Comparison of Preoperative Angle Kappa Measurements in the Eyes of Cataract Patients Obtained from Pentacam Scheimpflug System, Optical Low-Coherence Reflectometry, and Ray-Tracing Aberrometry

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Abstract

Background

Angle kappa plays a vital role in the implantation of multifocal intraocular lens (MIOLs). Large angle kappa is related to higher risk of postoperative photic phenomena. This study aims to compare preoperative angle kappa in the eyes of cataract patients obtained from Pentacam Scheimpflug system (Pentacam), optical low-coherence reflectometry (Lenstar), and ray-tracing aberrometry (iTrace).

Methods

One hundred thirteen eyes of 113 patients with cataracts were included. Each eye was examined by the devices to obtain angle kappa (X-Y Cartesian coordinates) and pupil diameter. When considering dependent eyes for one individual, angle kappa in right eyes and left eyes should be analyzed separately. The difference, correlation, and agreement between values for horizontal and vertical components of angle kappa were evaluated by paired *t*-tests, Pearson or Spearman tests, and Bland-Altman analysis, respectively.

Results

No significant differences in the pupil diameter were found between Pentacam and Lenstar or Lenstar and iTrace in both eyes ($P > 0.05$). Positive angle kappa (nasal light reflex) was found in most cataract patients (79.25–84.91%) through 3 different devices in both eyes. The significant differences of angle kappa were not found between Pentacam and Lenstar compared to Pentacam and iTrace or Lenstar and iTrace in both eyes ($P > 0.05$). Pentacam and Lenstar showed strong correlation in the horizontal and vertical components of angle kappa compared to Pentacam and iTrace or Lenstar and iTrace in both eyes ($r = 0.906$ to 0.939). The 95% limits of agreement (LoA) in the horizontal and vertical components of angle kappa with Pentacam and Lenstar were narrower respect to Pentacam and iTrace or Lenstar and iTrace in both eyes.

Conclusions

There were no differences, strong correlation, and good agreement in angle kappa with Pentacam and Lenstar for cataract patients. Based on these findings, the measurement of preoperative angle kappa in the eyes of patients with cataracts by Pentacam and Lenstar has good agreement, and can be used interchangeably, but caution is warranted for outcomes-based iTrace that report angle kappa.

Background

Angle kappa represents the angle between the visual axis and the pupillary axis [1]. The visual axis connects the fovea with the fixation point and this line passes the nodal, and the pupillary axis is the line passing through the center of the pupil perpendicular to the cornea. According to light reflex located to the pupillary center, angle kappa can be classified as positive (nasal) or negative (temporal). Also, angle kappa can be classified as horizontal or vertical direction on the basis of X and Y Cartesian values of angle kappa. A positive angle kappa of average 5.0° is generally found in normal human eye [2].

Angle kappa is a crucial examination for some surgical decisions in ophthalmology. In keratorefractive surgery with a large angle kappa, there is a greater chance of the decentration of ablation zones, and it may lead to negative visual effects such as irregular astigmatism and under correction [3, 4]. Similarly, during intraocular refractive surgery implantation of intraocular lenses (IOL), especially the multifocal intraocular lens (MIOLs), a large angle kappa can cause lens decentration, and it can increase the risk for photic phenomenon including halos, glare, and dysphotopsia [5, 6]. Therefore, angle kappa is clinically significant to consider in the preoperative assessment of patients.

Many devices have been commercially released for measuring angle kappa. The exact angle kappa is commonly measured using a synoptophore or major amblyoscope which has not become commercially available [1]. With the improvements of higher precision in biometers, newer instruments measuring angle kappa are applied in clinical practice. Pentacam has been more and more popular in measuring angle kappa for the past few years [7]. In addition, some reports have shown that Lenstar and iTrace were also commonly used to estimate angle kappa [8, 9]. However, no published data has reported a comparison in the angle kappa among three devices. The aim of this study was to compare preoperative angle kappa in the eyes of cataract patients obtained from those instruments and to provide a reference for the selection and judgment of surgeons.

Methods

The retrospective study enrolled 113 eyes of 113 patients with cataracts who attended the Department of Ophthalmology, Affiliated Hospital of Nantong University, between Oct 2018 and Dec 2019 for cataract surgery. The study was approved by the ethics committee of the Affiliated Hospital of Nantong University of and complied with the tenets of the Declaration of Helsinki. All patients were willing to volunteer for the research and signed a written informed consent.

