Assessment of the Anterior Structures of Eyes in a Normal Northern Thai Group Using the Orbscan II

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Objectives: *To evaluate the anterior structures of the eyes in normal Northern Thais include the corneal topography and thickness, as well as the anterior chamber depth (ACD) and the white-to-white (WTW) using the Orbscan II system.*
Material and Method: *One hundred and six eyes of 56 normal subjects were investigated using the Orbscan II. The simulated keratometry (SimK), astigmatism, corneal thickness, ACD and WTW were collected. The axial power maps as well as anterior and posterior elevation maps were read and categorized. Corneal thickness was measured in different regions and the pachymetry patterns were classified.*
Results*: The mean SimK was 44.18 (1.41)/43.30 (1.46) diopters (D) and the mean astigmatism was 0.93 (0.58) D.Symmetric bow tie was the most common axial power pattern in the anterior cornea (57.6%), followed by asymmetric bow tie (19.8%), irregular patterns (12.3%), round (9.4%), and oval (0.9%). Incomplete ridge (40.6%) and island (34%) were common elevation patterns observed in the anterior corneal surface, and island (92.5%) was the most common topographic pattern in the posterior. The thinnest point on the cornea had an average thickness of 512.49(35) micron and was located at an average of 0.43 (0.24) mm from visual axis. In the pachymetry maps, round (47.2%) and oval (45.3%) were common patterns. The mean ACD and WTW was 2.79 (0.35) and 11.61 (0.36) mm, respectively.*
Conclusion: *The present study demonstrated the normal variations of anterior segment structures of the eyes in normal Northern Thais using the Orbscan II topography system. This information may be useful for comparison with further quantitative studies of various abnormal states.*

Keywords: *Orbscan II, Corneal topography, Pachymetry, Anterior chamber depth, White-to-white*

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The computerized videokeratoscope (CVK) has been recognized as an important tool in assessing, diagnosing, treating, and monitoring the cornea, and it has become a routine aspect of clinical practice. Recently, CVK techniques and accuracy have improved and varieties of CVK methods based on different principles have been developed. The most common technique used to measure the shape of the cornea is still the Placido-based CVK[1], unfortunately, its ability to acquire information from the anterior surface of the cornea only is a major intrinsic limitation. However, the posterior surface of the cornea also contributes to the refractive power of the cornea, which plays important roles in relation to structural integrity[2,3].

The Orbscan II system (Orbtek, Inc.) of corneal topography is a synergy of 2 CVK techniques. A Placido disk attachment is used to acquire the front surface data, while slit-scanning technology enables elevation topography mapping of the anterior and posterior surface of the cornea as well as the anterior surface of the lens and iris. In addition, Orbscan II adopts the white-to-white (WTW) measurement, which represents the horizontal corneal diameter. In 1995, the Orbscan corneal topography system was introduced into clinical practice and it has become a useful step toward assessing of the anterior structures of the eye. This relatively new technology has been widely

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applied and has undergone tests in diverse areas of ophthalmic use.

The dimensions of the anterior structure of the human eye are of particular ophthalmic interest, however, the reported normal variables have not been established in Thai. The purpose of the present study was to evaluate the anterior structure of the eyes in normal Northern Thai people including corneal contour (anterior and posterior corneal elevation map and axial curvature), thickness of the entire cornea, as well as anterior chamber depth (ACD) and WTW using the Orbscan II system.

Material and Method

Prior to study initiation, the protocol was approved by the Medical Ethic Committee of the Faculty of Medicine, Chiang Mai University (73/2003). The purpose and methods of the study were explained and written informed consent was obtained from all participants before enrolment.

Selection of Subjects

The present study was conducted from May 2003 to August 2004 and had evaluated 106 eyes (54 rights and 52 lefts) of 56 normal subjects (21 male and 35 female). Criteria for entry into the present study included (1) aged between 20 and 60 years old, (2) no symptoms of ocular irritation, (3) no history of contact lens use, eye trauma, previous ocular surgery, (4) no anterior segment abnormalities on biomicroscopic examination, and (5) a manifest refractive error of between +3.00 to -6.00 diopters(D) of sphere, and less than 2.00 D of astigmatism with a best corrected visual acuity (VA) of 20/20 or better. Subjects were recruited from employees in Maharaj Nakorn Chiang Mai Hospital, medical students, and patients presenting for routine eye examination.

