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Comparison of Spectral Domain Optical Coherence Tomography and Ultrasonic Pachymetry for Assessment of Central Corneal Thickness

Merkezi Kornea Kalınlığının Değerlendirilmesinde Spektral Domain Optik Koherans Tomografinin ve Ultrasonik Pakimetrinin Karşılaştırılması

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Summary

Objectives: The aim of this study was to determine if there is a difference in central corneal thickness (CCT) measurements obtained by Cirrus spectral domain optical coherence tomography (SD-OCT) and ultrasonic pachymetry in healthy individuals.

Materials and Methods: The study included 50 healthy consecutively selected individuals without ocular or systemic disease. CCT was first measured using OCT, and then using ultrasonic pachymetry.

Results: Mean age of the participants was 31.44 years. Mean CCT measured using SD-OCT was 531.78 µm versus 535.15 µm by ultrasonic pachymetry. Mean CCT measurement obtained by Cirrus SD-OCT showed statistically significant difference by approximately 3.37 µm than the one obtained by ultrasonic pachymetry (t-test, $p<0.05$); however, Bland-Altman analysis proved that there was high concordance between the measurements.

Conclusion: CCT measurements obtained by Cirrus SD-OCT were very similar to those obtained by ultrasonic pachymetry, and as such we think that Cirrus SD-OCT can be used in our present ophthalmology practice to measure OCT. (Turk J Ophthalmol 2014; 44: 259-62)

Key Words: Spectral domain optical coherence tomography, central corneal thickness, ultrasonic pachymetry

Özet

Amaç: Bu çalışmanın amacı Cirrus spektral domain optik koherans tomografi (SD-OKT) ve ultrasonik pakimetri tarafından elde edilen, sağlıklı bireylerdeki santral kornea kalınlık (SKK) ölçümleri arasında bir fark olup olmadığını belirlemektir.

Gereç ve Yöntem: Çalışma oküler veya sistemik hastalığı olmayan 50 sağlıklı ardışık olarak seçilen bireyleri içermektedir. SKK ilk olarak OKT ile daha sonra da ultrasonik pakimetri kullanılarak ölçülmüştür.

Bulgular: Katılımcıların yaş ortalaması 31,44 idi. SD-OKT ile saptanan ortalama SKK 531,78 µm iken ultrasonik pakimetri ile 535,15 µm olarak saptanmıştır. Cirrus SD-OKT ile elde edilen SKK ölçümleri ultrasonik pakimetriden elde edilen ölçümlere göre yaklaşık 3,37 µm istatistiksel olarak anlamlı farklılık göstermiştir (t-test, $p<0,05$), ancak Bland-Altman analizi ölçümler arasında yüksek bir uyum olduğunu kanıtlamıştır.

Sonuç: Cirrus SD-OKT ile elde edilen SKK ölçümleri ultrasonik pakimetriden elde edilen ölçümlere çok benzerdir, Cirrus SD-OKT'nin bugünkü oftalmoloji pratiğinde SKK ölçümlerinde kullanılabilir olduğunu düşünmekteyiz. (Turk J Ophthalmol 2014; 44:259-62)

Anahtar Kelimeler: Spektral domain optik koherans tomografi, santral korneal kalınlık, ultrasonik pakimetri

Introduction

Central corneal thickness (CCT) measurement is diagnostically and therapeutically of great importance. Reliable CCT measurement is necessary for accurate diagnosis of anterior segment abnormalities, such as corneal ectasia, corneal edema, and ocular hypertension. CCT measurement can be obtained using a variety of methods, including ultrasonic pachymetry,[1] scanner slit technology,[2] rotating Scheimpflug camera,[3] interferometry,[4] corneal confocal microscopy, non-contact specular microscopy,[5] and optical coherence tomography (OCT).[6-9]

The current gold standard technique for measuring the CCT is conventional ultrasonic pachymetry because of its

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established reliability and utility;[1] however, this technique requires use of a probe contact, which has several shortcomings because of the contact between the probe and the eye: increase likelihood of patient discomfort and risk of microbial contamination.[1] OCT was originally used to diagnose retinal pathologies; however, since 2008, it has also been used for evaluating the anterior segment. The latest generation of OCT [Fourier domain (FD) and spectral domain (SD)-OCT] facilitates acquisition of more data and 3-dimensional image analysis in less time with higher axial resolution.[10] The Cirrus SD-OCT (Carl Zeiss Meditec, Inc., Dublin, CA) is one of the latest-generation devices based on SD-OCT technology; it has a scan rate of 27.000 A-scans/s with an axial image resolution of 5 µm.[11] The Cirrus SD-OCT can image structures in the anterior segment by changing the focus of the OCT beam.[12]

The reliability of the measurements obtained by any ophthalmic instrument should be determined to avoid misdiagnosis based on the readings. The re-test variability of Cirrus SD-OCT for posterior segment diseases has been previously reported.[13] The aim of the present prospective observational study was to determine if there is a difference in CCT measurements obtained by the Cirrus SD-OCT and ultrasonic pachymetry in healthy individuals. In this current study, intra-examiner reproducibility in CCT measurements by these two devices was also evaluated.