All patients performed a comprehensive ophthalmologic examination, including uncorrected and best-corrected visual acuity, manifest refraction, intraocular pressure, slit-lamp anterior segment evaluation, and fundus examination with the pupil dilated. Inclusion criteria included age-related cataract patients, and eyes with preoperative uncorrected distance visual acuity (UDVA, recorded in logMAR units) less than 0.7. Exclusion criteria were any corneal opacities, poor fixation, strabismus, dry eye, a history of ocular surgery for refractive error and trauma, use of contact lenses, and other ocular pathology or neurological lesions that might affect vision.

When considering dependent eyes for one individual, angle kappa in right eyes and left eyes should be analyzed respectively. Each eye was examined by each device. The pupil diameter and angle kappa were recorded by three different instruments (Pentacam, Lenstar and iTrace), and angle kappa was displayed through X-Y Cartesian coordinates. According to X-Y Cartesian coordinates, the distribution of angle kappa can be classified as 8 positions: superior nasal, inferior nasal, superior temporal, inferior temporal, nasal, temporal, superior and inferior. All measurements were performed consecutively by a single experienced examiner for each of the devices until the day before surgery and were also taken under photopic condition. Prior to taking examinations, all subjects were asked to blink with the purpose of an optically smooth tear filming over the cornea. Each patient was measured 4 times in consecution by each device.

Scheimpflug System Measurements

The Pentacam system (70700; Oculus, Wetzlar, Germany) is a Scheimpflug-based instrument that obtains a three-dimensional model of the anterior segment of the eye which indicate an image from the anterior corneal surface to posterior lens surface. The device captures up to 25 slit-images of the anterior segment of the eye by a 360-degree rotating Scheimpflug camera, collecting 25000 true elevation data points (respecting to 500 true elevation points per slit image) within 2 seconds. The patients placed their chins on a chin rest, and forehead against a forehead strap and looked at the fixation target according to the manufacturer's instructions. The operator visualizes a real-time image of the patient's eye on a computer screen, with the machine marking the pupil edge and center and the corneal apex. Arrows are showed on the screen, which guide the operator's alignment of the device in the horizontal, vertical, and translatory axes. Angle kappa was measured by the coordinates (X, Y) between the center of the corneal vertex and the pupil (Fig. 1, A). Each patient was measured 4 times in consecution and the automatic release mode was used in order to reduce operator-dependent variables. Only automatical scans with quality factor of > 95% were considered for analysis.

Optical Low-coherence Reflectometer Measurements

The non-contact ocular biometry Lenstar (LS900; Haag-Streit, Koniz, Switzerland) calculates ocular distances of the eye by the effect of time domain interferometric or coherent superposition of light waves. It is based on optical low-coherence reflectometry using a 20–30 nm broadband light source with an 820 nm center wavelength. The patients seated with his or her chin on a chin rest and pressed their forehead against the forehead strap. The Lenstar was focused and aligned using eye's image on the computer monitor while the patients were asked to fixate straight ahead on an internal fixation light. The instrument obtained 16 consecutive scans for each measurement and 4 consecutive measurements were taken per eye. The mean value of those measurements automatically was calculated by the software of the instrument. The eccentricity of the visual optical line was assessed according to the distance of white to white and the pupil center. Angle kappa was calculated using the X and Y co-ordinates of the pupil barycenter (pupil dx, pupil dy) (Fig. 1, B). Pupil dx indicated x co-ordinate of pupil center relative to corneal apex and pupil dy indicated y co-ordinate of pupil center relative to corneal apex.

Ray-tracing Aberrometry

The iTrace aberrometer analyzer (iTrace; Tracey Technologies, Houston, USA) which combines ray-tracing aberrometry and corneal topography. The ray-tracing principle which sequentially projects 256 near-infrared laser beams with a 785 nm center wavelength into the eye in a specific scanning pattern is used for the aberrometer. Placido-based corneal topographer is captured by topographies. The subjects placed his or her chin on the chin rest, pressed their forehead against the strap and was asked to fixate on the red light. An iris image with an infrared camera was captured automatically by the aberrometer to display the center of the pupil and the center of the visual axis, and the visual axis was estimated by the center of the first Purkinje reflex (anterior corneal surfaces). Therefore, angle kappa was measured through the instrument (Fig. 1, C). To reduce operator-dependent factors, each patient was measured 4 times in consecution and the automatic release mode was used. Only the scans with the minimum of reject points were chosen for statistical analysis.

