Comparison of Central Corneal Thickness Measurements by Ultrasound Pachymeter, Optical Coherence Tomography and Corneal Topography

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Objective: *To compare central corneal thickness (CCT) measured by standard ultrasound pachymeter with optical coherence tomography (OCT) and corneal topography.*

Material and Method*: A cross-sectional study of central corneal thickness measurement by ultrasound pachymeter, OCT and corneal topography in 30 eyes of 30 healthy volunteers was done by a single examiner at Thammasat University Hospital between October 2010 and January 2011. The results were compared using ANOVA for repeated measures and Pearson correlation.*

Results*: Mean central corneal thickness by ultrasound pachymeter, OCT and corneal topography were 552.1 $\pm$ 33.6 μm, 554.5 $\pm$ 33.0 μm and 552.8 $\pm$ 39.0 μm respectively. There were no statistically significant differences in the measurement results among the three modalities (p = 0.718). There was a significant linear correlation between OCT and ultrasound pachymeter (Pearson correlation = 0.985, p < 0.001), corneal topography and ultrasound pachymeter (Pearson correlation = 0.965, p < 0.001) and corneal topography and OCT (Pearson correlation = 0.965, p < 0.001).*

Conclusion*: Mean central corneal thickness among ultrasonic pachymeter, OCT and corneal topography were comparable and had significant linear correlations. In clinical practice, these three modalities could be interchangeable.*

Keywords*: Central corneal thickness, Ultrasound pachymeter, Optical coherence tomography, Corneal topography*

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Central corneal thickness measurement is useful for diagnosis of eye diseases and systemic diseases[1,2], evaluation before refractive surgeries[2-7] and evaluation risks of glaucoma progression in patients with ocular hypertension[8].

There are many methods for measurement of central corneal thickness. Ultrasound pachymeter is usually the gold standard[6,9,10]. The advantages are: easily used[6,7] and widespread but it requires perpendicularly contact cornea which may cause errors[4]. Besides, it does require a topical anesthetic agent which may cause eye irritation and drug allergy.

There are other methods that use non-contact technique, allowing for short measurement time and considered more convenient. Example: optical coherence tomography (OCT) and corneal topography.

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The objective of the present study was to compare central corneal thickness measurement by: ultrasound pachymeter, OCT and corneal topography; and evaluate the possibility of using OCT and corneal topography as another option in hospital that has only one machine.

Material and Method

The cross-sectional study was done at Department of Ophthalmology, Thammasat University Hospital between October 2010 and January 2011. Thirty healthy volunteers were recruited. Inclusion criteria were male or female age 18-30 years old. An exclusion criterion was corneal disease, post corneal surgery or contact lens users. Discontinuation criteria were uncooperating. One eye in each volunteer was selected at random. Age, sex, visual acuity, auto refraction, intra-ocular pressure and central corneal thickness were recorded. Central corneal thickness was measured with three different methods, as follows.

1. Ultrasound pachymeter by Pocket II (Quantel Medical, Cedex, France). The velocity was

1,620 m/sec. Before measurement, the volunteer was instilled with one drop of 0.5% tetracaine hydrochloride. The volunteer looked straight when the examiner placed the probe gently and perpendicularly at the center of the cornea. Mean of 5 measurements was recorded.

2. Optical coherence tomography by Cirrus High Definition OCT model 4000 (Carl Zeiss Meditec. Inc., Dublin, CA) which was a non-contact, high resolution tomographic and bio-microscopic imaging device. It used the method of low-coherence interferometer. Light source was super luminiscent diode; wavelength was 840 nm; scanning beam was 3 mm in length and 2 mm in depth. Total was 5 lines (4096 A-scans/line). Space between lines was 0.25 mm.

Measurement was done by the volunteer placing his/her chin on a chinrest, forehead touching headband, eye fixed at internal fixator. The examiner adjusted the machine until the pupil was at the center of the monitor and focused before capturing the image which is the cross- section of the cornea. The thickness of cornea was measured as shown in Fig. 1.

Mean of 2 measurements was recorded.

3. Corneal topography by Orbscan II (Technolas Perfect Vision GmbH, Munchen, Germany)

Using the method of Placido disk system and light slit scan analyzer into 3 dimensions of the corneal image which showed corneal thickness, corneal curvature, and corneal elevation. The acoustic correction factor was 0.92.

Measurement was done by the volunteer placing his/her chin on a chinrest, forehead touching headband, eye fixed at internal fixator. The machine scanned using narrowed beam light with 45 degree angle. Twenty slits are projected on the eye from the right side and twenty slits from the left side. The image was detected by high resolution CCD camera then processed as in Fig. 2.

Mean of 2 measurements was recorded.