Materials and Methods

The study was performed in accordance with the Declaration of Helsinki. Informed consent was obtained from all the participants after they were provided with information about the nature and possible consequences of the study. The study protocol was approved by the Erciyes University Ethics Committee (acceptance no. 2012/732). The study included 50 consecutive healthy individuals without any ocular or systemic disease who underwent full ophthalmic examination at Niğde State Hospital, Clinic of Ophthalmology. Individuals with a history of corneal surgery and those with evidence of active infection in the conjunctiva and cornea or a localized corneal scar anywhere in the cornea were excluded from the study. All eyes included in the study were subjected to comprehensive refractive examination and anterior and posterior segment examination; all cases of posterior segment anomalies were also excluded.

All participants underwent CCT measurement by Cirrus SD-OCT (4000 model) first due to the corneal epithelial defects that can occur during ultrasonic pachymetry CCT measurement. Corneal images were obtained using the Cirrus SD-OCT device's anterior segment 5-line raster mode and adjustment of the OCT beam focus. This scan method uses 5 horizontal scan lines, each 3 mm long, with a 250-µm distance between each line. Each scan line is composed of a scan of 4096 A-scans/s. This scan mode has a higher resolution than the 512x128 cube scan mode (1024 A-scans/s); therefore, the upper and lower boundaries of the cornea are imaged with greater clarity, and the digital caliper can be placed more accurately between the cornea's inner and outer boundaries. After sitting in front of the device, each participant was asked to focus on the fixation goal in the device, and then, CCT anterior segment 5-line raster images were obtained for both eyes. Among the CCT anterior segment 5-line raster images, the image closest to the center was enlarged. Then, via manual use of the digital caliper, the distance between the inner and outer borders of the cornea was measured (Figure 1). Measurements were obtained during the day between 10.00 and 14.00, in consideration of the diurnal variation in corneal thickness.

Immediately following CCT measurement by Cirrus SD-OCT, 1 drop of topical 0.5% proparacaine was placed

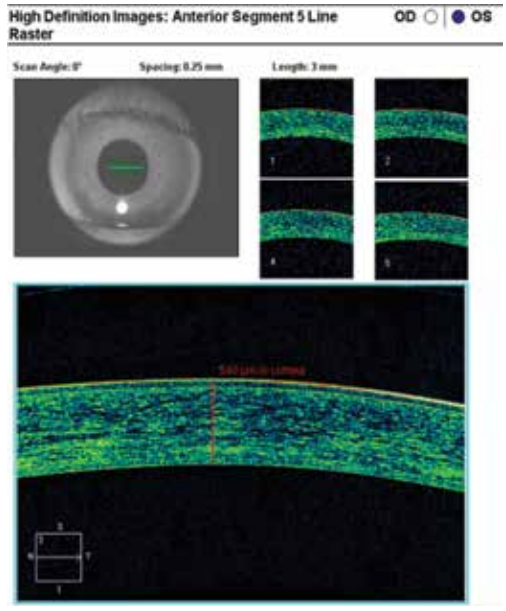

Figure 1. CCT measurement via the Cirrus SD-OCT

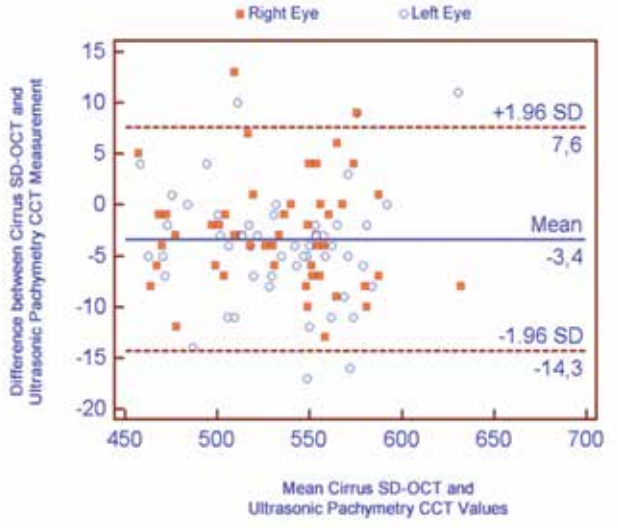

Figure 2. Bland-Altman plot of the differences in mean Cirrus SD-OCT and ultrasonic pachymetry CCT values

in the same eye. Then, 5 measurements of the cornea center were obtained using an PacScan 300P (Sonomed Escalon, Pennsylvania, the USA) ultrasonic pachymetry device while the participants were looking at a fixed external fixation point; CCT was calculated as the mean of the 5 measurements.