Statistical Analysis

Statistical analysis was done using SPSS software (version 23, SPSS Inc) and MedCalc software (version 14.12.02; MedCalc, Ostend, Belgium). Values was presented as means $\pm$ standard deviations (SD). Paired *t*-test assessed the statistical significance of the difference between two means measured by any 2 of 3 devices. The distributions of the datasets were checked for normality using Kolmogorov-Smirnov tests. Depending on the data distribution, Pearson or Spearman rank-order correlation coefficient values were calculated the correlations by any 2 of 3 devices. The between-instrument agreement in estimating the mean horizontal and vertical components of preoperative angle kappa was analyzed by Bland-Altman method. The 95% limits of agreement (LoA) for each comparison (mean $\pm$ 1.96 SD) represented the range where 95% of all differences between two measurements were likely to fall. A *P* value less than 0.05 was considered statistically significant.

Results

The study comprised 113 eyes of 113 patients: 60 eyes of 60 patients in right eyes and 53 eyes of 53 patients in left eyes. Table 1 shows the preoperative patient parameters. There was no statistically significant difference in age, axial length (AL), mean keratometry (Km), anterior chamber depth (ACD), nuclear opalescence (NO), and UDVA between the 2 groups (all *P* > 0.05).

Table 1
Comparison of preoperative patient parameters in both eyes(Mean $\pm$ SD)

Parameter	Right eyes	Left eyes	<i>t</i> Value	<i>P</i> Value
Age (y)	63.12 $\pm$ 12.59	62.87 $\pm$ 9.34	0.120	0.905
AL (mm)	24.36 $\pm$ 2.49	24.32 $\pm$ 2.29	0.094	0.925
Km (D)	44.02 $\pm$ 2.23	44.07 $\pm$ 1.45	-0.146	0.884
ACD (mm)	3.15 $\pm$ 0.44	3.22 $\pm$ 0.43	-0.771	0.442
NO (LOCS $\boxtimes$)	1.89 $\pm$ 0.60	2.01 $\pm$ 0.53	-1.605	0.111
UDVA (logMAR)	0.48 $\pm$ 0.12	0.50 $\pm$ 0.12	-0.878	0.382
SD = standard deviations; AL = axial length; Km = mean keratometry; ACD = anterior chamber depth; NO = nuclear opalescence; LOCS $\boxtimes$ = lens opacities classification systems $\boxtimes$; UDVA = uncorrected distance visual acuity; logMAR = logarithm of the minimum angle of resolution				

The pupil diameter measuring by Pentacam, Lenstar and iTrace in right eyes was (3.51 $\pm$ 0.54) mm, (3.56 $\pm$ 0.51) mm, and (3.71 $\pm$ 0.46) mm, respectively, and in left eyes was (3.60 $\pm$ 0.50) mm, (3.69 $\pm$ 0.53) mm, and (3.80 $\pm$ 0.38) mm, respectively. There were no statistically significant differences in the pupil diameter with Pentacam and Lenstar or Lenstar and iTrace in both eyes (all $P > 0.05$). However, there were statistically significant differences in the pupil diameter with Pentacam and iTrace in right eyes and left eyes, respectively ($P = 0.02$ and 0.011). Besides, no significant differences in the pupil diameter were noted between right eyes and left eyes by Pentacam, Lenstar and iTrace, respectively ($P = 0.325$, 0.207 , and 0.305).

Table 2 shows the distribution and percentage of the preoperative angle kappa. The distribution of positive angle kappa by Pentacam, Lenstar and iTrace in right eyes was 50 eyes (83.33%), 49 eyes (81.67%), and 53 eyes (88.33%), respectively, and in left eyes was 42 eyes (79.25%), 42 eyes (79.25%), and 45 eyes (84.91%), respectively (Fig. 2). There were no statistically significant differences in percentage of positive angle kappa with any 2 of 3 devices in right eyes and left eyes, respectively ($P > 0.05$).

