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·Clinical Research·

Comparison of corneal measurements in keratoconic eyes using rotating Scheimpflug camera and scanning-slit topography

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Abstract

• AIM: To compare the anterior segment measurements obtained by rotating Scheimpflug camera (Pentacam) and Scanning-slit topography (Orbscan IIz) in keratoconic eyes.

• METHODS: A total of 121 patients, 71 males (58.7%) and 50 females (41.3%) (214 eyes) with the diagnosis of keratoconus (KC) were enrolled in this study. Following diagnosis of KC by slit-lamp biomicroscopic examination, central corneal thickness (CCT), thinnest corneal thickness (TCT), anterior chamber depth (ACD), and pupil diameter (PD) were measured by a single examiner using successive instrumentation by Pentacam and Orbscan.

• RESULTS: There was no significant difference between the two instruments for the measurement of CCT and TCT. In contrast, scanning-slit topography measured ACD (3.46±0.40 mm *vs* 3.38±0.33 mm, *P*=0.019) and PD (4.97±1.26 mm *vs* 4.08±1.19 mm, *P*<0.001) significantly larger than rotating Scheimpflug camera.The two devices made similar measurements for CCT (95% CI: -2.94 to 5.06, *P*=0.602). However, the mean difference for TCT was -6.28 (95% CI: -10.51 to -2.06, *P*=0.004) showing a thinner measurement by Orbscan than by Pentacam. In terms of the ACD, the mean difference was 0.08 mm (95% CI: 0.04 to 0.12, *P*<0.001) with Orbscan giving a slightly larger value than Pentacam. Similarly, Orbscan measurement for PD was longer than Pentacam (95% CI: 0.68 to 1.08, *P*<0.001).

• CONCLUSION: A good agreement was found between Pentacam and Orbscan concerning CCT measurement while comparing scanning-slit topography and rotating Scheimpflug camera there was an underestimation for TCT and overestimation for ACD and PD.

• KEYWORDS: keratoconus; Orbscan; Pentacam; rotating Scheimpflug camera; scanning-slit topography; corneal pachymetry; central corneal thickness; thinnest corneal thickness; anterior chamber depth; pupil diameter
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INTRODUCTION

Corneal thickness (CT) measurement has become the mainstay of diagnosis, the follow-up of patients with a variety of corneal conditions and also an approach to postoperative evaluations of treatment modalities [1,2]. Precise measurement of corneal profiles including central CT (CCT) and thinnest CT (TCT) has gained more importance since the availability of newer treatment modalities [3,4].

With the advent of slit-based eye examination systems, a three-dimensional view of both anterior and posterior corneal surfaces has become possible [5]. Previously, ultrasonic biometry used to be the most common method for anterior chamber depth (ACD) and CT measurements. However, the risk of damage to the corneal epithelium and variable test results were disadvantages of this semi-invasive diagnostic technique [6,7]. Orbscan IIz and Pentacam are two non-contact devices used in measuring the anterior and posterior surfaces of the cornea [8]. They obtain the thickness of the central 8-10 mm of the cornea using translational or rotational imaging and slit-scanning topography [9].

Although with the use of acoustic factor, the agreement of CCT measurements of Orbscan IIz increases with ultrasonic measurements, it has been shown that with the removal of acoustic factor, there is a better agreement with Pentacam for central measurements [10]. On the other hand, it has been indicated that Orbscan IIz may overestimate CCT in virgin corneas and that the quality of images obtained by this device decreases in hazy corneal surfaces [6, 11, 12]. Pentacam (Oculus, Wetzlar, Germany) however, employs a rotating Scheimpflug camera to measure the thickness of the entire cornea by determining the front and back surfaces in the corneal tomography [13].

The agreement between the Orbscan IIz and Pentacam systems were directly compared as to the CCT measurement, mostly in normal [14, 15] and keratoconic eyes [1, 16], yet data for the comparison of other corneal measurements were scarce. The aim of this study was to evaluate the accuracy of corneal measurements of keratoconic eyes by Pentacam (rotating scheimpflug camera) and Orbscan (scanning-slit topography) and to calculate their measurement agreement.