The SD-OCT measurements and CCT calculations were made by the same physician who was masked to the ultrasonic pachymetry CCT measurements to avoid bias. All ultrasonic pachymetry examinations were made by the same ophthalmic technician to avoid inter-examiner variability for ultrasonic pachymetry measurements.

Statistical Analysis

Datas were analyzed using SPSS v.16.0 for Windows (SPSS Inc., Chicago, IL). The t-test was used to compare quantitative data with normal distribution, as were descriptive statistical methods (mean ± SD). Correlations between the 2 CCT measurement methods were evaluated with Bland-Altman plot analysis using Med Calc v.11.6 (MedCalc Software, Mariakerke, Belgium). Ninety-five percent limits of agreement (Loa) were defined as the mean ± 1.96 SD. Intra-examiner reproducibility was based on the analysis of the three independent consecutive measurements. Reproducibility was evaluated by means of intraclass correlation coefficient (ICC).[14] A 1.0 value represents perfect agreement, while 0.81 to 0.99 values represent almost perfect agreement.[14] Results were evaluated at the 95% CI and $p<0.05$ level of statistical significance.

Results

The study included 50 participants (16 female and 34 male) with a mean age of 31.44±8.28 years. Mean CCT measured by Cirrus SD-OCT was 531.78±38.395 µm versus 535.15±38.528 µm by ultrasonic pachymetry. The difference between the 2 mean measurements was 3.37 µm, which is significant (t-test $p<0.05$).

Bland-Altman plots showed the consistency of the measured values between the 2 methods (Figure 2). The upper limit of the Loa was 7.6, while the lower limit was -14.3. The width of Loa was 21.9 µm which showed good agreement between the devices for both eyes.

Both devices showed good intra-examiner reproducibility (ICC: 0.984 for ultrasonic pachymetry; ICC: 0.988 for SD-OCT).

Discussion

CCT measurement is useful in a wide range of diagnostic applications. CCT measurements are important in the diagnosis of glaucoma.[15] The Ocular Hypertension Treatment Study (OHTS) by Gordon et al.[16] reported that each 40-µm decrease in CCT increases the risk of open-angle glaucoma 1.7-fold. Kim et al.[17] reported that visual field progression in glaucoma patients with thin corneas (mean: 529±36 µm) is greater than in those with thick corneas (mean: 547±35 µm). A meta-analysis reported that a 10% decrease in CCT leads to a 3.4-mmHg increase in IOP.[18]

CCT measurement is critical for selecting the most appropriate refractive surgery technique. Preoperative CCT <500 µm is a contraindication for LASIK surgery.[19] In addition, CCT measurements ≤400 µm are contraindicative for excimer laser ablation.[20,21]

Currently, ultrasonic pachymetry is considered the gold standard for CCT measurement, in terms of accuracy;[1,22,23] however, contact between the eye and pachymeter and use of topical anesthetic eye drops have a negative effect on patient comfort. In addition, microbial contamination by the device is possible between individuals. Moreover, changes can be observed in the surface corneal epithelium as a result of ultrasonic pachymetry probe contact with the eye, and associated discomfort will become more apparent as the effect of topical anesthesia dissipates. In addition, ultrasonic pachymetry has several possible sources of error in terms of measuring CCT. Its accuracy depends on the cornea, and the perpendicularity of the probe with respect to cornea is often difficult to ascertain. If the probe is placed slightly off the center at an oblique incidence, the corneal thickness may be overestimated.[24] In the current study, mean CCT value with ultrasonic pachymetry was 3.37 µm higher than the one taken with SD-OCT. Such these higher results taken with ultrasonic pachymetry could be also caused because of the instillation of topical anesthesia that produces epithelial edema during measuring the CCT.[25] Due to these characteristics of ultrasonic pachymetry, various non-contact methods of CCT measurement have attracted the attention for more widespread use. As such, a variety of SD-OCT devices have become available.

