Impact of correlation of angle $\alpha$ with ocular biometry variables

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Purpose: To analyze the association between angle $\alpha$ and ocular biometry in the general population at a third-level ophthalmology hospital.

Setting: Anterior Segment Surgery Department, Asociación para Evitar la Ceguera en México I.A.P., Mexico City, Mexico.

Design: Prospective, cross-sectional study.

Methods: Healthy subjects who attended the hospital for a comprehensive ophthalmological evaluation were examined, and general data were collected. A complete ophthalmological assessment and biomicroscopy evaluation were performed and biometry and clinical data were obtained, including visual acuity, axial length (AL), keratometry (K), white-to-white (WTW) measurement. An OPD-Scan III analyzer was used to assess both the angle $\alpha$ distance and biometry parameters.

Results: 74 eyes from the same number of patients were included; 43 (58.10%) were women. A statistically significant inverse correlation was found between the angle $\alpha$ and the AL ($r = -0.585; P < .0001$) and between the WTW distance and the mean K ($r = 0.557; P < .0001$). A significant correlation was found between the mean K and the angle $\alpha$ ($r = 0.271; P = .019$). A significant inverse correlation was observed regarding the WTW distance and angle $\alpha$ ($r = -0.359; P = .001$). By contrast, a direct correlation was evidenced between the WTW and the AL ($r = 0.385; P = .0007$).

Conclusions: There was a significant inverse correlation between the AL and the angle $\alpha$ magnitude. Hyperopic patients demonstrated significantly higher angle $\alpha$ values when compared with those of myopic patients. In addition, hyperopic eyes with steeper mean K and lesser WTW distance were associated with an increased angle $\alpha$.

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The current trend in premium cataract surgery is to consider specific parameters demonstrated to improve the performance of intraocular lens (IOL) platforms, including the angle $\kappa$ and the angle $\alpha$ since they play an essential role when it comes to IOL centration. However, the eye is not a perfectly aligned system at all times; biometric values show variation and a correlation with other biometric variables that are not always considered and that could affect the outcome.

Currently, multiple reports of the angle $\kappa$ describe the relationship with other biometric measurements and their impact on multifocal IOL (mIOL) placement. Nonetheless, few reports describe the angle $\alpha$ and the association with biometry assessment, in addition to the possible implications for mIOL surgery depicted.

Thus emerges the need to assess the angle $\alpha$ in a healthy population to analyze its associations with relevant biometric variables most commonly used for structuring normative scales capable of guiding management criteria in premium platforms. Most patients achieve satisfactory results. However, some patients have ocular symptoms such as glare, starburst, or halos after mIOL implantation, which affects their quality of life. It has been previously reported that mIOL can induce increased dysphotopic phenomena and glare compared with monofocal IOLs. Key risk factors associated with dysphotopic phenomena include IOL decentration, posterior capsular opacification, dry eye syndrome, and postoperative astigmatism. Prakash et al. suggested a relationship between visual axis misalignment with the pupillary axis (angle $\kappa$ distance or $\mu$ chord >0.50 mm) that can lead to higher-order aberrations postoperatively, resulting in decreased visual quality contributing to the dysphotopic phenomena. However, there is no consensus regarding the maximum angle $\alpha$ cutoff to be considered a risk factor for dysphotopic phenomena. The angle $\alpha$ is defined as the relation between the center of the
white-to-white (WTW) diameter (optical center) and the visual axis, as depicted in Figure 1. Therefore, if a diffractive mIOL is decentered from the visual axis, it could result in decreased vision, inducing higher-order aberrations and photic phenomena, including reduced contrast sensitivity, glare, and halos.6–9 In addition, the lens tends to allocate on the center of the capsular bag, which is more closely related to the center of the limbus. Therefore, it is necessary to know in advance whether the visual axis and the center of the WTW diameter of the patient are misaligned.7–9

This study outlines the overall associations of angle α distance among the healthy population. It has been described that the optical axis/center of the capsular bag may not match the patient’s visual axis when a considerable angle α distance (>0.5 mm) is evidenced, leading to potentially poor outcomes. Moreover, there is no clear consensus about how the angle α affects the surgical outcome. Therefore, measuring the angle α distance among the healthy population and obtaining its correlation with several biometric variables, including the axial length (AL), keratometry (K), and WTW distance (optic center), can provide valuable insights. The purpose of this study was to estimate average distance in healthy patients attending for a comprehensive ophthalmological assessment, in addition to the scrutiny for other possible associations with biometry variables.