SUBJECTS AND METHODS

Study Design This is a prospective observational study conducted in the largest referral hospital of eye diseases in Iran from January 2013 to January 2014. The institutional Review Board of the hospital has approved the study protocol and informed consent has been obtained from all the subjects and if under the age of 18 from their parents to enter this study.

All the patients underwent a comprehensive ophthalmic examination including assessment of visual acuity, refraction, and slit lamp biomicroscopy which was followed by corneal measurements through the use of two Slit-based eye examination devices.

Subjects One of the inclusion criteria was for the patients to have established keratoconus (KC) and to show at least two signs from the following series on examination by slit-lamp: Fleischer's ring, Vogt striae, scissoring reflex on retinoscopy and corneal thinning with ectasia. The other inclusion criterion included eyes with inferior skewing and maximum simulated keratometry reading more than 48.4 diopters (D) [17]. Exclusion criteria comprised prior ocular surgery or trauma, corneal scar, and any related corneal pathology.

Instrumentation, Ophthalmic Examination and Corneal Measurement All examinations were on the same day between 9 a.m. and 2 p.m. conducted by a single examiner with a 5min to 10min interval between the measurements, all of which were taken by successive instruments. Patients were asked to look at a fixed object while the single measurement was being made.

Scheimpflug imaging was carried using the Pentacam (OCULUS Optikgerate GmbH, Wetzlar, Germany). In this imaging technique, the object, lens, and image planes intersect in a common straight line with the geometry yielding a wide depth of focus. The technique measures the corneal thickness and profiles of the posterior surface of the cornea by capturing slit images from the opposite sides of the illuminated slit and then average the data obtained from the corresponding opposite slit images.

Orbscan IIz (Bausch & Lomb, Rochester, NY, USA) measures three-space points of the anterior and posterior corneal surfaces along with the Placido scanning-slit corneal topography and pachymetry. The light is projected on the cornea and the device catches the beams reflected from a 45-degree angle, one from the left side and the other from the right side. CT and other parameters are calculated through analyzing the differences in the obtained elevation images among the anterior and posterior corneal surfaces, the anterior and posterior lens surfaces, and the anterior iris surface.

Parameters CCT, TCT, ACD, and pupil diameter (PD) were measured by both devices. ACD was defined as the distance between the epithelium of the cornea to the lens.

Statistical Analysis Data were analyzed using Statistical Package for Social Sciences version 19 (SPSS Inc., Chicago, IL, USA) and Stata software version 10.0 (StataCorp, College Station, TX, USA). Corneal parameters were compared between the 2 instruments by Student's t-test. Moreover, interclass correlation coefficients (ICCs) of corneal measurements were calculated so as to compare reproducibility between the two measurement devices. A P value < 0.05 was considered statistically significant.

Agreement between corneal measurements was determined by plotting the difference of measurement values against the mean of each value using the Bland-Altman method [14]. In this regard, the Bland-Altman plot detects the proportional bias in the obtained values which is the relationship between the difference in the measurements and the true value.

Also the 95% limit of agreement (mean difference ±1.96 standard deviation) was calculated for each pair of measurements by the two instruments. Furthermore, linear regression analysis was used to evaluate the linear relationship between the measurements of the two devices. In the regression model, a correction factor was calculated in order to obtain exact values of each measurement by the Scanning slit system.