Tables 2
The distribution and percentage of angle kappa in 8 positions in both eyes [N (%)]

Parameter	Right eyes			Left eyes		
	Pentacam	Lenstar	iTrace	Pentacam	Lenstar	iTrace
Superior nasal	3(5.00)	7(11.67)	0(0)	5(9.43)	6(11.32)	1(1.89)
Inferior nasal	6(10.00)	4(6.67)	6(10.00)	4(7.55)	3(5.66)	7(13.21)
Superior temporal	19(31.67)	21(35.00)	16(26.67)	13(24.53)	10(18.87)	7(13.21)
Inferior temporal	29(48.33)	26(43.33)	37(61.67)	28(52.83)	31(58.49)	37(69.81)
Nasal	0(0)	0(0)	0(0)	0(0)	0(0)	0(0)
Temporal	2(3.33)	2(3.33)	0(0)	1(1.89)	1(1.89)	1(1.89)
Superior	0(0)	0(0)	1(1.67)	1(1.89)	0(0)	0(0)
Inferior	1(1.67)	0(0)	0(0)	1(1.89)	2(3.77)	0(0)
SD= standard deviations; N=the number of eyes; %=percentage of data expressed as eyes						

Table 3 shows the difference, correlation, and agreement by any 2 of 3 devices. There were no statistically significant differences in the angle kappa, with Pentacam and Lenstar compared to Pentacam and iTrace or Lenstar and iTrace (Pentacam and Lenstar: the horizontal and vertical components of angle kappa in right eyes, $P = 0.093$ and 0.105 ; the horizontal and vertical components of angle kappa in left eyes, $P = 0.277$ and 0.325). Similarly, strong correlation was found for the angle kappa between Pentacam and Lenstar respect to Pentacam and iTrace or Lenstar and iTrace (Pentacam and Lenstar: the horizontal and vertical components of angle kappa in right eyes, $r = 0.906$ and 0.911 ; the horizontal and vertical components of angle kappa in left eyes, $r = 0.939$ and 0.905). Figures 3 and 4 show the interdevice agreement for mean angle kappa. The 95% LoA between Pentacam and Lenstar were narrower than Pentacam and iTrace or Lenstar and iTrace (Pentacam and Lenstar: the horizontal and vertical components of angle kappa in right eyes, -0.13 to 0.16 mm and -0.13 to 0.11 mm; the horizontal and vertical components of angle kappa in left eyes, -0.14 to 0.12 mm and -0.11 to 0.12 mm). However, the 95% LoA was wider in the comparisons involving the iTrace.

Table 3
Comparison of angle kappa by any 2 of 3 devices in both eyes

Device Pairing		Right eyes		Left eyes	
		X	Y	X	Y
Pentacam-Lenstar	<i>P</i> Value*	0.093	0.105	0.277	0.325
	<i>r</i> Value	0.906†	0.911†	0.939†	0.905†
	95% LoA(mm)	-0.13, 0.16	-0.13, 0.11	-0.14, 0.12	-0.11, 0.12
Pentacam-iTrace	<i>P</i> Value*	< 0.001	0.019	< 0.001	< 0.001
	<i>r</i> Value	0.669†	0.268†	0.853†	0.610††
	95% LoA(mm)	-0.20, 0.34	-0.33, 0.45	-0.27, 0.13	-0.16, 0.36
Lenstar-iTrace	<i>P</i> Value*	0.003	0.005	< 0.001	< 0.001
	<i>r</i> Value	0.692†	0.308†	0.841†	0.687††
	95% LoA(mm)	-0.21, 0.32	-0.32, 0.47	-0.27, 0.16	-0.16, 0.34
LoA = limits of agreement; X = horizontal components of angle kappa; Y = vertical components of angle kappa					
*paired <i>t</i> test					
†Pearson correlation analysis					
††Spearman correlation analysis					

Table 4 shows the horizontal and vertical components of angle kappa in right eyes and left eyes, respectively. The left eyes were found to give higher average angle kappa values than the right eyes in horizontal and vertical direction, respectively, and there were not significant differences between right eyes and left eyes in horizontal components of angle kappa by Pentacam, Lenstar and iTrace, respectively, (Pentacam, Lenstar and iTrace: $P = 0.684$, 0.841 , and 0.779), so was in vertical components of angle kappa (Pentacam, Lenstar and iTrace: $P = 0.830$, 0.311 , and 0.240).

