Measurement of Angle Kappa With Synoptophore and Orbscan II in a Normal Population

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ABSTRACT

PURPOSE: To obtain normative values of angle kappa in a normal population by synoptophore and Orbscan II and to compare the reliability of these devices.

METHODS: Three hundred consecutive healthy individuals were enrolled in the study. A complete orthoptic and ophthalmologic examination was performed. Synoptophore and Orbscan II corneal topography were used to measure angle kappa. To evaluate the association of the angle kappa and refraction measures, individuals were further classified according to the degree of myopia and hyperopia. The spherical equivalent error measures were grouped into six categories: ⩾−3.00 diopters (D); −2.75 to −1.50 D; −1.25 to −0.50 D; +0.50 to +1.25 D; +1.50 to +2.75 D; and ⩾+3.00 D. Paired *t* test and Pearson's correlation test were used for statistical analysis.

RESULTS: The mean age of the individuals was 28.74±1.63 years (range: 20 to 40 years). The angle kappa values obtained by synoptophore and Orbscan II were normally distributed. In the myopic group, angle kappa values decreased significantly towards negative refractive errors. In contrast, there was a correlation between large positive angles and positive refractive errors in the hyperopic group. Angle kappa values obtained by Orbscan II were significantly higher in all groups when compared to synoptophore ($P<.0001$). A significant correlation was noted between synoptophore and Orbscan II measurements ($r=0.932$, $P<.0001$).

CONCLUSIONS: A significant correlation exists between positive refractive errors and large positive angle kappa values. Refractive surgeons must take into account angle kappa, especially in hyperopic patients, to avoid complications related to decentration of the ablation zone. [*J Refract Surg*. 2007;xx:xxx-xxx.]

Refractive surgery has gained significant popularity in the past two decades by reducing or eliminating the need for spectacles or contact lenses. Although lasers and software have become more sophisticated, alignment errors still occur during photoablation that could lead to decentration and inhomogenous ablation patterns. Decentered ablations can lead to negative visual effects including irregular astigmatism, reduced best corrected visual acuity, glare, etc.[1-3] Thus, proper centration of the ablation zone during refractive procedures is an essential goal. A large angle kappa, which is defined as the angle between the visual and pupillary axis, although not significantly different in the clinical setting from angle lambda (the angle between the line of sight and pupillary axis), it may cause alignment errors during photoablation. This issue is more important in hyperopic patients who tend to have larger angle kappa values.[4-6] Because the fovea lies slightly temporal to the point at which the pupillary axis intersects with the posterior pole of the globe, the normal angle kappa is slightly positive.[5] Because of this, some refractive surgeons prefer to alter the location of the ablation to take into account a large angle kappa. However, few data are available concerning the normative values of angle kappa in healthy individuals.

Various methods can be used to measure the amount of angle kappa. Synoptophore is one of the most widely used methods in clinical practice. It measures angle kappa using corneal reflection methods. Recently, newer devices such as Orbscan II (Orbtek Inc, Bausch & Lomb, Rochester, NY) have become commercially available and can be used in the

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TABLE 1

Normative Values of Angle Kappa Among Groups According to Refractive Status

	Mean±Standard Deviation					
	Myopic Group (Mean SE <−0.50 D)		Emmetropic Group (Mean SE −0.50 to 0.50 D)		Hyperopic Group (Mean SE >0.50 D)	
Method	Right Eye	Left Eye	Right Eye	Left Eye	Right Eye	Left Eye
Synoptophore	1.74±0.13	1.91±0.14	2.78±0.12	3.32±0.13	3.44±0.14	3.84±0.17
Orbscan II	4.51±0.11	4.73±0.11	5.55±0.13	5.62±0.10	5.65±0.10	5.73±0.10

SE = spherical equivalent refraction
Note. The hyperopic group and left eyes have larger angle kappa values. Also note that Orbscan II measured angle kappa significantly higher when compared to that of synoptophore in each group.

evaluation of angle kappa. However, no published data evaluating the reliability of Orbscan in measuring angle kappa are currently available.

The aim of this study is to obtain normative values of angle kappa in healthy individuals by using synoptophore and the Orbscan II corneal topography system and to compare the reliability of the devices.

PATIENTS AND METHODS

Three hundred healthy individuals (150 women and 150 men) were enrolled in this prospective study. Mean age was 28.74±1.63 years (range: 20 to 40 years).