RESULTS

Two hundred and fourteen eyes of 121 patients with KC, 71 males (58.7%) and 50 females (41.3%), were examined. Mean± SD age of patients was 24.74±6.0y (range: 13y to 41y) and the average K value was 50.3 ±3.5 D(range: 44.4 D to 66.4 D). Table 1 compares the corneal measurements between the two methods where there was no significant difference between the two instruments for the measurement of CCT and TCT. However, scanning-slit topography measured ACD (3.46 ± 0.40 mm *vs* 3.38±0.33 mm, P=0.019) and PD (4.97±1.26 mm *vs* 4.08±1.19 mm, P<0.001) significantly larger than Rotating scheimpflug camera (Table 1). There was a significant linear correlation between scanning slit topography and the rotating Scheimpflug camera when it came to CCT (r=0.837,

Table 1 Comparison of the corneal measurements between the two devices $\bar{x} \pm s$

Parameters (μm)	Rotating Scheimpflug camera	Scanning-slit topography	*P*
CCT	472.6±45.1 (351-584)	473.6±54.3 (325-585)	0.826
TCT	458.4±48.8 (283-582)	452.3±58.5 (259-569)	0.239
ACD	3.38±0.33 (2.04-4.74)	3.46±0.40 (2.50-4.55)	0.019
PD	4.08±1.19 (2.15-7.60)	4.97±1.26 (3.00-8.30)	<0.001

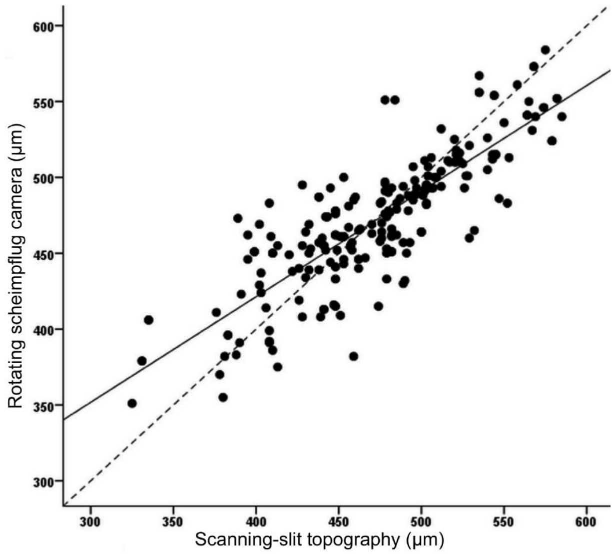

Figure 1 There was a significant linear correlation between CCT measurements (r=0.837, P<0.001). The best-fit line (y=143 +0.7x) is designated by the solid line, and the line of equivalence (y = x) by a dash.

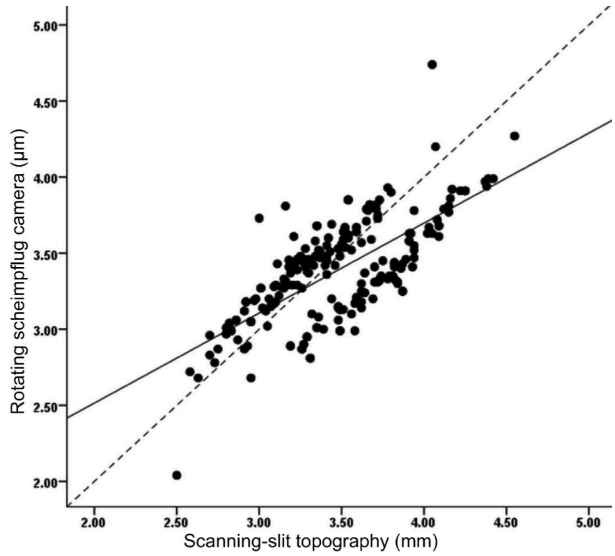

Figure 3 There was a significant linear correlation between anterior chamber depth measurements (r=0.709, P<0.001). The best-fit line (y=1.33+0.59x) is designated by the solid line, and the line of equivalence (y=x) by a dash.

