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Correlation between Intraocular Pressure and Angle Configuration Measured by OCT: The Chinese American Eye Study

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Abstract

PURPOSE: To characterize the relationship between angle configuration measured by anterior segment optical coherence tomography (AS-OCT) and intraocular pressure (IOP).

DESIGN: Cross-sectional study.

PARTICIPANTS: Subjects aged 50 years or older were identified from the Chinese American Eye Study (CHES), a population-based epidemiological study in Los Angeles, CA.

METHODS: Each subject underwent a complete ocular exam including Goldmann applanation tonometry, gonioscopy, and AS-OCT imaging. Four AS-OCT images were analyzed per eye and parameters describing angle configuration were measured, including angle opening distance (AOD), angle recess area (ARA), trabecular iris space area (TISA), trabecular iris angle (TIA), and scleral spur angle (SSA). The relationship between AS-OCT measurements and IOP was assessed using locally-weighted scatterplot smoothing (LOWESS) regression and change-point analyses.

MAIN OUTCOME MEASURES: Correlation between AS-OCT measurements and IOP.

RESULTS: 702 eyes (382 closed angle and 320 open angle) from 555 subjects were analyzed. Mean IOP for angle closure eyes was 16.3 ± 3.9 mmHg and open angle eyes was 15.3 ± 2.7 mmHg. Mean IOP increased as AS-OCT measurements decreased for all parameters except TIA750. Once measurement values dropped below parameter-specific threshold values, AS-OCT measurements and IOP were significantly correlated ($p < 0.05$) for AOD500 ($r = -0.416$), AOD750 ($r = -0.213$), ARA500 ($r = -0.669$), ARA750 ($r = -0.680$), TISA500 ($r = -0.655$),

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TISA750 ($r = -0.641$), SSA500 ($r = -0.538$), and SSA750 ($r = -0.208$). There was no correlation between AS-OCT measurements and IOP in open angle eyes ($p > 0.40$).

CONCLUSIONS: There is an anatomic threshold for angle configuration below which IOP is strongly related to the degree of angle closure. This finding suggests reconsideration of current definitions of angle closure and may be relevant for developing new OCT-based methods to identify patients at higher risk for elevated IOP and glaucoma.

Précis

In eyes with gonioscopic angle closure, strong correlations between intraocular pressure and angle configuration measured by anterior segment optical coherence tomography emerge once measurement values of some angle parameters drop below parameter-specific threshold values.

Primary angle closure glaucoma (PACG), the most severe form of primary angle closure disease (PACD), is a leading cause of permanent vision loss worldwide.^{1,2} Appositional or synechial closure of the iridocorneal angle by the peripheral iris impairs aqueous humor outflow through the trabecular meshwork (TM). Progression of the angle closure process contributes to elevation of intraocular pressure (IOP), an important risk factor for the development of glaucomatous optic neuropathy. The relationship between angle configuration and IOP is presumed to play a key role in the pathogenesis of PACG.³ However, the extent or degree of angle closure required to affect the function of aqueous outflow pathways and cause elevation in IOP has not been clearly characterized.

The diagnosis of PACD relies on the ability of an examiner to visualize the pigmented portion of the TM on gonioscopy, the current clinical standard for evaluating the iridocorneal angle. Based on other clinical findings, such as peripheral anterior synechiae (PAS), IOP above 21 mmHg, or evidence of glaucomatous optic neuropathy, patients are assigned to one of three discrete categories of PACD: primary angle closure suspect (PACS), primary angle closure (PAC), and PACG.⁴ Population-based epidemiological studies on the prevalence of PACD report that PACS outnumbers PAC and PACG by approximately 3 to 1 and 10 to 1, respectively.^{5,6} One longitudinal study on the progression of PACS to PAC and PAC to PACG found that the five-year rates of progression were 22.0% and 28.5%, respectively.^{7,8} Based on this evidence, gonioscopy appears to have limited efficacy in identifying which patients with early angle closure are at higher risk for developing elevated IOP and glaucoma.