Complete orthoptic and ophthalmologic examination including best corrected visual acuity, slit-lamp microscopic examination of the anterior segment, cycloplegic refraction, and dilated fundus examination were performed. Individuals with a history of intraocular and/or extraocular surgery, strabismus, and corneal disease were not included in the study. Study participants were grouped into three categories according to cycloplegic spherical equivalent error measures: emmetropia (n=102, mean spherical equivalent refraction between −0.50 and 0.50 diopters [D]), myopia (n=103, mean spherical equivalent refraction <−0.50 D), and hyperopia (n=95, mean spherical equivalent refraction >0.50 D). The myopic and hyperopic groups were further divided into three subgroups: ≥−3.00 D; −2.75 to −1.50 D; −1.25 to −0.50 D; +0.50 to +1.25 D; +1.50 to +2.75 D; and ≥+3.00 D.

A specially designed slide (Maddox test slide series A White Binding No: 16; Richmond Products Inc, Albuquerque, NM) was used in the synoptophore to measure the angle kappa. A visual axis was formed and consecutive fixation was rotated until a pupillary axis had formed. The angle between the visual and pupillary axis was measured as the angle kappa.

The Orbscan II corneal topography system uses the same principle as the synoptophore. It is a three-dimensional scanning slit topographic device that measures angle kappa automatically with special software by measuring the distance between the center of the pupil and the center of the placedo ring reflection on the cornea. The latter center represents the axis of sight. Each individual sat on a chair, placing his or her chin on the chin rest and forehead against the forehead strap and fixated on the central blinking fixation light. The cornea was centered in the monitor by viewing the half slits on the cornea, and the images were captured.

Three consecutive measurements with each device were taken. All measurements were performed by the same experienced observer (A.S.). Each measuring device was used in random order and the mean value was used for analysis. All statistical analyses were performed using SPSS for Windows, version 11.0 (SPSS Inc, Chicago, Ill). The level of significance was set at $P<.05$. Because the eyes for one individual are not independent when considering ocular parameters such as angle kappa, right and left eyes were analyzed separately. The differences between the devices in measuring angle kappa were calculated using a paired sample *t* test. Pearson's correlation test was used to determine the correlation between variables.

We used angle kappa as a substitute for angle lambda.

RESULTS

The angle kappa values for the three groups according to refraction status (myopic, emmetropic, and hyperopic) are shown in Table 1. The angle kappa values obtained by Orbscan II were significantly higher in all groups compared to synoptophore ($P<.0001$).

To evaluate the association of angle kappa and refraction measures, individuals were further classified according to the degree of myopia and hyperopia. In the myopic group, angle kappa values decreased sig-

TABLE 2

Average Angle Kappa Values in Myopic Subgroups

Method	Right Eye			Left Eye		
	⩾−3.00 D	−2.75 to −1.50 D	−1.25 to −0.50 D	⩾−3.00 D	−2.75 to −1.50 D	−1.25 to −0.50 D
Synoptophore	0.94±0.19	2.05±0.23	2.17±0.17	0.92±0.21	2.20±0.29	2.39±0.17
Orbscan II	4.17±0.19	4.32±0.18	4.79±0.17	4.41±0.19	4.75±0.22	4.90±0.17

Note. Angle kappa values decrease significantly towards negative refractive errors.

TABLE 3

Average Angle Kappa Values in Hyperopic Subgroups

Method	Right Eye			Left Eye		
	⩾+3.00 D	+2.75 to +1.50 D	+1.25 to +0.50 D	⩾+3.00 D	+2.75 to +1.50 D	+1.25 to +0.50 D
Synoptophore	4.81±0.26	3.82±0.20	2.63±0.14	5.30±0.20	3.94±0.39	3.05±0.16
Orbscan II	6.07±0.21	5.60±0.17	5.05±0.11	6.13±0.21	5.74±0.23	5.51±0.12

Note. Angle kappa values increase significantly towards positive refractive errors.

nificantly towards negative refractive errors (Table 2). In contrast, a significant correlation was noted between large positive angles and positive refractive errors in the hyperopic group (Table 3).

There was a slight tendency towards higher angle kappa values in the left eye in all groups with each device. The differences were statistically significant in all groups ($P<.05$). Figure 1 demonstrates a comparison of angle kappa values measured with synoptophore and Orbscan II.