METHODS
Design and Setting
This prospective, cross-sectional study included patients undergoing comprehensive ophthalmological evaluation at the Anterior Segment Surgery Department of the Asociación para Evitar la Ceguera en México I.A.P., in Mexico City, Mexico. The Institutional Review Board approved this study, which was conducted following the tenets of the Declaration of Helsinki and Good Clinical Practices Guidelines. All participants were briefed extensively and provided written informed consent after an explanation of the nature and possible consequences of the study.

Patients
The study included healthy patients who attended a comprehensive evaluation; a detailed ophthalmological assessment was performed, where biometry and clinical data were obtained, including visual acuity, AL, K and WTW measurements, intraocular pressure (IOP), biomicroscopy, and fundus evaluation. The key inclusion criteria were adult patients with +6.00 to −10.00 diopters (D), less than 5.00 D regular astigmatism, and 1.3 logMAR or less vision. Patients with a history of strabismus, glaucoma, corneal dystrophy, and previous ocular surgery were excluded.

Main Outcome Measure
The OPD-Scan III (Nidek, Co., Ltd.) was used for the assessment of the angle α, average keratometry, and WTW distance. Similarly, the AL Scan (Nidek Co., Ltd.) device was used for AL measurement by a single trained ophthalmologist (A.A.-D.). The collected data were captured on an Excel spreadsheet (Microsoft Corp.) for further analysis. First, the device was calibrated, and then, the room was kept in semidarkness to facilitate fixation. The subjects were asked to align according to the manufacturer’s instructions and verified before each examination. A complete blink was indicated just before each measurement to prevent potential errors. For each participant, 3 measurements were performed in both eyes; however, only the right eye was selected for the study.

Statistical Analysis
Descriptive data are shown as the mean ± SD and range. Significance was assessed using the Student t-test and Mann-Whitney tests according to data distribution. Pearson correlation coefficient (r) or Spearman tests were used to determine the correlation between the angle α and the biometric variables. Moreover, linear regression analyses were obtained. Gaussian distribution was determined using the D’Agostino-Pearson omnibus normality test for all variables. A P value less than 0.05 was considered statistically significant. Statistical analyses were performed using the SPSS software (v.15; SPSS, Inc.). Plots and layouts were composed using the Prism GraphPad software (Prism, Inc., v.8.0).

A sample size of 74 participants was considered necessary with a level of significance of 0.05 (2-tailed α, β, 0.2) and power at 80%.

RESULTS
Seventy-four right eyes from 74 patients (31 men [41.89%], 43 women [58.10%]) were included. The mean age was 38.74 ± 15.00 years for men, and 45.67 ± 15.12 years for women (95% CI: −13.51 to 0.52; P = .069). Demographic data are included in Table 1. The correlation coefficient between the angle α and the AL, mean K, and WTW distance are summarized in Table 2.

A statistically significant inverse correlation between the angle α and the AL was noticed (P < .0001), meaning that with the shorter ALs, the higher angle α can be expected, as illustrated in Figure 2. The correlation coefficient (r) obtained between all biometry variables is portrayed in Figure 3.
**DISCUSSION**

A major finding in our study was a significant correlation between the angle $\alpha$ and the AL. This concept has not been reported for the angle $\alpha$; however, it was previously reported for the angle $\kappa$ by Hashemi et al. in 2010, registering higher values for the hyperopic population when compared with the myopic population. Moreover, Choi et al., in 2013, concluded that the angle $\kappa$ increases with the spherical equivalent.

Another significant finding in our study was regarding the correlation between the WTW distance and the angle $\alpha$. Our results evidenced an inverse correlation between these parameters. Therefore, the smaller the WTW distance is, the higher the mean keratometry value, the greater the magnitude of the angle $\alpha$. To the authors’ knowledge, these observations have not been previously reported in the literature.