Anterior segment optical coherence tomography (AS-OCT) is a non-contact method of obtaining cross-sectional images of the anterior segment.⁹ Quantitative measurements of parameters that describe the configuration of the anterior segment, including the width of the iridocorneal angle, can be derived from AS-OCT images.^{10–12} However, the clinical utility and adoption of AS-OCT has been limited by several factors. One reason is that there is limited evidence demonstrating a correlation between AS-OCT measurements of angle configuration and physiologic measures related to the risk of developing glaucomatous damage, such as IOP. Another reason is that there is currently no standardized OCT-based definition of angle closure that facilitates the identification of patients at higher risk of having or developing PACG. Our study uses population-based data on previously

undiagnosed and untreated Chinese American subjects to characterize the relationship between angle configuration measured by AS-OCT and IOP and determine if there an anatomical threshold below which the two are correlated.

Methods

Ethics committee approval was previously obtained from the University of Southern California Medical Center Institutional Review Board. All study procedures adhered to the recommendations of the Declaration of Helsinki.

Clinical Assessment

Subjects with who fit the gonioscopic definition of angle closure or open angle were identified from the Chinese American Eye Study (CHES), which was a population-based, cross-sectional study that included 4,582 Chinese participants aged 50 years and older residing in the city of Monterey Park, California. As participants of CHES, each subject received a complete eye exam between the hours of 0800 and 1700 by a trained ophthalmologist including, in order, Goldmann applanation tonometry (GAT), gonioscopy, and AS-OCT imaging.¹³ GAT was performed in a lighted environment with the room lights on (27 cd/m^2). Three consecutive IOP measurements were obtained and averaged. Gonioscopy was performed with a Posner-type 4-mirror lens (Model ODPSG; Ocular Instruments, Inc., Bellevue, WA, USA) under dark ambient lighting (0.1 cd/m^2) by two trained ophthalmologists (DW, CL) masked to other examination findings. A 1-mm light beam was reduced to a narrow slit. Care was taken to avoid light from falling on the pupil and to avoid inadvertent indentation during examination. The gonioscopy lens could be tilted to gain a view of the angle over the convexity of the iris. The angle in each quadrant was graded using the modified Shaffer grading system based on identification of anatomical landmarks: grade 0, no structures visualized; grade 1, non-pigmented TM visible; grade 2; pigmented TM visible; grade 3, scleral spur visible; grade 4, ciliary body visible. AS-OCT imaging was performed with the Tomey CASIA SS-1000 swept-source Fourier-domain device (Tomey Corporation, Nagoya, Japan). Imaging was performed first in the dark and then in the light prior to pupillary dilation.

Inclusion criteria for the study included CHES subjects with gonioscopic angle closure, defined as any eye in which the pigmented TM could not be visualized in three or more quadrants (greater than 270 degrees) of the angle on gonioscopy, or open angles. Exclusion criteria included eyes receiving medications that could affect IOP or pupil size. Subjects with a history of prior eye procedures, including laser peripheral iridotomy (LPI) and cataract surgery, were also excluded. Both eyes from a single subject could be recruited so long as they fulfilled the inclusion and exclusion criteria.

Image Analysis

128 two-dimensional cross-sectional AS-OCT images were acquired per eye. AS-OCT data from eyes imaged in the light were imported into the Tomey SS OCT Viewer software (version 3.0, Tomey Corporation, Nagoya, Japan) which automatically segmented the anterior segment structures and produced measurements of the anterior segment parameters

once the scleral spurs were marked. Four images per eye were analyzed to capture the majority of each angle's anatomical variation.¹⁴ The first image analyzed was oriented along the horizontal (temporal-nasal) meridian. Additional OCT images were evenly spaced 45 degrees apart from the horizontal meridian.

One observer (AAP) masked to the identities and examination results of the subjects confirmed the structure segmentation and marked the scleral spurs in each image. The scleral spur was defined as the inward protrusion of the sclera where a change in curvature of the corneoscleral junction was observed.¹⁵ Eyes with missing or corrupt images and eyes in which 3 or more of the 8 scleral spurs could not be identified were excluded from the analysis.

