Comparison of central corneal thickness by ultrasound pachymetry, optical coherence tomography and specular microscopy

Salil Babbar1, Matthew R Martel2 and James B Martel1*  
1California Northstate University College of Medicine, Elk Grove, CA, USA  
2Martel Eye Medical Group, Rancho Cordova, CA, USA  
3Dignity Health, Carmichael, CA USA

Abstract
The purpose of this study was to compare and correlate the central corneal thickness (CCT) measurement obtained by ultrasound pachymetry, optical coherence tomography (OCT) pachymetry, and specular microscopy to better understand the importance of central corneal thickness in the evaluation and diagnosis of glaucoma. The study compared the central corneal thickness of 8 patients (16 eyes) with each modality.

The mean CCT was 531.47 ± 42.20 µm by ultrasound pachymetry. In comparison, CCT averaged 517.63 ± 43.29 µm by OCT, and 529.88 ± 57.02 µm by specular microscopy. Correlations (r²) of CCT were analyzed, whereby the three modalities were compared to one another. For ultrasound pachymetry vs. OCT pachymetry, r²=0.93 and P<0.0001. For ultrasound pachymetry vs. specular microscopy, r²=0.88 and P<0.0001. For OCT pachymetry vs. specular microscopy, r²=0.98 and P<0.0001.

In conclusion, OCT pachymetry, specular microscopy, and ultrasound pachymetry can be used in clinical settings to measure CCT. Our study showed statistically significant linear correlations among the three modalities of measurement. Accurate measurement of CCT aid ophthalmologists in managing glaucoma. The ultrasound pachymeter showed the least variance among the techniques and therefore, may be the most accurate method of measuring central corneal thickness.

Introduction
Glaucoma is defined as optic disc atrophy with characteristic thinning of the outer rim of the optic nerve head with increased intraocular pressure (IOP), usually greater than 21 mmHg. This disease is characterized by significant retinal ganglion cell death, which can lead to progressive peripheral visual field loss if untreated. By the time patients with glaucoma begin to experience visual loss, extensive optic nerve damage has already occurred. Glaucoma is diagnosed primarily by observing optic nerve cupping and retinal nerve fiber loss, along with increased intraocular pressure. Additionally, the importance of measuring the central corneal thickness (CCT) of both eyes in suspected glaucoma patients has been previously reported [1]. IOP readings obtained by non-contact applanation tonometry can be falsely decreased in individuals with thin corneas and falsely elevated in individuals with thick corneas [2]. Therefore, it is important to accurately assess the CCT in order to obtain correct IOP values to aid in the diagnosis and management of glaucoma.

The most common technique used to measure CCT is ultrasound pachymetry, which involves the direct apposition of an ultrasound probe to the anterior corneal surface [3]. There are a few disadvantages to this method. First, the ultrasound probe must make physical contact with the patient’s cornea. Additionally, the probe must be perpendicular to the corneal surface to obtain an accurate reading. Two additional non-contact techniques for measuring CCT are specular microscopy and optical coherence tomography (OCT). Specular microscopy uses reflections of light from the anterior and posterior corneal surface as a means to distinguish corneal layers and measure central corneal thickness [3]. OCT uses interference patterns of reflected laser light to measure the layers of the cornea [4]. In this study, all three modalities were utilized to obtain CCT measurements for each eye from every participant.

Materials and methods
Subjects
In this study, the CCT of 16 eyes from 8 individuals were measured by each modality. The inclusion criteria were patients with glaucoma. The exclusion criteria were patients with normal, healthy eyes (Table 1).

Techniques and instrumentation
“...”

Correspondence to: James Benjamin Aguayo-Martel, Clinical Professor of Ophthalmology, California Northstate University College of Medicine, 9700 W Taron Drive, Elk Grove, CA 95757, USA, Tel: (916) 686-7300; Fax: (916) 686-7310; E-mail: james.martel@cnsu.edu

Key words: central corneal thickness, optical coherence tomography, ultrasound pachymetry, specular microscopy

Received: March 28, 2017; Accepted: May 09, 2017; Published: May 12, 2017
of the central corneal thickness by ultrasound pachymetry, optical coherence tomography and specular microscopy

Demographics.