Both the angles $\alpha$ and $\kappa$ have been demonstrated to be relevant in determining eligibility for patients considering mIOL implantation. Moreover, the cutoff angle $\alpha$ limits have been reported to be useful in deciding whether to use a mIOL or not. In a recent report by Mahr et al., they stated that, even though an optimal angle $\alpha$ cutoff limit and its impact on visual acuity and optical aberrations is yet to be determined, they suggest that using 0.3 mm as an angle $\alpha$ cutoff limit would potentially exclude 82% of eyes.

An angle $\alpha$ limit of 0.5 mm would likely exclude 32% of eyes from mIOL implantation. Our findings are in concordance with this approximation since an elevated proportion of the healthy population demonstrates angle $\alpha$ values above the recommended cutoff limit. In addition, it is essential to consider that hyperopic patients tend to demonstrate significantly higher angle $\alpha$ values when compared with myopic patients. Therefore, close consideration should be performed to determine whether this cutoff limit is appropriate when considering mIOL implantation.

According to the current consensus, an angle $\alpha$ value of 0.50 or less is considered appropriate for a trifocal IOL or mIOL. However, most subjects included in our study surpassed this limit (55%), which demonstrated that angle $\alpha$ measurements more significant than 0.5 mm is a widespread occurrence in healthy patients, suggesting that other variables should be taken into account in relation to ocular measurements. Therefore, this instance would make them increasingly predisposed to developing both positive and negative dysphotopic phenomena, including halos, glare, starburst, and ghosting, which fail to be the case for most patients. Nonetheless, in their daily practice, cataract surgeons face low percentages of dissatisfaction on patients implanted with premium IOL even when these measures were not considered preoperatively.

In this study, an inverse correlation was evidenced between the AL and the angle $\alpha$’s magnitude. This outcome suggests that, in hyperopic patients with a smaller AL, an increased angle $\alpha$ will be observed, whereas, in myopic patients depicting a higher AL, a lesser angle $\alpha$ chord will be measured. This outcome could be explained by the displacement of the nodal point between the visual and the optical axis. The nodal point’s extension toward the retina observed in a myopic patient with increased AL would consequently create a narrow chord (angle $\alpha$) at the corneal epithelium. Conversely, for a hyperopic patient, the nodal point advancement toward the lens will have the opposite effect, with a tendency to evidence a more significant chord, as depicted in Figure 4.

Similarly, an inverse correlation between the mean WTW distance and the angle $\alpha$ was found in our study, in addition

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<th>Table 1. Demographic Data.</th>
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<td><strong>Parameter</strong></td>
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<tr>
<td>Patients, RE, n (%)</td>
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<tr>
<td>Mean ± SD (range)</td>
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<td>Age (yr)</td>
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<td>Km (D)</td>
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<td>WTW (mm)</td>
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<td>AL (mm)</td>
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<td>Angle $\kappa$</td>
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<td>Angle $\alpha$</td>
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AL = axial-length; Km = mean keratometry; RE = right eye; WTW = white-to-white

*Student t test

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<th>Table 2. Angle $\alpha$ and Ocular Biometric Correlation.</th>
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<td><strong>Parameter</strong></td>
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<tr>
<td>Age</td>
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$r = $Person’s correlation coefficient; $R^2 = $simple linear regression
to a significant correlation between the mean keratometry and the angle $\alpha$. These results, nevertheless, share the same general principle. These results indicate that the higher the mean keratometry is and the lesser the WTW distance, an increased angle $\alpha$ is more likely to be evidenced. This phenomenon follows a similar pattern, where the nodal point is influenced by the relative increase or decrease in the AL by any of the above-mentioned factors.

Moreover, we found a statistically significant correlation between the WTW and the AL. This outcome suggests that an increased WTW distance is directly associated with a longer AL. Furthermore, the WTW also demonstrated an inverse correlation with the mean keratometry, which, in turn, would prompt that the lesser the WTW distance is measured, it would be associated with higher mean keratometry measurements. In addition, previously described findings are consistent with another key feature described in our study: an inverse correlation between the mean keratometry and the AL. A lesser mean keratometry is likely to be found, alongside higher AL assessments. Therefore, considerable variability in AL measurement is ordinarily present in hyperopic, myopic, and emmetropic patients, which has an impact on the angle $\alpha$ assessment.