Table 4
Horizontal and vertical components of angle kappa in both eyes(Mean $\pm$ SD)

Device	Right eyes		Left eyes	
	X(mm)	Y(mm)	X(mm)	Y(mm)
Pentacam	0.12 $\pm$ 0.15	0.05 $\pm$ 0.14	0.14 $\pm$ 0.17	0.05 $\pm$ 0.13
Lenstar	0.14 $\pm$ 0.17	0.04 $\pm$ 0.15	0.15 $\pm$ 0.19	0.06 $\pm$ 0.14
iTrace	0.20 $\pm$ 0.18	0.11 $\pm$ 0.19	0.21 $\pm$ 0.19	0.15 $\pm$ 0.17
SD = standard deviations; X = horizontal components of angle kappa; Y = vertical components of angle kappa				

Discussion

The human eye is not a perfect optical system. The larger the discrepancy between the visual axis and pupillary axis or visual axis and optical axis is, which decreased the visual quality. In the MIOLs of eyes with a large angle kappa, the light might pass the center of the macula through other diffractive rings instead of the central area of the MIOLs, which is also known as functional IOL decentration [10], thereby leading to the photic phenomena and surgical aberrations [11, 12]. Therefore, according to the angle kappa, adjusting the position of the MIOLs may help reduce photic phenomena [11, 13]. In addition, some studies also indicated that more than 0.5 mm of preoperative angle kappa should be carefully considered in cataract patients implanted with diffractive or refractive types of MIOLs [6, 11, 14]. Hence, the measurement about angle kappa is particularly important, and this has been paid more and more attention by ophthalmologists.

Previous study has shown that angle kappa value was different from the different instruments [13]. A study has compared the measurement of angle kappa with Synoptophore and Orbscan II in a population of 300 normal individuals, and found there was a strong correlation between synoptophore and Orbscan II measurements, but angle kappa obtained from Orbscan II were dramatically higher compared to synoptophore [15]. Another study has performed the angle kappa between Orbscan II and Galilei G4, and concluded that Orbscan II measured significantly higher angle kappa than Galilei G4. However, angle kappa did not change significantly for different accommodation levels [13]. In addition, a report designed a new method using UBM and corneal topography to calculate the angle kappa and compared the new method with Orbscan II, which found good correlations and agreement between the two methods. But there was statistically significant difference in angle kappa measured by the devices [2]. One explanation for the discrepancy between measurements might be the different principles in different devices, producing slightly different results. The agreement between devices could be significant in research reports that use angle kappa as an important parameter before surgery. In our study, different from the angle and length displaying angle kappa, this study represented the angle kappa through X-Y Cartesian coordinates to get the distribution of angle kappa and horizontal and vertical components of angle kappa. In addition, angle kappa was affected by dependent eyes and pupil diameter for one individual

[16, 17]. Angle kappa in right eyes and left eyes should be analyzed separately, and there were no significant differences in pupil diameter with Pentacam and Lenstar in our study. This excluded the effect dependent eyes and pupil diameter on angle kappa, which showed our results were more convincing.

Our study demonstrated that angle kappa for a majority of cataract patients was positive (nasal light relex) with 3 different devices, which was consistent with those obtained by the other research [4]. This might be related to the anatomical location of the macular fovea on the temporal side of the intersection of the pupil axis at the posterior pole of the eyeball. In addition, we found there were no statistically significant differences in percent of positive angle kappa between any 2 of 3 types. Thus, 3 instruments may replace each other in the measurement of positive angle kappa. Moreover, there were no differences, strong correlation, and good agreement in the angle kappa with Pentacam and Lenstar for cataract patients in both eyes. Therefore, the measurement of angle kappa obtained from Pentacam and Lenstar can be trusted and referred by each other in clinic practice, especially for patients with large angle kappa or poor coordination in clinic practice. However, angle kappa measured by iTrace was significantly different when compared with Pentacam or Lenstar, this may be because 3 devices have different principles. Pentacam and Lenstar represents angle kappa to display X–Y Cartesian coordinates between the corneal vertex and pupil center while iTrace displays X–Y Cartesian coordinates between the visual axis and pupil center. Besides, iTrace needed automatic radiation for 3 times to get a result while Pentacam and Lenstar only identified automatically for 1 time. Compared with Pentacam and Lenstar, iTrace had a greater impact on the stability of the tear film, thereby affecting the measurement of angle kappa. Hence, iTrace should be carefully considered for the measurement of angle kappa in dry eyes. In clinical practice, due to the lower wavelength compared to Lenstar, iTrace decreased laser penetration. In the case of mature cortex cataract, Ⅲ grade hard nucleus cataract, and high myopia, the laser cannot enter the eye, leading to the inability to measure the angle kappa. Hence, iTrace should be carefully considered for the measurement of angle kappa in mature cortex cataract, Ⅲ grade hard nucleus cataract, and high myopia.