Three methods of central corneal thickness measurement were performed by one examiner. The measurement began with non-contact method (OCT or corneal topography) first, followed by contact method (ultrasound pachymeter). All volunteers had to sign the informed consent. The present study was approved by the ethics committee of the Faculty of Medicine, Thammasat University.

Statistical analysis

The results were reported as frequency, mean ± standard deviation (SD), range and 95% confidence interval (CI). One way analysis of variance (ANOVA) with repeated measurement was used to compare mean of central corneal thickness among the three modalities: ultrasound pachymeter, OCT and corneal topography. Scatterplot and linear correlation coefficient between two methods of measurement were reported. A p-value of less than 0.05 was considered statistically significant. Data analysis was performed by SPSS version 13.0.

Results

Total number of volunteers was 30 individuals: 14 males (7 right eyes and 7 left eyes) and 16 females (8 right eyes and 8 left eyes). Mean age was 22.67 ± 2.31 (18-28) years old. Mean intra-ocular pressure was 13.12 ± 2.9 (9.1-18.1) mmHg. Spherical equivalent was -2.24 ± 2.44 (-8.75 to +0.25) Diopters.

Mean central corneal thickness by ultrasound pachymeter, OCT and corneal topography were 552.1 ±

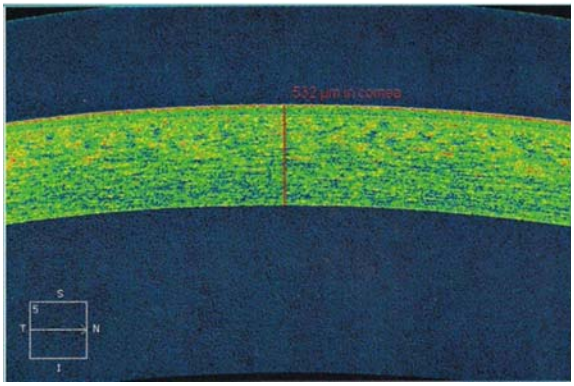

Fig. 1 Central corneal thickness by optical coherence tomography (OCT)

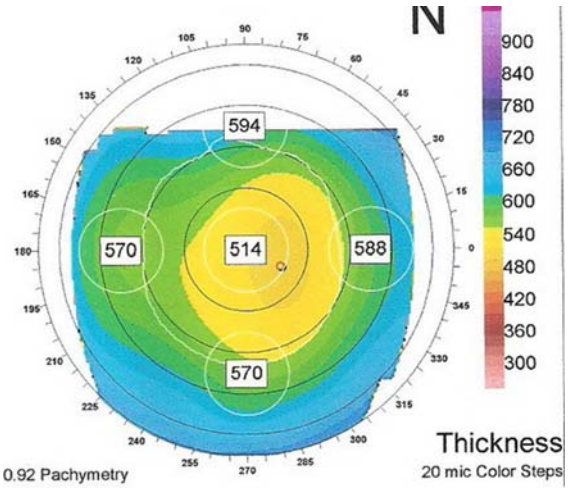

Fig. 2 Central corneal thickness by corneal topography

33.6 μm, 554.5 ± 33.0 μm and 552.8 ± 39.0 μm respectively. There were no statistically significant differences in the measurement results among the three modalities (p = 0.718).

Table 1 and Fig 3 show the mean central corneal thickness of 3 modalities with 95% confidence interval (adjusted by general linear model).

There was significant linear correlation between the OCT and ultrasound pachymeter (Pearson correlation = 0.985, p < 0.001), corneal topography and ultrasound pachymeter (Pearson correlation = 0.965, P < 0.001) and corneal topography and OCT (Pearson correlation = 0.965, P < 0.001), as in Fig. 4-6 respectively.

Discussion

Mean CCT by ultrasound pachymeter, OCT and corneal topography were 552.1 ± 33.6 μm, 554.5 ± 33.0 μm and 552.8 ± 39.0 μm respectively with p-value at 0.718 by General Linear Model (Repeated Measure) which was not statistically significant.

In the present study, CCT measurements using corneal topography with an acoustic correction factor set at 0.92 were comparable to those using ultrasound pachymeter and OCT.

In previous studies, mean CCT by ultrasound pachymeter was more or less than OCT and corneal topography as shown in Table 2. The differences might be from fluctuation in corneal hydration effects ultrasound pachymeter[6], or different ultrasound pachymeters which can cause different values[8], or the ultrasound probe could displace tear film[4,5] and compress epithelium[11] or even ethnic differences might account in the different thickness[12].