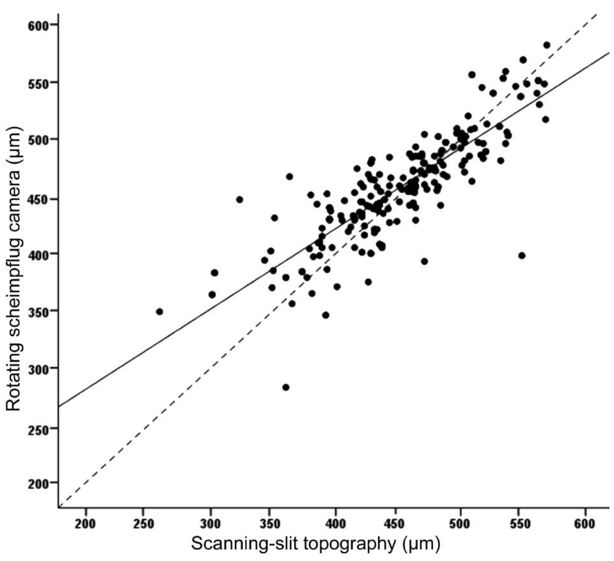

Figure 2 There was a significant linear correlation between TCT measurements (r=0.841, P<0.001). The best-fit line (y=141 +0.7x) is designated by the solid line, and the line of equivalence (y=x) by a dash.

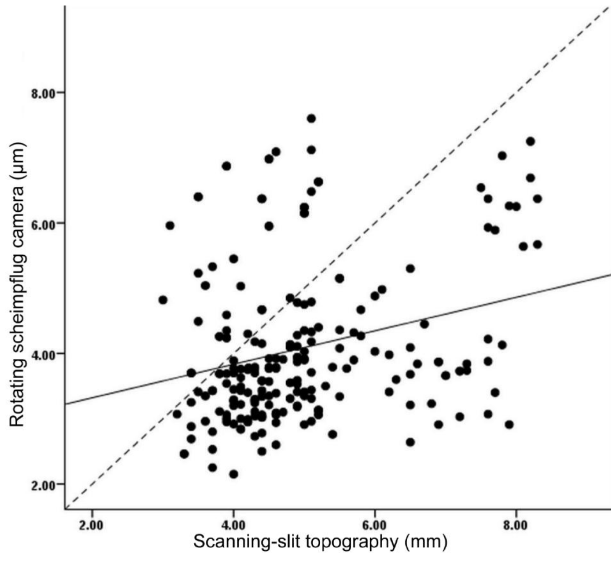

Figure 4 There was a significant linear correlation between pupil diameter measurements (r=0.269, P<0.001). The best-fit line (y=2.81+0.26x) is designated by the solid line, and the line of equivalence (y=x) by the dash line.

P<0.001), TCT (r=0.841, P<0.001), ACD (r=0.709, P<0.001), and PD (r=0.269, P<0.001). Figures 1 to 4 show the linear regression analysis between the two devices demonstrating the best-fit and the equivalence line for each corneal measurement.

The results of the paired comparison between Pentacam and Orbscan are presented in Table 2. These two devices made similar measurements for CCT with an ICC of 0.322 (95% CI: -2.94 to 5.06, P=0.602). However, the mean difference for TCT was -6.28 with an ICC of 0.339 (95% CI: -10.51 to -2.06, P=0.004) showing a thinner measurement was made by Orbscan than by Pentacam. In terms of the ACD, the

Table 2 Comparison of corneal measurements made by rotating Scheimpflug camera and scanning-slit topography (difference: Orbscan-Pentacam)

Parameters (μm)	Mean	SD	Median	Min	Max	95% CI	aP	95% LoA	bICC
CCT	1.06	29.72	4.50	-84.00	77.00	-2.94 to 5.06	0.602	-57.20 to 59.32	0.322
TCT	-6.28	31.32	-8.00	-124.00	151.00	-10.51 to -2.06	0.004	-67.69 to 55.12	0.339
ACD	0.08	0.28	-0.04	-0.73	0.62	0.04 to 0.12	<0.001	-0.48 to 0.64	0.251
PD	0.88	1.48	0.95	-2.97	4.99	0.68 to 1.08	<0.001	-2.02 to 3.80	0.051

CI: Confidence interval; LoA: Limits of agreement; ICC: Interclass correlation coefficient. [a] Paired *t*-test; [b] Pearson correlation.