Data from ten anterior segment parameters describing the configuration of the angle were analyzed: angle opening distance (AOD), angle recess area (ARA), trabecular iris space area (TISA), trabecular iris angle (TIA), and scleral spur angle (SSA) measured at 500µm and 750µm from the scleral spur. AOD is calculated as the perpendicular distance measured from the trabecular meshwork at 500 or 750 µm anterior to the scleral spur to the anterior iris surface. ARA is the area of the angle recess bounded anteriorly by the AOD. TISA is an area bounded anteriorly by AOD; posteriorly by a line drawn from the scleral spur perpendicular to the plane of the inner scleral wall to the opposing iris; superiorly by the inner corneoscleral wall; and inferiorly by the iris surface. TIA and SSA are defined as an angle measured with the apex in the iris recess or at the scleral spur, respectively, and the arms of the angle passing through a point on the trabecular meshwork 500 or 750 µm from the scleral spur and the point on the iris perpendicularly. Measurement values from each of the four cross-sectional images was averaged to produce a single mean measurement value. Intra-observer reproducibility of measurements was calculated in the form of intraclass correlation coefficients (ICCs). ICCs were calculated for each parameter based on images from 20 open angle and 20 angle closure eyes graded three months apart. All data analysis was performed using MATLAB (Mathworks, Natick, MA).

Statistical Analyses

AS-OCT data for each parameter was divided into deciles based on 10 evenly spaced bins of measurement values ranging from the minimum to the maximum value. The mean and standard deviation (SD) of IOP values were calculated for each decile. Mean IOP values from each decile were compared using ANOVA and least square mean differences using Tukey honest significance difference tests for multiple comparisons. Deciles that differed significantly ($p < 0.05$) from at least two other deciles were considered as having different IOP overall. All analyses were conducted at the significance level of 0.05.

LOWESS regression analysis was performed on AS-OCT and IOP measured in the light from individual eyes. We applied the 'turning point' method described by Mazhar et al. in order to determine the change-point for each LOWESS regression curve, defined as the point at which there is the greatest increase in the rate of change of IOP.¹⁶ We computed the slope m between all consecutive points (y_i, y_{i+1}) of the LOWESS curve. The consecutive tangent slope values for any two pairs of points (x_i, y_i) , (x_{i+1}, y_{i+1}) on the LOWESS curve are given by $m_{i,i+1} = (y_{i+1} - y_i) / (x_{i+1} - x_i)$. The slope measure takes into account the change in both

independent (AS-OCT measurement) and dependent (IOP) variables, thus describing the magnitude of change in IOP between consecutive measurements of angle width. Finally, we compared the change in slope values for each pair of consecutive points.

The relationship between AS-OCT and IOP measurements below the change-point value was evaluated for each AS-OCT parameter. The distribution of the data points was assessed for normality using the Kolmogorov-Smirnov (K-S) test. Spearman correlation coefficients and their p-values were calculated for each set of measurements. These analyses were repeated for angle closure eyes with measurement values above the change-point value and for open angle eyes.

LOWESS and change-point analyses were repeated on data limited to one eye per subject. In subjects with two eyes that fulfilled the inclusion and exclusion criteria, one eye was selected at random using Matlab.

Multivariable regression analysis was performed to adjust for the effects of age, sex, body mass index, central corneal thickness (CCT), systolic blood pressure, and diabetes on IOP. LOWESS regression, change-point, and correlation analyses were repeated with adjusted IOP. Adjustments of IOP were performed using SAS (SAS Institute, Inc., Cary, NC).

LOWESS regression, change-point, and correlation analyses were repeated with AS-OCT measurements obtained in the dark and IOP measurements.

Results

508 (11.9%) of the 4,257 CHES subjects who received complete eye exams fit the gonioscopic definition of angle closure. 366 (72.0%) of these 508 subjects underwent AS-OCT imaging. 243 (66.4%) of these 366 subjects fit the definition of angle closure in both eyes for a total of 609 eyes. 382 (62.7%) of these 609 eyes were included in the analysis. The remaining 227 (37.3%) eyes were excluded due to usage of IOP-lowering or pupil-affecting medications and/or history of LPI or intraocular surgery (n = 30; 4.9%), incomplete or corrupt imaging data (n = 124; 20.3%), eyelid artifacts (n = 41; 6.7%), or poor image quality that precluded identification of the scleral spur in 3 or more images (n = 32; 5.3%).