Scatterplot of CCT measurements comparing 3 modalities barely demonstrate significant linear correlation between OCT and ultrasound pachymeter (Pearson correlation = 0.985, p < 0.001), corneal topography and ultrasound pachymeter (Pearson

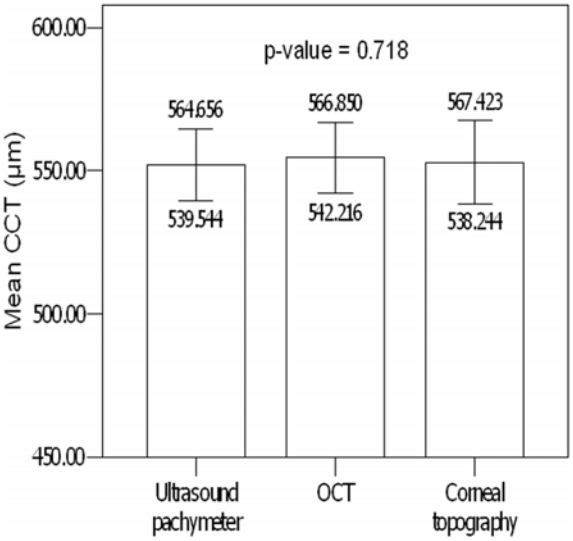

Fig. 3 Comparison of mean central corneal thickness (CCT), 95% confidence interval of ultrasound pachymeter, OCT and corneal topography (p-value = 0.718)

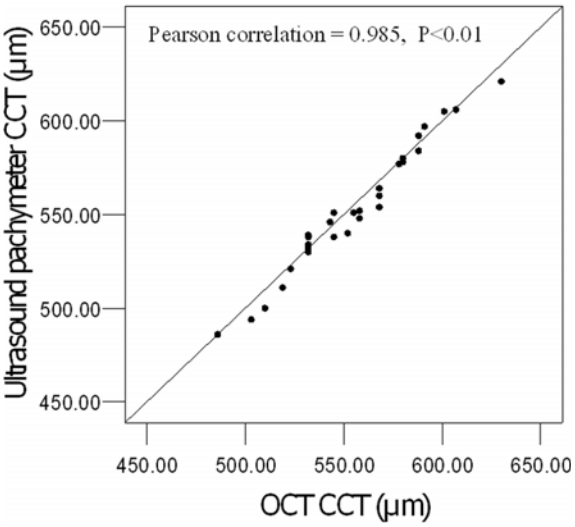

Fig. 4 Scatterplot of central corneal thickness (CCT) measurements by OCT vs ultrasound pachymeter

Table 1. Comparison of mean, standard deviation, 95% confidence interval of ultrasound pachymeter, OCT and corneal topography

Methods of central corneal thickness measurement	Number of volunteers (eyes)	Mean (μm)	Standard deviation	95% Confidence interval	
				Lower bound	Upper bound
Ultrasound pachymeter	30(30)	552.10	33.63	539.54	564.66
OCT	30(30)	554.53	32.99	542.21	566.85
Corneal topography	30(30)	552.83	39.07	538.24	567.42

Table 2. Comparison of mean CCT measured by ultrasound pachymeter, OCT and corneal topography in previous study

Author	year	number of subjects (eyes)	Age ± SD	Central corneal thickness			
				Ultrasound pachymeter ± SD	OCT ± SD	Corneal topography ± SD	
Christensen A et al	2008	50 (100)	22-74	552.3 ± 37.6		547 ± 36.0	p < 0.002
Amano S et al	2006	54 (54)	46 ± 20	545.0 ± 31.3		541 ± 40.7	
Radford SW et al	2004	35 (66)	62 ± 13	557.74-559.03		564.74-565	
Kim HY et al	2008	155	57 ± 12	525.3 ± 33.5	499 ± 32		p < 0.001
Zhao PS et al	2007	285	57.9 ± 10.8	542.3 ± 36.7	527 ± 34.14		p < 0.001
Leung DYL et al	2006	50 (50)		543 ± 33	565 ± 33		p < 0.0001
Wong ACM et al	2002	39 (74)	65.5 ± 11.8	555.11 ± 35.3	523.21 ± 33.54	555.96 ± 32.41	

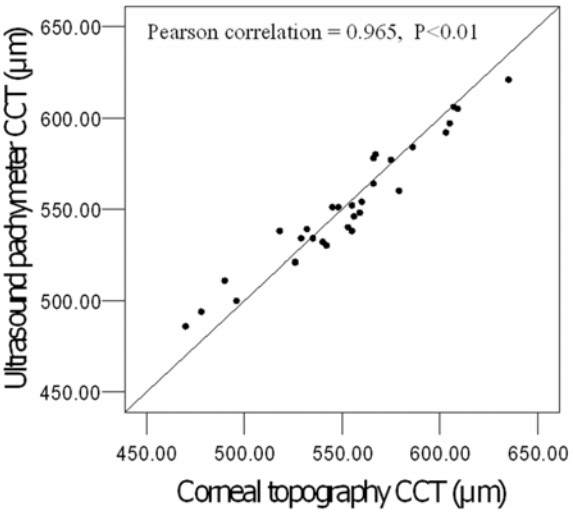

Fig. 5 Scatterplot of central corneal thickness (CCT) measurements by corneal topography vs ultrasound pachymeter

