Comparison of Central Corneal Thickness Measurements by Rotating Scheimpflug Camera, Ultrasonic Pachymetry, and Scanning-Slit Corneal Topography

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Purpose: To compare central corneal thickness measurements and their reproducibility when taken by a rotating Scheimpflug camera, ultrasonic pachymetry, and scanning-slit corneal topography/pachymetry.

Design: Experimental study.

Participants: Seventy-four eyes of 64 subjects without ocular abnormalities other than cataract.

Methods: Corneal thickness measurements were compared among the 3 methods in 54 eyes of 54 subjects. Two sets of measurements were repeated by a single examiner for each pachymetry in another 10 eyes of 5 subjects, and the intraexaminer repeatability was assessed as the absolute difference of the first and second measurements. Two experienced examiners took one measurement for each pachymetry in another 10 eyes of 5 subjects, and the interexaminer reproducibility was assessed as the absolute difference of the 2 measurements of the first and second examiners.

Main Outcome Measures: Central corneal thickness measurements by the 3 methods, absolute difference of the first and second measurements by a single examiner, absolute difference of the 2 measurements by 2 examiners, and relative amount of variation.

Results: The average measurements of central corneal thickness by a rotating Scheimpflug camera, scanning-slit topography, and ultrasonic pachymetry were 538 ± 31.3 μm, 541 ± 40.7 μm, and 545 ± 31.3 μm, respectively. There were no statistically significant differences in the measurement results among the 3 methods (P = 0.569, repeated-measures analysis of variance). There was a significant linear correlation between the rotating Scheimpflug camera and ultrasonic pachymetry (r = 0.908, P < 0.0001), rotating Scheimpflug camera and scanning-slit topography (r = 0.930, P < 0.0001), and ultrasonic pachymetry and scanning-slit topography (r = 0.887, P < 0.0001). Ultrasonic pachymetry had the smallest intraexaminer variability, and scanning-slit topography had the largest intraexaminer variability among the 3 methods. There were similar variations in interexaminer reproducibility among the 3 methods.

Conclusions: Mean corneal thicknesses were comparable among rotating Scheimpflug camera, ultrasonic pachymetry, and scanning-slit topography with the acoustic equivalent correction factor. The measurements of the 3 instruments had significant linear correlations with one another, and all methods had highly satisfactory measurement repeatability. Ophthalmology 2006;113:937–941 © 2006 by the American Academy of Ophthalmology.
reproducibility using Pentacam, ultrasonic pachymetry, and Orbscan scanning-slit corneal topography/pachymetry.

Subjects and Methods

The Miyata Eye Hospital institutional review board approved this study, which followed the tenets of the Declaration of Helsinki. It consisted of 3 parts. In the first, corneal thickness measurements were compared among rotating Scheimpflug camera, ultrasonic pachymetry, and scanning-slit corneal topography in 54 eyes of 54 subjects without ocular abnormalities other than cataract. One eye in each patient was randomly selected, and 34 right eyes and 20 left eyes were included in this study. The mean age of the subjects in each patient was randomly selected, and 34 right eyes and 20 left eyes were included in this study. The mean age of the subjects was 46±20 (mean ± standard deviation [SD]) years (range, 19–83). There were 21 men and 33 women. In the second part, to compare the repeatability of the 3 methods, 2 sets of measurements were repeated by a single examiner for each type of pachymetry in another 10 eyes of 5 subjects with a mean age of 23±1.6 years. The intraexaminer repeatability was assessed as the absolute difference of two values, $|x_1 - x_2|$, where $x_1$ and $x_2$ are the first and second measurements, respectively. The relative amount of variation was evaluated as the percentage of the mean of the 2 measurements, $100 \times \frac{|x_1 - x_2|}{(x_1 + x_2)/2}$.

In the first and second parts, all measurements were performed by a single experienced examiner. In the third part, to compare the interexaminer reproducibility of the 3 methods, 2 experienced examiners took one measurement for each pachymetry in another 10 eyes of 5 subjects with a mean age of 38±6.8 years, and the interexaminer reproducibility was assessed as the absolute difference of two values, $|x_1 - x_2|$, where $x_1$ and $x_2$ are the measurements of the first examiner and second examiner, respectively.