This study also found that there was a slight tendency towards higher angle kappa values in left eyes when compared to right eyes and there were not significant differences between right eyes and left eyes in angle kappa. The underlying cause is likely be eye dominance, mean anatomic difference of lens and corneal radii head posture, facial asymmetries, and eye habit, but it does not clearly indicate that which factor is the main reason for the difference between left eyes and right eyes. Therefore, it should be carefully considered for patients with left eyes in strabismus surgery, corneal refractive surgery, and implantation of MIOLs. In addition, angle kappa reduces significantly with the AL and age [18, 19], but it has no significant difference between gender. Furthermore, some other studies have shown that the angle kappa was affected by a variety of factors, such as different postures [20], the change of illumination [21, 22], strabismus [23], and refraction errors (myopia, emmetropia, and hypermetropia) [15]. Therefore, it tells us that clinicians must take into comprehensive factors affecting the angle kappa account when performing surgery about the angle kappa in clinical work.

This study has several limitations. Firstly, there was a relatively small number of patients in this research. Therefore, it is necessary to study larger sample population about the angle kappa in the future to provide further guidance for refractive cataract surgery. Secondly, there was no control group (normal eyes), so angle kappa in the normal eyes measured by three instruments was not compared. In addition, whether there will be good agreement in the normal eyes between Pentacam and Lenstar can be confirmed.

Conclusions

Our results suggest that the measurement of preoperative angle kappa in the eyes of patients with cataracts by Pentacam and Lenstar has good agreement, and can be used interchangeably, but caution is warranted for outcomes-based iTrace that report angle kappa.

Abbreviations

IOL: intraocular lens; MIOLs: multifocal intraocular lens; SD: standard deviation; LOA: limit of agreement; UDVA: uncorrected distance visual acuity; LoA: limits of agreement; AL: axial length; Km: mean keratometry; ACD: anterior chamber depth; NO: nuclear opalescence; LOCS III: lens opacities classification systems III; logMAR: logarithm of the minimum angle of resolution

Declarations

Ethics approval and consent to participate

The study was approved by the ethics committee of the Affiliated Hospital of Nantong University of and complied with the tenets of the Declaration of Helsinki. All patients were willing to volunteer for the research and signed a written informed consent.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

MMQ and YRY contributed to the concept and study design. YW, JWL, JMT, XJC and PFL collected the data. MY, YW, JW and YMH participated in data analysis. MMQ, YRY, WC and MJ wrote the manuscript. HJG conceived the research, and critically reviewed the manuscript and interpreted the data. All authors read and approved the final manuscript.

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References

1. Park CY, Oh SY, Chuck RS. Measurement of angle kappa and centration in refractive surgery. *Curr Opin Ophthalmol*. 2012; 23(4):269-275.
2. Yeo JH, Moon NJ, Lee JK. Measurement of Angle Kappa Using Ultrasound Biomicroscopy and Corneal Topography. *Korean J Ophthalmol*. 2017; 31(3):257-262.
3. Majid M, Michael M, Hamid K, et al. Use of angle kappa in myopic photorefractive keratectomy. *Clin Ophthalmol*. 2015; 29(9):193-195.
4. Harrer A, Hirschschall N, Tabernero J, et al. Variability in angle kappa and its influence on higher-order aberrations in pseudophakic eyes. *J Cataract Refract Surg*. 2017; 43(8):1015-1019.
5. Tchah H, Nam K, Yoo A. Predictive factors for photic phenomena after refractive, rotationally asymmetric, multifocal intraocular lens implantation. *Int J Ophthalmol*. 2017; 10(2):241-245.
6. Qi Y, Lin J, Leng L, Zhao G, et al. Role of angle kappa in visual quality in patients with a trifocal diffractive intraocular lens. *J Cataract Refract Surg*. 2018; 44(8):949-954.
7. Garzon N, Garcia-Montero M, Lopez-Artero E, et al. Influence of angle kappa on visual and refractive outcomes after implantation of a diffractive trifocal intraocular lens. *J Cataract Refract Surg*. 2020; 46(5):721-727.
8. Cankaya C, Ozsoy E, Demirel EE, et al. Estimation of angle kappa and pupil barycentre configuration in myopic tilted disc syndrome. *Clin Exp Optom*. 2020; 103(2):192-196.
9. Fu Y, Kou J, Chen D, et al. Influence of angle kappa and angle alpha on visual quality after implantation of multifocal intraocular lenses. *J Cataract Refract Surg*. 2019; 45(9):1258-1264.
10. Prakash G, Prakash DR, Agarwal A, et al. Predictive factor and kappa angle analysis for visual satisfactions in patients with multifocal IOL implantation. *Eye (Lond)*. 2011; 25(9):1187-1193.
11. Moshirfar M, Hoggan RN, Muthappan V. Angle Kappa and its importance in refractive surgery. *Oman J Ophthalmol*. 2013; 6(3):151-158.