Method of Clinical Examination

All subjects underwent the following examinations by one investigator (NP): demographic and ocular history, Snellen VA, slit lamp microbioscope examination, and autorefraction if uncorrected or spectacle-corrected VA < 20/20. An anterior segment evaluation with Orbscan II (Orbtek, Inc, Salt Lake City, UT, USA) was performed by one examiner.

Anterior Segment Parameters and Classification Schemes

The Orbscan II measured the anterior and posterior corneal elevation, corneal thickness of the entire cornea, as well as ACD, using a scanning optical slit device. The surface curvature of the cornea was obtained from an incorporated Placido-disk. The computer automatically detected the corneal limbus (the border between white sclera and the darker iris image) by comparing gray-scale steps and calculated horizontal corneal diameter (WTW distance).

The axial power maps of the anterior corneal surface were classified according to the classification scheme described by Bogan and co-authors: round, oval, symmetric bow tie, asymmetric bow tie, and irregular patterns[4].

The elevation maps of the anterior and posterior surface of the cornea were classified according to a classification scheme for anterior elevation maps of normal corneas using the PAR corneal topography system[5]. This scheme classified the maps into regular ridge, irregular ridge, incomplete ridge, island, and unclassified patterns.

Orbscan II determined pachymetry from the difference in elevation between the anterior and posterior surface of the cornea. This instrument averaged pachymetry in five circles of 2 mm diameter, which were located in the centre of the cornea and at four locations in the mid-peripheral cornea (superior, temporal, inferior, nasal), each located 3 mm from the visual axis. The thinnest point on the cornea was identified and marked its distance from the visual axis and its quadrant location.

The pachymetry maps were classified according to a previous study using the Orbscan topography system[6]. This classification used 20 micron (μm) scale intervals to categorize normal pachymetry into four different patterns: round, oval, decentred round, and decentred oval.

All patterns (elevation, curvature, and pachymetry maps) were reviewed by one investigator (NT). The instrument software analyzed the data and calculated all parameters. The relationships of the central corneal thickness (CCT), ACD, and WTW attributed to age were determined.

Statistical Analysis

Statistical analysis was performed with the SPSS program for windows 13.0 (Statistical Product and Service Solutions, Inc., Chicago, IL). The mean and standard deviation of all the parameters were used for various descriptive quantities. Wilcoxon Signed Rank test was used to compare the differences of the thickness between eyes. Pearson's correlation coefficients were calculated to analyze the relationships between age and parameters. A probability level of 0.05 or less was considered significant.

Results

A total of 106 eyes of 56 subjects (both eyes of 50 subjects and one eye of 6 subjects) were investigated using the Orbscan II system. The fellow eye of 6 subjects was excluded from the present study because of corneal scar (four eyes), unstable tear film (one eye), and astigmatism of more than 2 D (one eye). The mean age of the subjects was 38.5 years (range, 21 to 60 years, SD 11.2). Of the 106 eyes, 54 were right eyes and 52 left. There were 83 eyes (78.3%) of emmetropia [$\pm$ 0.5D sphere, $\pm$ 0.25 D cylinder], 13 eyes (12.3%) of myopia [mean sphere -1.92 D (-0.50 to -4.5) and cylinder -0.47 D (0 to -0.75)], 7 eyes(6.6%) of hyperopia [mean sphere +1.36D (+0.25 to +2.75), cylinder -0.33 (0 to -1.00)], and 3 eyes (2.8%) had astigmatism between -1.00 to -1.75 D. The mean simulated keratometry (SimK) was 44.18 (1.41)/43.30 (1.46) D and the mean astigmatism was 0.93 (0.58) D.

The findings on axial power patterns of the anterior cornea are demonstrated in Table 1 and the most common pattern was symmetric bow tie (57.5%). Incomplete ridge (40.6%) and island (34.0%) were common elevation patterns in anterior corneal surface, and island (92.5%) was the most common pattern in the posterior (Table 2).