Consequently, we should be cautious regarding rendering a useful single cutoff value for assessing the $\alpha$ angle performance for a presbyopia-correcting approach using an mIOL. Hyperopic patients tend to demonstrate significantly higher angle $\alpha$ values when compared with myopic patients. Moreover, hyperopic eyes with steeper mean keratometry and the lesser WTW distance are associated with an increased $\alpha$ angle. It is essential to bear in mind, however, that these are not cataract patients, and therefore this cutoff value could not be extrapolated to other ocular pathologies.

Because of the increased mIOL implantation worldwide, it is becoming key to consider all preoperative parameters for mIOL performance, including angles $\kappa$ and $\alpha$, to improve the postoperative outcome and performance.13–15 In addition, several reports in the literature about the angle $\kappa$ described a relationship with biometric measurements and their postoperative impact when implanting an mIOL.16–18 However, the angle $\alpha$ values and the impact on possible adverse visual effects are not considered, perhaps because of a lack of measurement or the clinical correlation.

It remains unknown whether angle $\kappa$ or $\alpha$ is more relevant for postoperative visual quality after mIOL implantation. However, Fu et al. found no statistically significant correlation between the angle $\kappa$ and the objective visual quality parameters, such as the objective scatter index and modulation transfer function cutoff values.19 Nonetheless, according to a recently published article by Wang et al., in patients with cataracts, the distribution of angle $\alpha$ is more predictable compared with that of angle $\kappa$.20 They reported an increased variability on the angle $\kappa$ values after phacoemulsification compared with those obtained for angle $\alpha$, concluding that, during preoperative evaluation for patients with cataract undergoing mIOL implantation, angle $\alpha$ may be a more reliable and stable factor compared with angle $\kappa$.20 On the other hand, the appropriate terminology needs to emphasize that measurement should be expressed in a distance unit (millimeters), leaving behind the angle concept. This term

Figure 2. Angle $\alpha$ measurement, according to the AL between the patients who measured an AL less than 23.99 and higher than 24.0 mm. AL = axial length

Figure 3. Pearson correlation coefficient was obtained between biometry variables. A: correlation between angle $\alpha$ and the AL of the total sample. B: Correlation between angle $\alpha$ and the AL from patients with less than 24.0 mm. C: Correlation between the angle $\alpha$ and the AL from patients with 24.1 mm or more. D: Correlation between the WTW distance and the mean keratometry. E: Correlation between the WTW distance and the total AL. F: Correlation between the mean keratometry and the total AL. AL = axial length; WTW = white to white
will soon be in trend because of the use of new technologies, such as the OPD-Scan III analyzer or the iTrace, which measures chord distances instead of estimating or inferring angle magnitudes.

Some limitations, nevertheless, should be considered. This study was relying on measurements of healthy patients. Therefore, more studies with larger sample sizes should be performed in cataract patients to assess possible effects after an IOL implantation. Another limitation is the lack of aberrometry assessment. We consider this could contribute to providing additional insight regarding the influence of the higher-order aberrations on visual quality employing two diffractive trifocal IOLs. J Ophthalmol 2019;2019:7018937

In summary, although there is no previous reported correlation of angle $\alpha$ with the AL, the WTW distance, and the mean keratometry, previous results agree with this study, where a statistically significant inverse correlation was observed, resulting in greater angle $\alpha$ with shorter AL. These concepts, including the angle $\alpha$ or chord $\alpha$, should be considered when planning an mIOL implantation to achieve optimal refractive outcomes.

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WHAT WAS KNOWN

- Association between angle $\kappa$ and unpleasant photic phenomena is unclear.
- Angle $\alpha$ is more stable as a predictor for multifocal IOL optimal outcomes.
- Angle $\kappa$ may not be reliable and stable enough to predict results.

WHAT THIS PAPER ADDS

- There is a significant inverse correlation between the AL and the angle $\alpha$ magnitude.
- Hyperopic patients tend to demonstrate significantly higher angle $\alpha$ values when compared with myopic patients.
- Hyperopic eyes with steeper mean keratometry and lesser white-to-white distance are associated with an increased $\alpha$ angle.

REFERENCES


Disclosures: R. Gonzalez-Salinas reports personal fees from Tarsus Pharmaceuticals, Inc., Kedalian Therapeutics, Inc., LayerBio, Inc., Allegro Ophthalmics LLC., and Laboratorios Sanfer, outside the submitted work. None of the previous disclosures conflict with this work. No other disclosures were reported.

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