Original article

Comparison of central corneal thickness measured with anterior segment optical coherence tomography versus ultrasonic pachymetry\textsuperscript{a,\textstar,\textdagger}

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\textbf{A R T I C L E  I N F O}

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\textbf{A B S T R A C T}

Purpose: To compare central corneal thickness measured with anterior segment optical coherence tomography (AS-OCT) and ultrasonic pachymetry (UP).
Method: A prospective, observational and cross-sectional study was performed. The central corneal thickness was measured in 112 eyes of 112 consecutive patients with AS-OCT and UP. All examinations were performed by the same examiner. The measurements obtained between the two instruments were compared to assess the level of agreement.
Results: The average corneal thickness value obtained by AS-OCT was \(531.47 \pm 26.23 \mu m\), while that measured by UP was \(532.51 \pm 26.04 \mu m\). The intraclass correlation coefficient was \(0.957 (p < .001)\). The Student’s t-test did not show a statistically significant difference \((1.04 \pm 7.70 \mu m, p = .158)\). Finally, the Bland–Altman analysis showed a high level of agreement between the two methods of measurement.
Conclusions: In the context of normal corneas, there was good agreement between the measurement of central corneal thickness with AS-OCT and UP, although there was a slight overestimation of the measurement using UP \((1.04 \mu m)\).

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\textbf{Comparación del espesor corneal central medido con tomografía de coherencia óptica de segmento anterior y paquimetría ultrasónica}

\textbf{R E S U M E N}

Objetivo: Comparar el espesor corneal central medido con tomografía de coherencia óptica de segmento anterior (OCT-SA) y paquimetría ultrasónica (PU).
Método: Se realiza un estudio prospectivo, observacional y transversal. Se midió el espesor corneal central en 112 ojos de 112 pacientes consecutivos mediante OCT-SA y mediante

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Paquimetría ultrasónica
Glucoma
Biometría ocular

**Introduction**

As corneal thickness measuring is a relevant factor for pondering intra-ocular pressure measures, it has become a crucial test for studying glaucoma patients. Various devices in the current market provide measurements of said parameter and therefore it is necessary to determine the precision and match between them.

The technologies for measuring corneal thickness include ultrasound pachymetry (UP), non-contact mirror microscopy, the Scheimpflug camera and anterior segment optical coherence tomography (AS-OCT).\(^1\)\(^-\)\(^11\) At present, UP is the reference instrument for measuring corneal thickness due to its demonstrated validity and reliability.\(^12\) However, corneal contact could involve contagion between different patients in addition to producing epithelial damage over the ocular surface. It can also become a source of measurement errors due to the pressure exerted over the cornea as well as to inadequate alignment of the terminal, which must be positioned absolutely perpendicular to the corneal surface.

The utilization of a “no contact” corneal thickness measuring instrument would be a magnificent option provided that the reproducibility of the measurements is verified and an adequate correlation with UP is demonstrated.

RTVue-100 (Optovue Inc., Fremont, CA, USA) is a Fourier domain optic coherence tomography that performs 26,000 scans to provide high resolution images with a depth of 5 μm and transversally of 15 μm. It includes an anterior segment module that analyzes corneal thickness in a diameter of 6 mm in 0.32 s, minimizing the possibility of errors related to involuntary patient movements. The objective is to compare this instrument with UP, the standard test at this time.

**Subjects, material and methods**

A prospective, observational and transversal study was carried out, measuring central corneal thickness in 112 eyes of 112 consecutive patients by means of AS-OCT (RTVue-100, software version 4.0) (Fig. 1) and by means of UP (Corneo-Gage Plus\(^\text{TM}\) ultrasonic pachometer, Sonogage Inc., Cleveland, OH, USA). The patients were recruited from the general practices of our hospital from January to April 2011, discarding all those having any ophthalmological disease excepting slight refractive defects. Patient consent was obtained to carry out the tests and the principles established in the Helsinki declaration were followed. Only one eye of each patient was examined, selecting it randomly in each case. All the measures taken with UP and AS-OCT were taken by the same examiner.

The exclusion criteria were as follows: pregnancy, use of contact lenses 72 h prior to the assessment, best corrected visual acuity under 0.8 (Snellen), intraocular pressure over 21 mmHg, endothelial count under 2000 cells/mm\(^2\), pathological changes in the cornea, the conjunctiva or the free palpebral edge, and ophthalmological surgery history which could affect the ocular surface.

The measurements taken with UP were made always after the AS-OCT because anesthetic drops had to be administered and contact had to be made with the corneal surface, which could distort subsequent measurements with AS-OCT. Ninety seconds after administering one drop of oxybuprocaine 0.4%–tetracaine 0.1% (Colircusi Anestésico Doble; Alcon Cusi SA, Barcelona, Spain), five consecutive central corneal thickness measurements were taken, with the final UP value being the mean of these five measurements. AS-OCT was made with patients adequately positioned, requesting them to fix their gaze in a diode placed in the axis of vision. Two additional red diodes placed on the headrest assisted the corneal image takes. The image captures were adjusted centering as much as possible in the corneal vertex and the center of the pupil. The measure was repeated on three occasions, taking a mean value thereof.

**Fig. 1 – Image demonstrating the central corneal thickness measurement taken with anterior segment optic coherence tomography (RTVue-100, software version 4.0, Optovue Inc., Fremont, CA, USA).**
Table 1 – Analysis result of individual differences between ultrasound pachimetry and anterior segment optic coherence tomography by means of the Bland and Altman method.