The thinnest point on the cornea had an average thickness of 512.49 (35) μm and was located at an average of 0.43 (0.24) mm from the visual axis. In 30.2% of the eyes, this point was located in the inferotemporal quadrant, followed by the superotemporal, temporal, and superonasal quadrants in 20.7%, 12.3%, and 12.3%, respectively. Among the five regions of the cornea (central, temporal, inferior, nasal, and superior), when only paired eyes were evaluated, the central cornea had the lowest average thickness [523.31(35) μm]. The nasal cornea had the greatest [630.21(38) μm], which was followed in order of decreasing thickness by the superior, inferior, and

Table 1. Axial power pattern of anterior corneal surface in 106 eyes

Identified pattern	No.	%
Round	10	9.40
Oval	1	0.94
Symmetric bow tie	61	57.55
Asymmetric bow tie	21	19.81
Irregular	13	12.26

Table 2. Elevation pattern of anterior and posterior corneal surfaces in 106 eyes

Identified pattern	Anterior		Posterior	
	No.	%	No.	%
Regular ridge	16	15.09	1	0.94
Irregular ridge	10	9.43	4	3.77
Incomplete ridge	43	40.57	2	1.89
Island	36	33.96	98	92.45
Unclassified	1	0.94	1	0.94

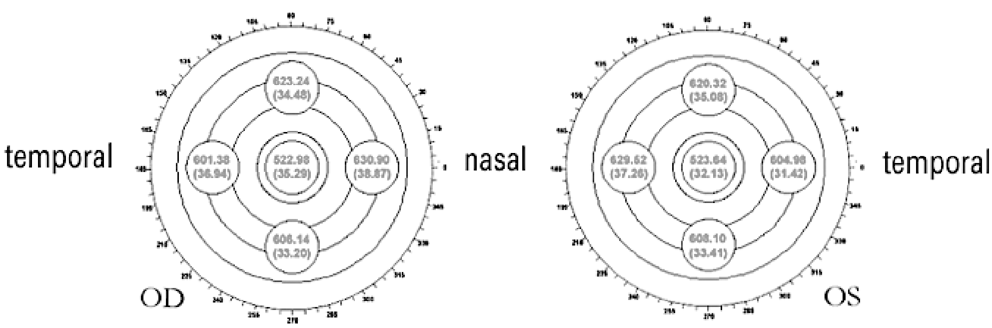

Fig. 1 The means corneal thickness of 5 regions of the right and left eyes (N = 100 paired eyes) OD = right eye, OS = left eye

temporal zones (Fig. 1). There was a high-degree of symmetry between two eyes (p = 0.494, 0.247, 0.421, 0.373, and 0.242 for central, superior, inferior, nasal, and temporal regions, respectively). The common patterns of the pachymetry maps were round (47.2%) and oval (45.3%) patterns (Table 3).

The mean ACD and WTW was 2.79 (0.35) and 11.61 (0.36) mm, respectively. Age was inversely correlated with ACD in high level (r = -0.696, p < 0.0001), and with WTW in low level (r = -0.203, p = 0.037), but not with CCT (r = -0.032, p = 0.745) (Table 4).

Discussion

The precise knowledge of the dimensions of the anterior structures of the human eyes is of particular ophthalmic interest. These parameters including corneal curvature and topography, corneal thickness, anterior chamber depth, and horizontal corneal diameter, are important in diagnosing of various ocular disorders and surgical planning in cataract and refractive surgeries.

Table 3. Pachymetric pattern in 106 eyes

Identified pattern	No.	%
Round	50	47.17
Oval	48	45.28
Decentred round	3	2.83
Decentred oval	5	4.72

The Orbscan topography system is a device developed for corneal topography analysis. The system is based on the hybrid slit scanning/Placido technology, which provides a great potential in analyzing corneal surface as well as structures of the anterior segment.

As cornea is the major refractive element of the eye, and numerous efforts have been made to provide qualitative and quantitative information about the corneal surface. Curvature topography is the most established method of depicting the shape of the cornea. Classification of the color-coded curvature maps has been described the variation in normal human corneas[4,7]. Bogan et al, by using the Corneal Modeling System (CMS), developed a normalized scale to classify normal axial power patterns into 5 basic groups[4]. Later, Rabinowitz et al used the Topographic Modeling System (TMS-1) and expanded Bogan's classification into 10 subgroups[7]. Asymmetric bowtie (32%) was the most common pattern in Bogan's study, whereas, in Rabinowitz's it was oval (25%). Rabinowitz concluded that when round, oval and symmetric bowtie were grouped as a symmetric group, this group became the most common pattern in both studies (61% and 67% in Bogan's and Rabinowitz's, respectively).