Central corneal thickness measurements with the 3 methods were compared using repeated-measures analysis of variance, Scheffé multiple comparison, and Bland–Altman plots. The correlation coefficient was also calculated. Previous studies reported that the SD of the central corneal measurements is approximately 30 μm. Thus, when the significance level is 0.05, the first part of this study with 54 subjects has 80% power to detect 45 μm of the difference of averages.

The participants gave informed consent. All measurements were taken at the same time of day, between 10 AM and 4 PM. Measurements were made sequentially using a rotating Scheimpflug camera (Pentacam), scanning-slit topography (Orbscan II, Bausch & Lomb, Rochester, NY), and ultrasonic pachymetry (SP-2000, Tomey Corp., Nagoya, Japan). For the rotating Scheimpflug camera, the subjects were asked to look at a fixation target, and 1 measurement was taken on the cornea. Immediately after the Pentacam measurements, corneal thickness was measured by Orbscan II. For Orbscan II, the acoustic equivalent correction factor (0.92) was used to achieve equivalence with the ultrasonic evaluation, as recommended by the manufacturer. After Orbscan measurement, the cornea was anesthetized with topical oxybuprocaine hydrochloride 0.4%, and 5 consecutive measurements were made by ultrasonic pachymetry. The probe of the ultrasonic pachymeter was placed manually on the center of the cornea as precisely as possible. The mean of 5 measurements was calculated.

Results

The average measurements of central corneal thickness by rotating Scheimpflug camera, scanning-slit topography, and ultrasonic pachymetry were 538±31.3 μm, 541±40.7 μm, and 545±31.3 μm, respectively. There were no statistically significant differences in the measurements among the 3 methods ($P = 0.569$, repeated-measures analysis of variance). There was a significant linear correlation between the rotating Scheimpflug camera and ultrasonic pachymetry ($r = 0.908$, $P < 0.0001$) (Fig 1), rotating Scheimpflug camera and scanning-slit topography ($r = 0.930$, $P < 0.0001$) (Fig 2), and ultrasonic pachymetry and scanning-slit...
Bland–Altman plots were created to assess the difference in individual measurement as a function of the mean of 2 measurements for that subject (Figs 4–6). All 3 methods showed good agreement, with the mean of difference centering around zero. In terms of variation of the difference, ultrasonic pachymetry and the rotating Scheimpflug camera displayed the smallest range of variation (Fig 4). Scanning-slit topography tends to underestimate corneal thickness relative to ultrasonic pachymetry and the rotating Scheimpflug camera for thickness of \( \leq 500 \) \( \mu \)m and to overestimate for thickness of \( \geq 550 \) \( \mu \)m (Figs 5, 6).

Ultrasonic pachymetry had the smallest intraexaminer variability, and scanning-slit topography had the largest intraexaminer variability among the 3 methods (Table 1). There was a significant difference in the measurement results among the 3 methods (\( P = 0.039 \), repeated-measures analysis of variance); ultrasonic pachymetry measurements were significantly smaller than those of scanning-slit topography (\( P = 0.040 \), Scheffé multiple comparison).

The 3 methods had similar interexaminer variabilities, and there was no significant difference (\( P = 0.963 \), repeated-measures analysis of variance) between the 3 methods (Table 2).

**Discussion**

Central corneal thickness measurements were comparable among the rotating Scheimpflug camera, scanning-slit topography, and ultrasonic pachymetry. Several studies\(^7\)–\(^9\) reported that Orbscan and ultrasonic pachymetry give similar measurements of corneal thickness when the acoustic equivalent correction factor (0.92) is used for Orbscan, which is consistent with our results. Previous studies that did not use the acoustic equivalent correction factor, however, report that Orbscan measurements are greater than those of ultrasonic pachymetry.\(^4\)–\(^6\) This discrepancy in measurements with Orbscan and ultrasonic pachymetry has been attributed to their distinct methodologies.\(^5\),\(^8\) Orbscan measures the thickness between the air–tear film interface and the posterior corneal surface. In ultrasonic pachymetry, the posterior corneal reflection point might be located between Descemet’s membrane and the anterior chamber.
Moreover, the ultrasonic probe can displace the tear film. Thus, Orbscan measurements are higher than ultrasonic measurements and require the use of the acoustic equivalent correction factor. Because Pentacam is an optical method of corneal thickness measurement similar to that of Orbscan, it might also require correction of the raw data to match its data to those of ultrasonic pachymetry. To our knowledge, however, the manufacturer has not disclosed whether this kind of correction is performed in the machine. In any case, our results demonstrated that corneal thickness measurements with Pentacam are comparable to and have good correlation with those with Orbscan and ultrasonic pachymetry, indicating that Pentacam is as clinically acceptable as Orbscan and ultrasonic pachymetry.