Table 1. Demographics.

| Parameter                  | Value          |
|----------------------------|----------------|
| Number of subjects         | 8              |
| Mean/median age (years)    | 57.25/53       |
| Age range                  | 34-85          |
| Sex ratio (male:female)    | 3:5            |

Table 2. Descriptive statistics for the central corneal thickness, as measured by the three different modalities.

|         | US Pachymetry | OCT | Specular Microscopy |
|---------|---------------|-----|---------------------|
| OD      | Mean CCT (µm) | 531.47 | 517.63 | 529.88 |
| SD      |               | 42.20 | 43.29 | 57.02 |
| P-value (paired with US pachymetry) | N/A | 0.55 | 0.95 |
| P-value (OCT paired with Specular Microscopy) | N/A | N/A | 0.66 |
| Mean ± (SD) CCT difference from US pachymetry (µm) | N/A | 13.84 ±1.09 | 1.59 ±(14.82) |
| Mean ± (SD) CCT difference from OCT (µm) | N/A | N/A | 12.25 ±(13.73) |
| Maximum | 593.00 | 588.00 | 634.00 |
| Minimum | 469.33 | 444.00 | 429.00 |
| Median  | 533.50 | 512.00 | 522.50 |

Abbreviations: US pachymetry, ultrasound pachymetry; OCT, optical coherence tomography; CCT, central corneal thickness. 

Results

Measurements by each technique were obtained from all subjects (8 patients and 16 eyes). The mean CCT measured by ultrasound pachymetry from the 8 subjects was 531.47 ± 42.2 µm. In comparison, the mean CCT was 517.63 ± 43.29 µm by OCT pachymetry and 529.88 ± 57.02 µm by specular microscopy (Table 2).

The first Bland-Altman plot shows that the measurements acquired via ultrasound pachymetry were greater than those obtained by OCT for all mean CCT values (Figure 3). Table 2 shows that the mean (± SD) difference was 12.25 ± (13.73) µm.

Among the three methods utilized for measuring CCT, specular microscopy had the best agreement with ultrasound pachymetry, since the mean difference between the two modalities was the smallest (Table 2). Among the three methods, ultrasound pachymetry and OCT had the least agreement, since the mean difference between the two modalities was the largest (Table 2).

The correlation (r²) of CCT measurements obtained via ultrasound pachymetry and OCT was r² =0.93, P<0.0001 (Figure 4). For CCT measurements obtained via ultrasound pachymetry and specular microscopy, r² =0.88, P<0.0001 (Figure 5), and for CCT measurements obtained via OCT and specular microscopy, r² =0.98, P<0.0001 (Figure 6). We found strong correlations between the CCT measurements acquired through these three techniques.

Discussion

Identification of glaucoma in patients may be difficult in certain circumstances. Correctly diagnosing glaucoma requires analysis of various parameters such as visual field, IOP, cup-to-disc ratios, retinal nerve fiber layer thickness, blood flow around the optic nerve, and central corneal thickness.

Measuring CCT is necessary for glaucoma patients since CCT influences IOP readings. Schuster has shown the utility of adjusting IOP with a known CCT [2]. Our study compared different techniques for evaluating CCT. The mean CCT measured by ultrasound pachymetry from the 8 subjects was 531.47 ± 42.2 µm. In comparison, the mean CCT measured by OCT was 517.63 ± 43.29 µm, and the mean CCT measured by specular microscopy was 529.88 ± 57.02 µm.