The findings on the axial power map in the present study demonstrated that symmetric bowtie was the most common pattern, similar to the study of Liu et al, on normal subjects using the Orbscan system[6] (Table 5). The symmetric group in the present

Table 4. The mean(SD) of central corneal thickness, ACD, and WTW according to age

Age (year) (eyes)	Mean (SD)		
	Central thickness (micron)	ACD (mm)	White-to-white (mm)
21-30 (N = 34)	521.62 (22.37)	3.14 (0.27)	11.71 (0.34)
31-40 (N = 22)	531.41 (44.63)	2.78 (0.18)	11.55 (0.29)
41-50 (N = 31)	513.55 (24.46)	2.58 (0.25)	11.62 (0.44)
51-60 (N = 19)	525.26 (44.68)	2.52 (0.26)	11.46 (0.31)
Total (N = 106)	521.94 (33.32)	2.79 (0.35)	11.61 (0.36)
Correlation coefficient (r)	-0.032	-0.696	-0.203
p-value	0.745	<0.001	0.037

ACD: anterior chamber depth, WTW: white-to-white

Table 5. Sim K, Astigmatism and axial power patterns: comparison with other studies

	This study	Liu, et al[6]	Bogan, et al[4]	Rabinowitz, et al[7]
Methods	Orbscan II	Orbscan	CMS	TMS-1
N(eyes)	106	94	216	390
Sim K(D)	44.18/43.30	44.24/43.31	43.39 (1.54)	43.7 (1.5)*
Astigmatism(D)	0.93 (0.58)	0.90 (0.41)	0.80 (0.70)	NA
Common axial power patterns (%)	Symmetric bowtie (57.6)	Symmetric bowtie (39.1)	Asymmetric bowtie (32.1%)	Oval (25.1%)

* Only right eyes
Sim K: simulated keratometry reading, CMS: the corneal modeling system,
TMS: the topographic modeling system, D: diopters

study and in Liu's was 67.9% and 71.7%, respectively. In addition, the present findings on Sim K and astigmatism were similar to those in Liu's study.

Naufal et al proposed the elevation map classification of normal eyes by using the PAR device, and was applied in the analysis of Orbscan elevation topography[5,6]. By using these definitions, the dominant features of an elevation map can be easily recognized and conveyed; ie, a ridge pattern indicates toricity, island indicates asphericity and unclassified indicates irregularity[8]. The present study demonstrated that incomplete ridge and island were the common patterns observed in anterior elevation maps, and island was the most common pattern in posterior elevation maps. When compared with Liu's study, island was the most common pattern in both anterior and posterior elevation maps. These different results may partly rise from the non-standardized display of each map. Elevation maps of Orbscan II have a set default that best fits the sphere to the entire area of the maps, however, not all acquisitions provide a complete map, due to the effect of eyelids, eyelashes, reflection, etc[8].

Corneal thickness is a sensitive indicator of corneal health, and measurement of corneal thickness is now considered essential in the diagnosis of multiple corneal diseases[9-11]. Pachymetry can avoid complications that may result from cataract or refractive procedures. One of the most common approaches to corneal pachymetry is ultrasound technology. Even though this technique has the benefit of portability, it is far from perfect, as it measures a very small area and multiple measurements of the probe are required for an impression of the cornea's global thickness. Other sources of variability include misalignment of the probe[12] and baring on the cornea, possibly causing tissue compression.

The Orbscan system uses the lateral displacement of 2 slit beams and a video camera. It takes several images of different corneal sections for 3-dimensional reconstruction of the corneal tissue, mapping of the anterior and posterior surfaces as well as the full or wide- field pachymetry.