12. Unsal U, Baser G. Evaluation of Different Power of Near Addition in Two Different Multifocal Intraocular Lenses. *J Ophthalmol*. 2016; 2016:1395302.
13. Dominguez-Vicent A, Monsalvez-Romin D, Perez-Vives C, et al. Measurement of angle Kappa with Orbscan II and Galilei G4: effect of accommodation. *Graefes Arch Clin Exp Ophthalmol*. 2014; 252(2):249-255.
14. de Vries NE, Franssen L, Webers CA, et al. Intraocular straylight after implantation of the multifocal AcrySof ReSTOR SA60D3 diffractive intraocular lens. *J Cataract Refract Surg*. 2008; 34(6):957-962.
15. Basmak H, Sahin A, Yildirim N, et al. Measurement of angle kappa with synoptophore and Orbscan II in a normal population. *J Refract Surg*. 2007; 23(5):456-460.
16. Kim HK, Cho KJ. The angle kappa in dominant and nondominant eye. *J Korean Ophthalmol Soc*. 2015; 56(4):494.
17. Hashemi H, KhabazKhoob M, Yazdani K, , et al. Distribution of angle kappa measurements with Orbscan II in a population-based survey. *J Refract Surg*. 2010; 26(12):966-971.
18. Gharaee H, Shafiee M, Hoseini R, et al. Angle Kappa Measurements: Normal Values in Healthy Iranian Population Obtained With the Orbscan II. *Iran Red Crescent Med J*. 2015; 17(1):e17873.
19. Schaeffel F. Kappa and Hirschberg ratio measured with an automated video gaze tracker. *Optom Vis Sci*. 2002; 79(5):329-334.
20. Qi H, Jiang JJ, Jiang YM, et al. Kappa angles in different positions in patients with myopia during LASIK. *Int J Ophthalmol*. 2016; 9(4):585-589.
21. Yang Y, Thompson K, Burns SA. Pupil location under mesopic, photopic, and pharmacologically dilated conditions. *Invest Ophthalmol Vis Sci*. 2002; 43(7):2508-2512.
22. Erdem U, Muftuoglu O, Gundogan FC, et al. Pupil center shift relative to the coaxially sighted corneal light reflex under natural and pharmacologically dilated conditions. *J Refract Surg*. 2008; 24(5):530-538.
23. Basmak H, Sahin A, Yildirim N, et al. The angle kappa in strabismic individuals. *Strabismus*. 2007; 15(4):193-196.

Figures

Figure 1

Angle kappa displayed through X-Y Cartesian coordinates measured by Pentacam (A), Lenstar (B) and iTrace (C). Aberrometer image (C) shows the center of the visual axis (red cross [C], representing the center of the 4 white reflection points) and pupillary center (green cross [C], representing the center of the green circle). Angle kappa is represented by the coordinates (X, Y) between the center of visual axis (red cross [C]) and the pupillary center (green cross [C]).

Figure 2

The distribution of angle kappa in right (A) and left (B) eyes. The + and – sign represent the positive and negative angle kappa, respectively (S= superior; I= inferior; T= temporal; N= nasal).

Figure 3

Bland–Altman plot of between Pentacam and Lenstar (A), between Pentacam and iTrace (B), and between Lenstar and iTrace (C) for in dx of angle kappa, and between Pentacam and Lenstar (D), between Pentacam and iTrace (E), and between Lenstar and iTrace (F) for in dy of angle kappa in right eyes. The dx and dy respectively represents horizontal and vertical components of angle kappa.

Figure 4

Bland–Altman plot of between Pentacam and Lenstar (A), between Pentacam and iTrace (B), and between Lenstar and iTrace (C) for in dx of angle kappa, and between Pentacam and Lenstar (D), between Pentacam and iTrace (E), and between Lenstar and iTrace (F) for in dy of angle kappa in left eyes. The dx and dy respectively represents horizontal and vertical components of angle kappa.