Khaja et al. [3] and Shetgar et al. [1] calculated the mean CCT values from these modalities using subjects with normal, healthy eyes and subjects with glaucoma, respectively. Shetgar et al. [1] found the mean CCT for glaucoma patients to be 503.91 ± 11.31 µm using ultrasound pachymetry. Ayala et al. [5] looked at glaucoma patients with elevated IOP.
Babbar S (2017) Comparison of central corneal thickness by ultrasound pachymetry, optical coherence tomography and specular microscopy

**Figure 1.** Bland–Altman plot illustrates the difference in central corneal thickness measurements (y-axis) between values obtained by ultrasound pachymetry vs. values obtained by optical coherence tomography (OCT) against the average CCT measurements of the two methods (x-axis). **Abbreviations:** US pachymetry, ultrasound pachymetry; CCT, central corneal thickness.

**Figure 2.** Bland–Altman plot illustrates the difference in central corneal thickness measurements (y-axis) between values obtained by ultrasound pachymetry vs. values obtained by specular microscopy against the average CCT measurements of the two methods (x-axis). **Abbreviations:** US pachymetry, ultrasound pachymetry; CCT, central corneal thickness.
Figure 3. Bland–Altman plot illustrates the difference in central corneal thickness measurements (y-axis) between values obtained by optical coherence tomography (OCT) vs. values obtained by specular microscopy against the average CCT measurements of the two methods (x-axis). Abbreviations: CCT, central corneal thickness.

Figure 4. Scatter plot display of ultrasound pachymetry with OCT measurement of CCT ($r^2=0.93281$). Linear equation: $y=0.9908x - 8.9336$. Abbreviations: US pachymetry, ultrasound pachymetry; CCT, central corneal thickness; OCT, optical coherence tomography.
US Pachymetry CCT vs. Specular Microscopy CCT

\[ y = 0.695x + 163.22 \]
\[ r^2 = 0.8817 \]

Figure 5. Scatter plot display of ultrasound pachymetry with specular microscopy measurement of CCT (\( r^2 = 0.8817 \)). Linear equation: \( y=0.695x+163.22 \). Abbreviations: US pachymetry, ultrasound pachymetry; CCT, central corneal thickness.

OCT CCT vs. Specular Microscopy CCT

\[ y = 0.7517x + 119.31 \]
\[ r^2 = 0.98024 \]

Figure 6. Scatter plot display of OCT with specular microscopy measurement of CCT (\( r^2 = 0.98024 \)). Linear equation: \( y=0.7517x+119.31 \). Abbreviations: OCT, optical coherence tomography; CCT, central corneal thickness.
IOPs and obtained a mean CCT value from OCT of 536 ± 29 μm and a mean CCT value from ultrasound pachymetry of 532 ± 32 μm.

Additionally, there was a strong correlation between each of the three techniques, especially between OCT and specular microscopy, where $r^2=0.98$. Among the various comparisons, the weakest correlation was found between ultrasound pachymetry and specular microscopy ($r^2=0.88$), but this correlation was statistically significant.

A limitation of our study was the small sample size. In the future, it would be best to repeat this experiment with a larger sample size.

Disclosure

The authors declare that they have no competing interests. No financial support was received for this submission.

References

1. Shetgar AC, Mulimani MB (2013) The central corneal thickness in normal tension glaucoma, primary open angle glaucoma, and ocular hypertension. J Clin Diagn Res 7: 1063-1067. [Crossref]
2. Schuster AK, Fischer JE, Vossmerbaeumer U (2016) Central corneal thickness in Spectral-Domain OCT and associations with ocular and systemic parameters. J Ophthalmol 2596956.
3. Khaja WA, Grover S, Kelmenson AT, Ferguson LR, Sambhav K, et al. (2015) Comparison of central corneal thickness: ultrasound pachymetry versus slit-lamp optical coherence tomography, specular microscopy, and Orbscan. Clin Ophthalmol 9: 1065-1070. [Crossref]
4. Aref AA, Budenz DL (2010) Spectral domain optical coherence tomography in the diagnosis and management of glaucoma. Ophthalmic Surg Lasers Imaging 41: S15-S27. [Crossref]
5. Ayala M, Strandis R (2015) Accuracy of optical coherence tomography (OCT) in pachymetry for glaucoma patients. BMC Ophthalmol 15: 124.