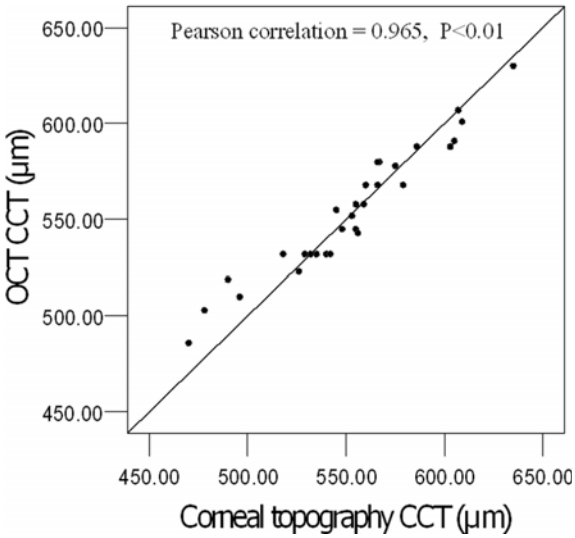

Fig. 6 Scatterplot of central corneal thickness (CCT) measurements by corneal topography vs OCT

correlation = 0.965, p < 0.001) and corneal topography and OCT (Pearson correlation = 0.965, p < 0.001), which is comparable to other studies[5,11].

The advantages of OCT and corneal topography are non-contact technique, which is a more convenient method. Besides, they also provide rapid and objective measurement. Their limitation occurred in opaque cornea. For corneal topography, the limitation is also in corneal scar and corneal edema.

Limitations of the present study included the relatively small sample size and narrowed-age range.

Conclusion

Mean central corneal thickness among ultrasonic pachymeter, OCT and corneal topography were comparable and had significant linear correlations. In clinical practice, these three modalities could be interchangeable in a hospital that has only one machine.

Potential conflicts of interest

None.

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เปรียบเทียบความหนาของกระจกตาส่วนกลางโดยเครื่อง ultrasound pachymeter, optical coherence tomography และ corneal topography

พรรณวิภา ผลชีวิน, วิมลวรรณ ตั้งปกาศิต

วัตถุประสงค์: *เพื่อเปรียบเทียบการวัดความหนากระจกตาส่วนกลางโดยเครื่อง ultrasound pachymeter ซึ่งเป็นมาตรฐานกับ optical coherence tomography (OCT) และ corneal topography*

วัสดุและวิธีการ: *วัดความหนากระจกตาส่วนกลางโดย ultrasound pachymeter, optical coherence tomography และ corneal topography ในตา 30 ข้าง ของอาสาสมัครที่มีสุขภาพแข็งแรงจำนวน 30 คน โดยผู้วัดเพียงคนเดียวที่โรงพยาบาลธรรมศาสตร์เฉลิมพระเกียรติ ตั้งแต่เดือนตุลาคม พ.ศ. 2553 ถึง มกราคม พ.ศ. 2554 เปรียบเทียบผลการศึกษาโดยใช้ Anova for repeated measure และ Pearson correlation*

ผลการศึกษา: *ค่าเฉลี่ยความหนากระจกตาส่วนกลางโดย ultrasound pachymeter, optical coherence tomography และ corneal topography มีค่า 552.1 $\pm$ 33.6 μm, 554.5 $\pm$ 33.0 μm และ 552.8 $\pm$ 39.0 μm ตามลำดับ ผลการวัดไม่พบว่ามีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติของทั้ง 3 วิธี ($p = 0.718$) และพบว่ามีความสัมพันธ์เชิงเส้นอย่างมีนัยสำคัญทางสถิติระหว่าง OCT และ ultrasound pachymeter (Pearson correlation = 0.985, $p < 0.001$), corneal topography และ ultrasound pachymeter (Pearson correlation = 0.965, $p < 0.001$) และ corneal topography และ OCT (Pearson correlation = 0.965, $p < 0.001$)*

สรุป: *ค่าเฉลี่ยความหนากระจกตาส่วนกลางระหว่าง ultrasound pachymeter, optical coherence tomography และ corneal topography มีค่าใกล้เคียงกัน และมีความสัมพันธ์เชิงเส้นไปในทางเดียวกันอย่างมีนัยสำคัญทางสถิติ ดังนั้นทั้ง 3 วิธีอาจนำมาใช้แทนกันในทางคลินิกได้*