<table>
<thead>
<tr>
<th>Bland and Altman method</th>
<th>Lower limit 95% confidence interval</th>
<th>Higher limit 95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample size</td>
<td>112</td>
<td></td>
</tr>
<tr>
<td>Arithmetical mean</td>
<td>1.04</td>
<td>−0.41</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>7.70</td>
<td>2.48</td>
</tr>
<tr>
<td>Lower limit</td>
<td>−14.06</td>
<td>−16.54</td>
</tr>
<tr>
<td>Higher limit</td>
<td>16.14</td>
<td>13.66</td>
</tr>
</tbody>
</table>

In the statistical analysis, the quantitative variables were described as mean and standard deviation. In all cases the distribution of the variable was checked against theoretical models, comparing with the variance homogeneity hypothesis. In all of these comparisons, the null hypotheses was rejected with a type I or alpha error under 0.05. The matching analysis between both methods was performed with the intraclass correlation coefficient. The Bland–Altman procedure was carried out to graphically represent the differences between both measurements as well as the matching limits at 95%. In addition, the Levene test for variance equality was carried out to subsequently perform the t Student test. For the statistical analysis, the SPSS statistical application was used (version 12.0; SPSS, Chicago, USA) as well as MEDCALC 11.6.1 (MedCalc Software, Mariakerke, Belgium).

Results

The mean age of analyzed patients was of 60 ± 6 years and the mean spherical equivalent was −2.75 ± 2.5 D (mean ± DE). The mean corneal thickness value obtained with AS-OCT was 531.47 ± 26.23 μm while the values measured with UP were of 532.51 ± 26.04 μm. Accordingly, the difference between both was of −1.04 ± 7.07 μm (p = 0.158), a statistically not significant difference. The intraclass correlation coefficient was 0.957 (p < 0.001) and the Pearson correlation was r = 0.957 (p < 0.01), both being statistically significant.

The Bland–Altman analysis showed an important match between both methods, with a difference of only 1 μm between both techniques, with UP being slightly higher. Up to 95% of differences were found between 16.1 and −14.1 μm. The full analysis is shown in Table 1 and Fig. 2.

Discussion

This paper shows an important match between corneal thickness measurement with UP and AS-OCT. Even so, an underestimation of AS-OCT over UP was evidenced even though this difference was not statistically or clinically significant.

Said results are in contrast to those published by Ishibazawa et al. who described an underestimation of 14 μm of AS-OCT vis-à-vis UP, utilizing the same device as in our paper, i.e. RTVue-100. This difference could be due to several reasons. First, the authors utilized a different ultrasound pachimetry to that used in our case. This factor could produce a distortion in the differences found between both techniques. In fact, in our case the mean corneal thickness observed with RTVue-100 was 531.47 ± 26.23 μm and in the Ishibazawa et al. group it was of 530.47 ± 33 μm. These results are remarkably similar in a control group in both studies. Accordingly, they could be an overestimation of the UP measurements with the pachymeter utilized by said author or an underestimation by our own pachymeter.

Likewise, the paper published by Nam et al. does not observe an underestimation of the corneal thickness measured with AS-OCT over UP and in addition it observes an overestimation thereof having a value of 12.8 μm. This is surprising if we take into account that the AS-OCT device utilized by these authors is the same used in our work even though the UP device is different. This supports the idea of different measures observed between different ultrasound pachymeters. Said study observed an overestimation of AS-OCT over the Scheimpflug camera of about 7 μm, whereas other studies observed an underestimation of up to 22 μm. Accordingly, we must be cautious when analyzing the results observed in these studies.

The variability of measurements made with UP has been emphasized in other papers, including a second study by Nam et al. which found corneal thickness variations after administering topical anesthesia. These factors could have contributed to the variations observed between the analyses. In contrast, other authors have not observed such differences after administering anesthetic eye drops, such as Díaz-Rey et al.

On the other hand it must be taken into account that the group analyzed in our case was more numerous than the group of Ishibazawa et al. (112 versus 30 cases) and this could have caused the variation in results. Similarly, the difference in the match limits which included 95% of observed differences was of 30.2 μm (16.1[−14.1]) in our study and of 31 μm in the Ishibazawa et al. study. This supports the idea of a possible systematic error in the measurements taken with UP in one of both studies.
It is very important to determine the possible matches between both techniques because this can be a crucial factor to assess the ocular hypertension grade being observed. Given the results that have been obtained in this study, the differences are not clinically significant and therefore, even though it cannot be said that both techniques have obtained interchangeable values, it can be stated that the results are comparable and therefore both allow us to make an objective analysis of corneal thickness.

As can be seen in Table 2, other studies exhibited a high degree of variability between both measurement techniques. It is not surprising to observe differences even between authors who used the same AS-OCT device because they can be explained by the same reasons discussed above. Thus, Prospero Ponce et al. observed a difference of ~7.5 μm utilizing the Visante device (Carl Zeiss Meditec, Dublin, CA, USA), while Zhao et al. found ~16.5 μm with the same device. In any case, all the analyzed studies demonstrate a significant match between both instruments. Even though our study has not determined reproducibility and intra- and inter-observer matching with this diagnostic technique, other studies have found a significant reproducibility and matching, including intra-examiner matches between 0.948 and 0.999 and inter-examiner matches between 0.767 and 0.996.

Accordingly, even though it would be convenient to have prospective studies with larger numbers of patients, the data available to date allow us to state that AS-OCT is a valid technique for corneal thickness studies.

Conflict of interest

No conflict of interest has been declared by the authors.

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