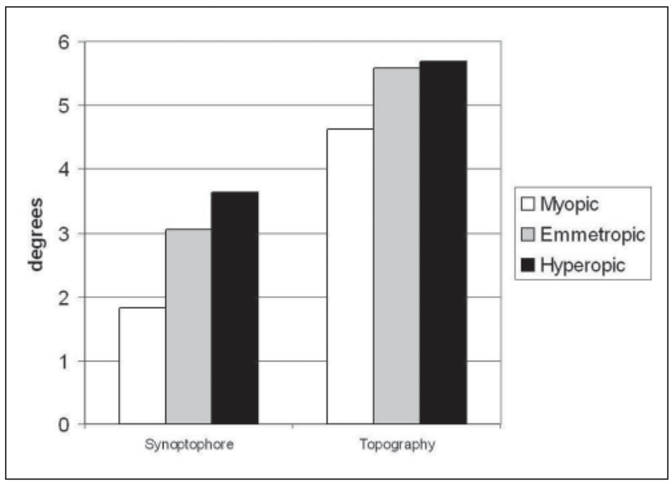

Figure 1. Comparison of angle kappa values measured with the synoptophore and Orbscan II.

DISCUSSION

Evaluation of angle kappa before refractive surgery has gained significant importance because ablation zone centration during refractive surgery is a critical step. Uozato and Guyton[7] asserted that centering on the pupil is the proper method of centration because the photoreceptors are aimed towards the center of a normal pupil; their method has since become standard practice. However, Pande and Hillman[1] stated that the optimal centration is the corneal intercept of the visual axis because this is the line joining the fovea to the fixation point. They concluded that coaxially sighted corneal reflex was nearest the corneal intercept of the visual axis.

Nepomuceno et al[2] performed hyperopic LASIK with the ablation centered on the coaxially sighted corneal light reflex. They concluded that the traditional centering method based on the pupil entrance could lead to decentration in the presence of a large angle kappa, especially in hyperopic patients. More recently, Bueeler et al[8] performed refractive corrections using computer simulations. They used four corneal reference points determined in the preoperative eye: the optical axis, line of sight, visual axis, and first corneal reflex. They found that the postoperative line of sight could move by >0.10 mm if the corneal reflex, which is used for centering in most topography systems, was used as a reference axis. They also concluded that the preoperative locations of the main corneal reference points depend on the refractive state of the eye. The corneal intercepts of the axes are located closer

