mm ring. It should be noted that previous studies only evaluated the 3-mm ring in normal corneas while we assessed 1—5 mm corneal rings in KCN corneas. Therefore, it can be concluded that keratometric readings of the Orbscan and Pentacam are repeatable in the 3-mm central cornea in normal and keratoconic corneas.

According to the results of the present study, despite a strong correlation between the two devices in all corneal rings, Orbscan and Pentacam readings had a significant difference in all rings (except the 5-mm ring) as Pentacam measurements were steeper than Orbscan readings. Some other studies have also shown a significant difference in curvature readings between these two devices[17—19]; however, in these studies, only the 3 or 4-mm zone of normal corneas were evaluated, and abnormal corneas like keratoconic ones and other parts of the cornea were not assessed. As reported earlier, the curvature reading of the Pentacam in the 3-mm ring was 1.34 D more than the Orbscan reading in the same ring. Some other studies have reported similar findings. For example, Tajbakhsh et al.[18] reported that Pentacam measurements were higher than Orbscan readings, but the difference was much smaller than our study (about 0.27 D). The reason for the difference

Table 5
Mean and standard deviation (SD) of paired differences and 95% limits of agreement (LOA) of curvature reading in 5 corneal rings with Pentacam and Orbscan.

Corneal rings	Grade 1		Grade 2		Grade 3	
	Mean ± SD	95% LOA	Mean ± SD	95% LOA	Mean ± SD	95% LOA
1 mm ring	−0.36 ± 0.51	−1.35 to 0.64	−2.41 ± 1.37	−5.09 to 0.27	−7.46 ± 3.35	−14.03 to −0.88
2 mm ring	−0.26 ± 0.42	−1.09 to 0.56	−2.05 ± 1.03	−4.06 to −0.03	−6.6 ± 3.52	−13.5 to 0.3
3 mm ring	−0.17 ± 0.41	−0.97 to 0.63	−1.53 ± 0.75	−2.99 to −0.06	−5.51 ± 3.02	−11.42 to 0.41
4 mm ring	−0.09 ± 0.28	−0.64 to 0.46	−0.97 ± 0.5	−1.94 to 0.00	−3.97 ± 2.38	−8.64 to 0.7
5 mm ring	0.17 ± 1.59	−2.95 to 3.28	−0.43 ± 0.64	−1.70 to 0.83	−2 ± 1.62	−5.16 to 1.17

LOA: Limits of agreement; SD: Standard deviation.

between these two studies may be that Tajbakhsh et al.[18] studied normal subjects since the results of normal and keratoconic corneas may be different considering high corneal surface irregularities in keratoconic corneas.

In our study, the Pentacam reading in the 4-mm ring was 0.90 more than the Orbscan reading in the same ring, while Shin[19] reported the opposite (lower Pentacam readings compared to the Orbscan). The reason may be that Shin also studied normal corneas.

As mentioned before, although Tajbakhsh et al.[18] reported a significant difference between the two devices, this difference was clinically unimportant while the difference was statistically and clinically important in all corneal rings except the 5-mm ring in our study. The reason may be that we assessed keratoconic corneas while Tajbakhsh et al.[18] studied normal corneas. Moreover, our findings suggest that the difference between the Orbscan and Pentacam is small and clinically unimportant at curvatures below 45 D (near normal corneal curvature) but larger and clinically significant in corneas with curvatures more than 45 D.

In conclusion, Orbscan and Pentacam in keratometry readings had acceptable repeatability, but their readings were different from one another and could not be used interchangeably. Since Pentacam readings are steeper than Orbscan measurements, this difference should be noted in KCN diagnosis and progression monitoring in corneas with more than 45 D curvature. Examiners should use other clinical signs and symptoms of KCN besides curvature, use one device to monitor KCN progression in different examinations, or consider the difference of these devices in determining corneal curvature.

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