Numerous studies have evaluated the accuracy and reliability of OCT for CCT measurement,[1,2,6,7] some of which have reported differences in CCT measured by SD-OCT and ultrasound pachymetry. Ishibazawa et al.[1] used an RTVue OCT device and ultrasonic pachymetry for CCT measurement in healthy corneas; mean CCT was 14 µm less according to OCT and the difference was significant. Rao et al.[26] reported that mean CCT measured by OCT was 10 µm less than that measured by pachymetry. In contrast, Chen et al.[27] reported that CCT measurements obtained by an RTVue device were 5.63 µm higher than those obtained using ultrasonic pachymetry. Nam et al.[28] reported that higher CCT values were obtained by the RTVue than by ultrasonic pachymetry. Kalayci et al.[29] also reported 1.11 µm higher CCT values with SD-OCT devices than by ultrasonic pachymetry. Vollmer et al.[30] found that CCT measurements made by SD-OCT were consistently thinner by approximately 12 µm than the measurements made by ultrasonic pachymetry. Correa-Perez et al.[31] reported that mean CCT measured by SD-OCT was 3.7 µm less than the one measured by ultrasonic pachymetry.

In the present study, mean CCT measured with the Cirrus SD-OCT was 3.37 µm less than that measured with ultrasonic pachymetry (t-test, $p<0.05$), which might be attributable to manual adjustment of the Cirrus SD-OCT device's scale. The slightest movement of the Cirrus SD-OCT measurement bar has a sensitivity of 4 µm, which precludes measurements <4 µm. Decreasing the level of sensitivity of the scale to 1 µm may result in exactly the same CCT measurements measured by ultrasonic pachymetry. User-dependent CCT differences can be prevented by potential

software updates, which may facilitate automated CCT measurement, as in retinal inspection. Despite the significant difference in CCT measurements obtain with the 2 methods in the present study, we think that the difference was not clinically meaningful, as shown by the high concordance rate based on Bland-Altman analysis.

In conclusion, CCT measurements obtained by the Cirrus SD-OCT and ultrasonic pachymetry were very similar and concordant, indicating that the Cirrus SD-OCT can be used regularly in ophthalmology practice.