The present study found that the central corneal and thinnest thickness of the cornea were 523 and 512 micron, respectively, whereas, these values in Liu's study were 560 and 550[6]. The lower results in the present study may partly be due to an acoustic equivalent factor which was applied to the Orbscan II measurement, and possible difference in refractive errors criteria. When compared with other methods, the results on means CCT in the present study was found to be lower than those in a study using ultrasound pachymeter[13].

The correcting factor recommended by the manufacturer seems to be useful in obtaining comparable CCT results between the Orbscan and ultrasound. However, substantial differences remain between the 2 methods, as this factor would not correct the disagreement at all points on the cornea[13]. The issue of disparity between Orbscan and ultrasound pachymetry is compounded when considering cornea that deviates from normal such as keratoconus and post refractive surgery[14,15].

When the entire corneal thickness was analyzed, the authors found that the central cornea was the thinnest, followed in order of increasing thickness by temporal, inferior, superior, and nasal. Compared to Liu's results, the central corneal was found to be the thinnest, followed by temporal, nasal, inferior, and superior[6]. In addition, our results showed that there was a high-degree of symmetry between the two eyes as illustrated by the high correlation of average corneal thickness in different regions of the cornea. Mirror image symmetry of quantitative indices of normal corneas had been described by others[16].

Estimation of central ACD provides important information on newer biometric formulas for intraocular lens (IOL) power calculation[17-19], implantation of phakic IOL[20,21], and glaucoma studies[22,23]. The ACD is the distance measured along the eye's optical axis, from the posterior vertex of the cornea to the anterior surface of the crystalline lens[24]. Applanation ultrasound is the most common method currently used. Recent technologies have been introduced for the measurements of ACD including the IOLMaster and Orbscan topography system.

Ultrasound measurement can be affected by various factors, as occur with pachymetry. Both IOL Master and Orbscan provide non-contact measurements and are reported to require minimal training compared to ultrasound method[25]. However, measurements with both these systems can be complicated or impossible in cases of severe dry eyes, corneal scars, tremor, or nystagmus. A recent study that compared ultrasound technique, Orbscan II, and IOLMaster found that the ultrasound method gave a consistently lower measurement for ACD compared to Orbscan II and IOLMaster, and a high degree of agreement between Orbscan II and IOLMaster was noted[26,27].

In the present study, the means ACD was lower than those found in other studies, using various methods (Table 6). These variations may partly attribute to the smaller anterior segment in Asian eyes, or other influences.

Measurement of corneal diameter from limbus to limbus (WTW distance) is required for cataract and refractive surgery as well as in diagnosing various corneal diseases. With the introduction of IOLs, it became necessary to assess the size of the intraocular spaces (i.e., anterior chamber or ciliary sulcus diameter) to determine an adequate IOL size[29]. This has gained increased attention with the wide use of phakic IOLs. Third generation formulas for IOL calculation use the WTW distance as a parameter in determining IOL power[30]. WTW measurements are done using both manual methods such as calipers or scales in a slit-lamp, and automated techniques. A study comparing manual and automated methods to determine horizontal WTW distance showed that the most accurate measurement was performed with the IOLMaster followed by the Orbscan II topographer, and both provided more precise results than those from using manual methods[31]. The means WTW in the present study seem smaller than those found in other studies using various methods including the Orbscan II, caliper, and IOLmaster (Table 6). The lack of controlled condition, and the differences in subjects and method of measurements may explain these variations.

The present study also investigated the relationships among the anterior segment structures including CCT, ACD, and WTW attributed to age. The authors found that age had an inverse relationship in high level with ACD and in low level with WTW, but did not correlate with corneal thickness. Compared to a study on human eyes using the Orbscan system, age was correlated with corneal thickness and inversely correlated with ACD and horizontal corneal diameter[28]. The decrease in ACD by age was explained by progressive thickening of the crystalline lens over time[32].

In conclusion, quantitative evaluation of anterior segment structures such as the corneal curvature and elevation maps, corneal thickness, ACD, and the WTW provides important information for both vision correction procedures and a tool for diagnosing ocular diseases. The authors have demonstrated the normal variations of anterior segment structures of the eyes in normal Northern Thais using the Orbscan II topography system. Variations in these parameters may attribute to many influences. The contradictory findings in literature may be explained by the differences in study population and size, refractive states, and measurement techniques. However, this information may be useful for comparison with further quantitative studies of various abnormal states.