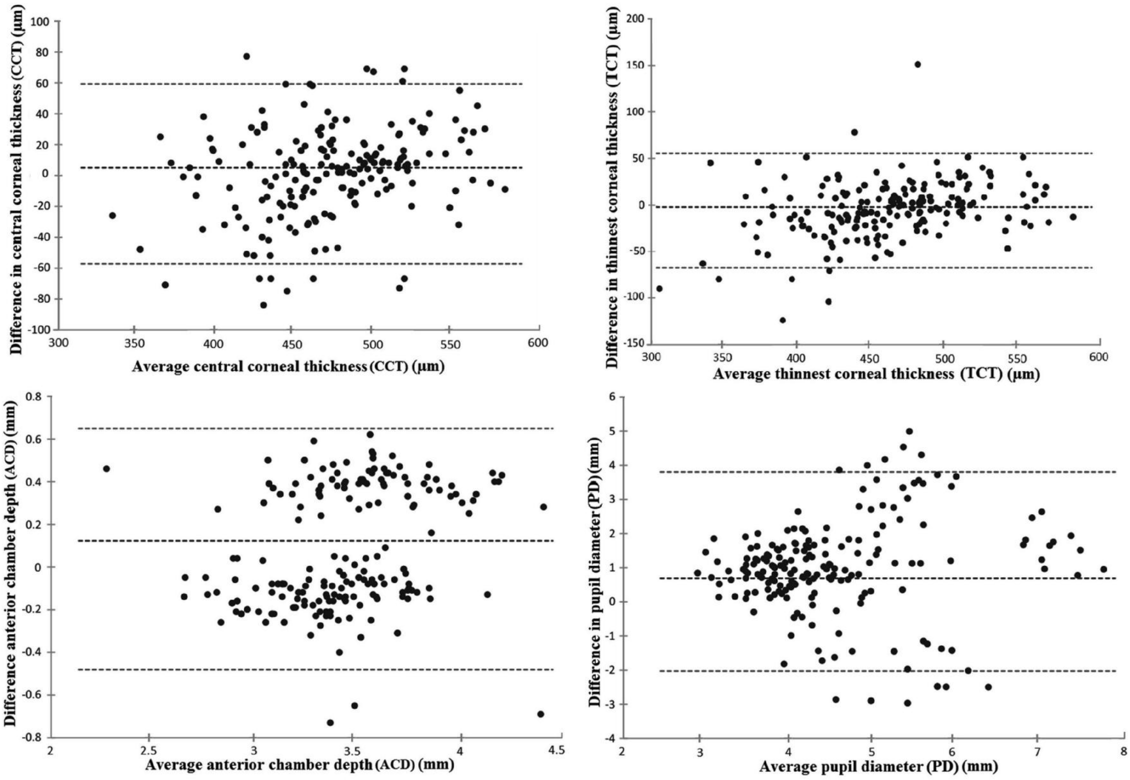

Figure 5 The Bland–Altman plots showing differences in the average measurement of the devices The horizontal line demonstrates the mean difference between the devices. The lines above and below represent the 95% limits of agreement interval.

mean difference was 0.08 mm with an ICC of 0.251 (95% CI: 0.04 to 0.12, P<0.001) with Orbscan rendering a slightly larger value than Pentacam. Similarly, Orbscan measurement of PD was longer than Pentacam with an ICC of 0.051 (95% CI: 0.68 to 1.08, P<0.001). The Bland-Altman plots also visualize the differences in average measurement of CCT, TCT, ACD, and PD by the two devices (Figure 5).