References

1. Ishibazawa A, Igarashi S, Hanada K, et al. Central corneal thickness measurements with Fourier-domain optical coherence tomography versus ultrasonic pachymetry and rotating Scheimpflug camera. Cornea. 2011;30:615-9.
2. Yazici AT, Bozkurt E, Alagoz C, et al. Central corneal thickness, anterior chamber depth, and pupil diameter measurements using Visante OCT, Orbscan, and Pentacam. J Refract Surg. 2010;26:127-33.
3. Sedaghat MR, Daneshvar R, Kargozar A, Derakhshan A, Daraei M. Comparison of central corneal thickness measurement using ultrasonic pachymetry, rotating Scheimpflug camera, and scanning-slit topography. Am J Ophthalmol. 2010;150:780-9.
4. Hitzenberger CK, Baumgartner A, Drexler W, Fercher AF. Interferometric measurement of corneal thickness with micrometer precision. Am J Ophthalmol. 1994;118:468-76.
5. Brugin E, Ghirlando A, Gambato C, Midena E. Central corneal thickness: z-ring corneal confocal microscopy versus ultrasound pachymetry. Cornea. 2007;26:303-7.
6. Kim HY, Budenz DL, Lee PS, Feuer WJ, Barton K. Comparison of central corneal thickness using anterior segment optical coherence tomography vs ultrasound pachymetry. Am J Ophthalmol. 2008; 145:228-32.
7. Li H, Leung CK, Wong L, et al. Comparative study of central corneal thickness measurement with slit-lamp optical coherence tomography and Visante optical coherence tomography. Ophthalmology. 2008;115:796-801.
8. Prakash G, Agarwal A, Jacob S, Kumar DA, Agarwal A, Banerjee R. Comparison of Fourier-domain and time-domain optical coherence tomography for assessment of corneal thickness and intersession repeatability. Am J Ophthalmol. 2009;148:282-90.
9. Huang JY, Pekmezci M, Yaplee S, Lin S. Intra-examiner repeatability and agreement of corneal pachymetry map measurement by time-domain and Fourier-domain optical coherence tomography. Graefes Arch Clin Exp Ophthalmol. 2010;248:1647-56.
10. Srinivasan VJ, Wojtkowski M, Witkin AJ, et al. High-definition and 3-dimensional imaging of macular pathologies with highspeed ultrahigh-resolution optical coherence tomography. Ophthalmology. 2006;113:2054. e1-14.
11. Leung CK, Cheung CY, Weinreb RN, et al. Retinal nerve fiber layer imaging with spectral-domain optical coherence tomography: a variability and diagnostic performance study. Ophthalmology. 2009;116:1257-63.
12. Cirrus HD-OCT 4000 User Manual Addendum. Anterior Segment Imaging. Dublin, CA: Carl Zeiss Meditec, Inc., Available at: http://www.thetechnologysource.biz/files/Cirrus_4.0_Anterior_Segment_Addendum.pdf. Accessed May 21, 2013.
13. Parravano M, Oddone F, Boccassini B, et al. Reproducibility of macular thickness measurements using Cirrus SD-OCT in neovascular age-related macular degeneration. Invest Ophthalmol Vis Sci. 2010;51:4788-91.
14. The equivalence of weighted kappa and the intraclass correlation coefficient as measures of reliability. Educ and Psychol Meas. 1973;33:613-9.
15. Morad Y, Sharon E, Hefetz L, Nemet P. Corneal thickness and curvature in normal-tension glaucoma. Am J Ophthalmol. 1998;125:164-8.
16. Gordon MO, Beiser JA, Brandt JD, et al. The Ocular Hypertension Treatment Study: baseline factors that predict the onset of primary open-angle glaucoma. Arch Ophthalmol. 2002;120:714-20.
17. Kim JW, Chen PP. Central corneal pachymetry and visual field progression in patients with open-angle glaucoma. Ophthalmology. 2004;111:2126-32.
18. Doughty MJ, Zaman ML. Human corneal thickness and its impact on intraocular pressure measures: a review and meta-analysis approach. Surv Ophthalmol. 2000;44:367-408.
19. Randleman JB. Post-laser in situ keratomileusis ectasia: current understanding and future directions. Curr Opin Ophthalmol.2006;17:406-12.
20. Taneri S, Zieske JD, Azar DT. Evolution, techniques, clinical outcomes, and pathophysiology of LASEK: Review of the literature. Surv Ophthalmol. 2004;49:576-602.
21. Condon PI, O'Keefe M, Binder PS. Long-term results of laser in situ keratomileusis for high myopia: risk for ectasia. J Cataract Refract Surg. 2007;33:583-90.
22. Yaycioglu RA, Pelit A, Toygar O, Akova YA. Comparison of two different methods in central corneal thickness measurement. T. Oft. Gaz. 2006;36:306-10.
23. Ayata A, Ates ZC, Unal M, Ersanli D. Comparison of central corneal thickness with two different ultrasonic pachymeter in normal population. Glo-Kat. 2009;4:27-9.
24. Chen S, Huang J, Wen D, Chen W, Huang D, Wang Q. Measurement of central corneal thickness by high-resolution Scheimpflug imaging, Fourier-domain optical coherence tomography and ultrasound pachymetry. Acta Ophthalmol. 2012;90:449-55.
25. Nam SM, Lee HK, Kim EK, Seo KY. Comparison of corneal thickness after the instillation of topical anesthetics: proparacaine versus oxybuprocaine. Cornea. 2006;25:51-4.
26. Rao HL, Kumar AU, Kumar A, et al. Evaluation of central corneal thickness measurement with RTVue spectral domain optical coherence tomography in normal subjects. Cornea. 2011;30:121-6.
27. Chen S, Huang J, Wen D, Chen W, Huang D, Wang D. Measurement of central corneal thickness by high-resolution Scheimpflug imaging, Fourier-domain optical coherence tomography and ultrasound pachymetry. Acta Ophthalmol. 2012; 90:449-55.
28. Nam SM, Im CY, Lee HK, Kim EK, Kim TI, Seo KY. Accuracy of RTVue optical coherence tomography, Pentacam, and ultrasonic pachymetry for the measurement of central corneal thickness. Ophthalmology. 2010;117:2096-103.
29. Kalayci M, Gunes A, Ozerturk Y. Comparison of central corneal thickness measurements by ultrasonic pachymetry, optical coherence tomography and Scheimpflug camera combined with placido-disk corneal topography. Yeni Tip Dergisi. 2014;31:37-9.
30. Vollmer L, Sowka J, Pizzimenti J, Yu X. Central corneal thickness measurements obtained with anterior segment spectral domain optical coherence tomography compared to ultrasound pachymetry in healthy subjects. Optometry. 2012;83:167-72.
31. Correa-Perez ME, Lopez-Miguel A, Miranda-Anta S, Iglesias-Cortinas D, Alio JL, Maldonado MJ. Precision of high definition spectral-domain optical coherence tomography for measuring central corneal thickness. Invest. Ophthalmol. Vis. Sci. 2012;53:1752-7.