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Table 6. The mean(SD) of ACD and WTW: comparison with other studies

Methods	Orbscan II					IOLmaster			A-scan	Caliper
Studies	This study	Reddy[26]	Rabsilber[27]	Cosar[28]	Baumeister[31]	Reddy[26]	Rabsilber[27]	Baumeister	Reddy[26]	Baumeister[31]
N (eyes)	106	81	40*	1,341**	100	81	40*	100	81	100
ACD (mm)	2.79 (0.35)	3.32 (0.60)	3.61 (0.24)	3.5 (0.4)	-	3.33 (0.61)	3.61 (0.24)	-	2.87 (0.55)	-
WTW (mm)	11.61 (0.36)	-	-	11.7 (0.4)	11.78 (0.43)	-	-	12.02 (0.38)	-	11.91 (0.71)

* Emmetropia group.
** Evaluation in patients at LASIK center.
ACD: anterior chamber depth, WTW: white-to-white

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การประเมินลักษณะโครงสร้างด้านหน้าของตาในคนไทยปกติทางภาคเหนือโดยเครื่อง Orbscan II

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วัตถุประสงค์: *เพื่อศึกษาลักษณะโครงสร้างด้านหน้าของลูกตาได้แก่ ลักษณะพื้นผิว ความโค้ง และความหนาของกระจกตารวมถึงความลึกของช่องหน้าลูกตาและขนาดของกระจกตาในตาของคนไทยปกติทางภาคเหนือโดยเครื่อง Orbscan II*

วัสดุและวิธีการ: *ได้ทำการศึกษาในตา 106 ตา (56 คน) โดยใช้เครื่อง Orbscan II เพื่อประเมินค่าความโค้งของกระจกตา ภาวะสายตาเอียง ลักษณะพื้นผิวและความหนาของกระจกตา รวมถึงความลึกของช่องหน้าลูกตาและขนาดของกระจกตา นอกจากนี้ได้ทำการวิเคราะห์และจัดกลุ่มรูปแบบค่าความโค้งของกระจกตา,ลักษณะพื้นผิวทั้งด้านหน้าและด้านหลังของกระจกตา รวมถึงรูปแบบความหนาของกระจกตา*

ผลการศึกษา: *ความโค้งเฉลี่ยของกระจกตาเท่ากับ 44.18 (1.41)/43.30 (1.46) ไดออบเตอร์ (D) ค่าเฉลี่ยของสายตาเอียงคือ 0.93 (0.58) D. รูปแบบความโค้งของกระจกตาที่พบมากที่สุดคือ symmetric bow tie (ร้อยละ 57.6) รองลงมาได้แก่ asymmetric bow tie (ร้อยละ 19.8), irregular (ร้อยละ 12.3), round (ร้อยละ 9.4), และ oval (ร้อยละ 0.9) ลักษณะพื้นผิวทางด้านหน้าของกระจกตาที่พบบ่อย คือ incomplete ridge (ร้อยละ 40.6) และ island (ร้อยละ 34) ส่วนลักษณะพื้นผิวทางด้านหลังของกระจกตานั้น ลักษณะ island (ร้อยละ 92. 5) พบมากที่สุดบริเวณที่กระจกตาบางที่สุด มีค่าเฉลี่ย 512.49(35) ไมครอน และอยู่ห่างจากแนวของสายตาโดยเฉลี่ย 0.43 (0.24) มิลลิเมตร รูปแบบความหนากระจกตาที่พบบ่อยคือ round (ร้อยละ 47.2) และ oval (ร้อยละ 45.3) ความลึกของช่องหน้าลูกตา และขนาดของกระจกตา มีค่าเฉลี่ย 2.79 (0.35) และ 11.61(0.36) มิลลิเมตรตามลำดับ*

สรุป: *การศึกษานี้ได้แสดงถึงค่าของโครงสร้างด้านหน้าลูกตาในคนไทยปกติทางภาคเหนือโดยใช้เครื่อง Orbscan II ข้อมูลที่ได้นี้สามารถนำมาเป็นประโยชน์ในการใช้เปรียบเทียบกับการศึกษาในภาวะที่มีความผิดปกติต่อไป*