DISCUSSION

KC is a chronic progressive ectatic disorder of the cornea for which the treatment may differ according to the severity of corneal changes [18,19]. For this reason, appropriate use of biometric devices and accurate measurements are indispensible when it comes to selecting KC patients for their ideal treatment option [1, 20]. Moreover, corneal measurements are also beneficial to postoperative follow-up and outcome measurements of KC patients undergoing a variety of surgical and non-surgical modalities [3,4,11,21]. Slit-based pachymetry devices use modern techniques for corneal measurements in several eye conditions [20]. Rotating Scheimpflug camera and scanning-slit topography are the two popular methods making accurate and repeatable measurements of the corneal structure while avoiding further damage to the delicate tissue of the cornea owing to their non-contact optical methods [4, 11, 22].

CT has been proposed to be a crucial parameter for clinical application of which CCT is the most popular one and TCT is commonly used for research and commercial purposes [9, 10]. In this study, CCT, TCT, ACD, and PD were measured in keratoconic eyes. The measurements made by Pentacam and Orbscan were further compared, a research that is rarely conducted in the literature. According to the study findings, there was a good agreement between the two devices in terms of CCT value. However, Orbscan tended to underestimate TCT and overestimate ACD and PD relative to the rotating Scheimpflug camera (Table 2 and Figure 5). Surprisingly enough, there was a linear correlation among all measurements of these two devices. Although the reason for this variation is not clear, some studies comparing the CCT measurements between three different devices, Scheimpflug camera, ultrasonic pachymetry, and scanning-slit topography, have revealed comparable results among the devices, applying the acoustic equivalent correction factor [13] while other studies have reported the highest agreement between Scheimpflug and ultrasonic pachymetry with/without acoustic correction factor [23]. Interestingly, a study regarding the effect of acoustic factor on the measurements of CCT and PCT with Orbscan IIz and Pentacam showed significant differences between the two methods with the removal of the acoustic factor in Orbscan IIz, which led to a lower rendering of mean differences, a decreasing agreement between both the systems and potentially an overestimation of the CCT and PCT by Orbscan II compared with Pentacam [9]. It is noteworthy that all of these measurements have been reported for normal eyes or of only refractory disorders. Our population, however, consisted of keratoconic eyes which may reveal different corneal features compared to the healthy eyes. Similar to our methodology, one study has measured the anterior segment parameters in KC patients [22]. The authors have reported that despite similar measurements of CCT, TCT, and ACD taken by three different non-contact optical devices in KC patients, PD was measured more largely by Orbscan than by Pentacam which is consistent with our study result. Furthermore, another study comparing optical devices against ultrasonic biometry suggested that despite clinical acceptance, ultrasonic biometry and Lenstar should not be used interchangeably for KC patients [20].

Orbscan measures the thickness between the air-tear film interface and the posterior corneal surface[24,25]. Pentacam uses a similar optical method for measuring the corneal thickness and therefore reveals comparable values with Orbscan. One downside of these slit-based instruments is that they require the examinee to fixate for 1 to 2s. On the other hand, all comparable values need to be obtained by the same observer or to be adjusted for inter-observer variability. Since all measurements in this study have been made by a single observer, the agreements between the two devices should be weighed with more reliability. It has been mentioned that Scheimpflug photography leads to higher repeatability and reproducibility compared to the scanning-slit topography and that a moderate agreement exists between these two methods for total corneal power [26]. Moreover, it has been stated that compared with Pentacam, Orbscan renders thinner corneal measurements after corneal operations [21,27]. Additionally, our study findings yielded an overestimation of the corneal measurements other than CCT by Orbscan compared to Pentacam. However, our literature review revealed a large heterogeneity in the application of these optical devices, their clinical setting, and selection of study subjects. Future studies are expected to define standardized criteria for their methodology, patient selection, and device adjustment mode to be able to extrapolate their findings with other studies.

Our study confirmed a good agreement between the Pentacam and Orbscan in terms of CCT measurement. However, Scanning-slit topography tended to underestimate TCT and overestimate ACD and PD compared with the rotating Scheimpflug camera.

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