Bland–Altman plots showed that scanning-slit topography tends to underestimate corneal thickness compared with ultrasonic pachymetry and the rotating Scheimpflug camera for thickness of $<500\ \mu m$ and to overestimate for thickness of $>550\ \mu m$. Although the reason for this tendency is unclear, distinct methodologies in each device and use of a correction factor in Orbscan might induce this tendency.

In this study, the intraexaminer repeatability of 2 consecutive measurements was examined, and ultrasonic pachymetry had the smallest variation and scanning-slit topography the largest variation among the 3 methods. In ultrasonic pachymetry, the probe must be placed manually on the corneal center perpendicularly. Thus, the reproducibility of measurements in ultrasonic pachymetry depends on examiner expertise. The examiner in our study was very experienced, which might have contributed to the smallest variation among the 3 methods. On the other hand, although alignment of the measurement is not affected by the examiners in Orbscan and Pentacam, the reproducibility largely depends on the fixation of the examinee in these 2 methods. The differences in the fixation light and the way the measuring light moves might affect the reproducibility of measurements in Orbscan and Pentacam.

In the present study, interexaminer repeatability also was investigated, and there were similar interexaminer repeatabilities in the 3 methods. Miglior et al reported that intraexaminer reproducibility in ultrasonic pachymetry is smaller than interexaminer reproducibility. Similarly, in our study intraexaminer repeatability was smaller than interexaminer repeatability for all 3 methods. In particular, the difference in intraexaminer and interexaminer variations was largest in ultrasonic pachymetry, which is attributable to the fact that repeatability of ultrasonic pachymetry largely depends on the examiner expertise.

Table 1. Variations between 2 Consecutive Sets of Measurements

<table>
<thead>
<tr>
<th>Method</th>
<th>Variation (Mean ± Standard Deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotating Scheimpflug camera</td>
<td>2.8±2.6 0.53±0.46</td>
</tr>
<tr>
<td>Scanning-slit topography</td>
<td>4.5±3.2 0.84±0.60</td>
</tr>
<tr>
<td>Ultrasonic pachymetry</td>
<td>1.6±0.7 0.30±0.13</td>
</tr>
</tbody>
</table>

Each device has inherent advantages and disadvantages in obtaining precise measurements of corneal thickness. Orbscan and Pentacam require the examinee to fixate for 1.0 to 2.0 seconds. On the other hand, whereas the center of the cornea was determined automatically by Orbscan and Pentacam, the probe of the ultrasonic pachymeter was placed manually on the corneal center. Probably due to this disadvantage in the centering scheme, it is a clinical routine that the measurement with the ultrasonic pachymeter is repeated several times on the same eye and the mean of the measurements is considered as the corneal thickness of the eye. Thus, in this study the average of 5 measurements was used for ultrasonic pachymetry, whereas the result of one measurement was used for the other 2 devices. Despite these inherent advantages and disadvantages in obtaining precise measurements in each device, the current study indicates that each method has satisfactory overall repeatability.

In summary, mean corneal thicknesses were comparable for the rotating Scheimpflug camera (Pentacam), ultrasonic pachymetry, and scanning-slit topography (Orbscan) with the acoustic equivalent correction factor. The measurements taken with the 3 instruments had significant linear correlations with one another, and all methods had highly satisfactory measurement repeatability.

Table 2. Variations between 2 Measurements by 2 Examiners

<table>
<thead>
<tr>
<th>Method</th>
<th>Variation (Mean ± Standard Deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotating Scheimpflug camera</td>
<td>5.4±5.4 0.97±0.94</td>
</tr>
<tr>
<td>Scanning-slit topography</td>
<td>5.8±4.4 1.05±0.79</td>
</tr>
<tr>
<td>Ultrasonic pachymetry</td>
<td>6.0±5.2 1.04±0.84</td>
</tr>
</tbody>
</table>

References