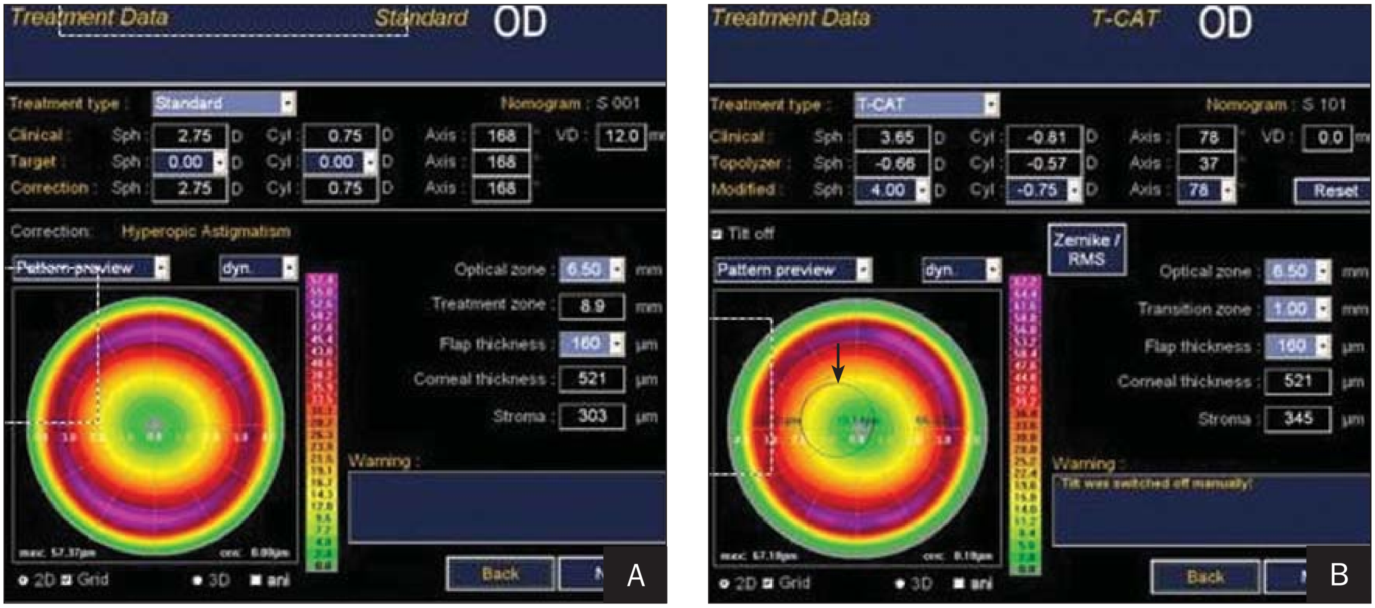

Figure 2. Treatment plan using the WaveLight topography-guided platform of a hyperopic ablation centered on the **A)** entrance pupil and **B)** line of sight. Note the significant decentration when using the line of sight in regard to the entrance pupil, which is defined by the topography-guided software taking into account the angle kappa. The entrance pupil is represented by the slightly decentered circle (arrow) off-center of the ablation profile.

to the optical axis in myopic eyes and farther away in hyperopic eyes. Furthermore, Krishnamurthy et al[9] performed topography-guided ablations in 120 hyperopic eyes to compensate for angle kappa. According to this study, the topography-guided platform appears to better center the ablation to the visual axis versus the pupillary axis, thus avoiding complications related to decentered ablations.[10] These results further support our findings.

In our study, we found that hyperopic individuals had greater positive angle kappa than emmetropic and myopic individuals. Thus, one must consider angle kappa before hyperopic refractive surgery.[11] Figure 2 demonstrates a treatment plan of a hyperopic ablation centered on the entrance pupil (Fig 2A) and the same treatment (topography-guided ablation) centered on the line of sight (Fig 2B). Of note is the significant decentration on Figure 2B in regard to the entrance pupil that is defined by the topography-guided software, taking into account the angle kappa. The pupil center is depicted by the black circle of approximately 2 to 3 mm in diameter. It is central in the standard treatment as expected because this is centered on the papillary axis and it is significantly eccentric in the topography-guided plan, depicting the large angle lambda in this patient.

A number of studies state the opposite, ie, that no correlation exists between angle kappa and refraction.[12,13] However, based on our findings, we disagree.

Data concerning the amount of angle kappa in a normal population is scarce. The average angle kappa values found in our study are similar to those previously reported. Looper,[17] using the corneal reflex in relation to the center of the cornea, found average angle kappa of 1.4°±1.6° in 55 individuals. Effert and Gruppe[4] found average angle kappa of 3.5°±1.3° and 3.8°±1.4° for right eyes and left eyes, respectively. However, Scott and Mash[5] found a negative angle kappa in 34% of 1268 individuals and a value of ±1° in 29%. The difference is that they made their measurements using only the corneal reflex; we believe it is difficult to locate the precise position of the cornea light reflex in relation to the center of the pupil. We could not reproduce similar measurements of a negative angle kappa as in the above cited studies. If our measurements are correct, a negative angle kappa is rare in any case.

A significant correlation was noted between right and left eyes with each device; however, there was a difference in the average angle kappa values between the right and left eyes. There was a slight tendency towards higher angle kappa values in left eyes in the emmetropic group. This finding has been reported elsewhere.[4,5] The underlying cause may be a true mean anatomic difference. Individual variations of lens and corneal radii (comparing one eye with the other) may also contribute to these differences,[15] but no evidence exists in the literature for anatomic differences between right and left eyes. A possible correlation with eye dominance being a contributing factor in this difference may be possible, but was not evaluated in the present study. Variations of head posture or facial asymmetries would create different distances from the cornea to the measurement unit, resulting in different reference angles in both eyes. Also, head posture variations, facial asymmetry, accommodation, and different distances to the stationery units might affect the values in a systematic manner. This, however, would need to be determined based on data from a larger study sample.

This study suggests that a significant correlation exists between positive refractive errors and large positive angle kappa values. Refractive surgeons must take into account angle kappa, especially in hyperopic patients, to avoid problems related to decentration of the ablation zone. We suggest that clinicians use the most conservative measurement, that is with the synoptophore, until topography devices can provide angle kappa values with quantitatively established precise measurements. Further studies are needed to obtain normative values of angle kappa in a normal population.

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