The mean age of all subjects was 61.0 ± 7.9 years (range 50 – 93) (Table 1). 372 (67.0%) of the subjects were female and 183 (33.0%) were male. The mean IOP was 15.9 ± 3.7 mmHg (range 8.7 – 43.3). The mean gonioscopy grade averaged among four quadrants was 1.72 ± 1.33 (range 0 – 4.00) and mean CCT was 560 ± 33 μ m (range 461 – 700). Characteristic data on subgroups of eyes with angle closure and open angles are shown in Table 1. Among angle closure eyes, 11 eyes had IOP greater than 2 SD above the mean and 1 eye had IOP less than 2 SD below the mean. Among open angle eyes, 10 eyes had IOP greater than 2 SD above the mean and 4 eyes had IOP less than 2 SD below the mean.

Intra-observer ICC values for AAP reflected excellent measurement reproducibility for all parameters. The ICC values were: AOD500, 0.90; AOD750, 0.96; ARA500, 0.86; ARA750,

0.91; TISA500, 0.89; TISA750, 0.92; TIA500, 0.82; TIA750, 0.94; SSA500, 0.90; SSA750, 0.94.

Relationship between AS-OCT measurement values and IOP under similar lighting conditions

Mean IOP tended to increase as AS-OCT measurements decreased when both were measured in the light for angle closure eyes (Figure 1). There was a significant difference in IOP values among analyzed deciles (ANOVA; $p < 0.006$) for all parameters except TIA750. IOP values of the first decile with the smallest AS-OCT measurements differed significantly (Tukey pairwise; $p < 0.05$) from IOP values of the other deciles for AOD500, ARA500, ARA750, TISA500, TISA750, and SSA500. IOP values of the first two deciles differed significantly (Tukey pairwise; $p < 0.05$) from IOP values of the other deciles for AOD750 and SSA750. For TIA500, only IOP values of the second decile differed significantly from IOP values of the other deciles. TIA750 did not have a single decile with IOP values that differed significantly from the other deciles (ANOVA; $p = 0.622$).

LOWESS curves with 95% confidence intervals were fit to AS-OCT and IOP measurements in the light from all 382 angle closure eyes for each parameter (Figure 2). As measurements decreased, IOP tended to increase for all parameters except TIA500 and TIA750. A change-point indicating the measurement at which the slope of the curve changed most rapidly was calculated for each parameter (Table 2).

Spearman correlation coefficients were calculated for AS-OCT and IOP measurements in the light below and above parameter-specific change-points. For measurements below the change-points, correlation coefficients ranged from -0.07 (TIA500) to -0.680 (ARA750) (Table 2). This relationship was significant ($p < 0.02$) for all parameters except TIA500 and TIA750. For measurements above the change-points, correlation coefficients ranged from -0.06 (TISA500) to 0.07 (TIA750). This relationship was not significant ($p > 0.17$) for any parameter. Spearman correlation coefficients were also calculated for AS-OCT and IOP measurements in the light for all angle closure eyes (Table 2). Spearman correlation coefficients ranged from -0.167 (TISA500) to 0.012 (TIA750), and were significant ($p < 0.02$) for ARA500, ARA750, TISA500, and TISA750.

There was no clear relationship between AS-OCT and IOP measurements in the light when LOWESS analysis was repeated for open angle eyes (Figure 3, ARA750; Supplemental Figure 1). Spearman correlation coefficients ranged between -0.049 to 0.045 and were not significant ($p > 0.40$) for any parameter (Table 2).

LOWESS and change-point analyses were repeated for AS-OCT and IOP measurements in the light for one eye per subject ($n = 234$) (Supplemental Figure 2). The results were similar to the data based on all eyes with angle closure (Supplemental Table 1).

Relationship between AS-OCT measurements and adjusted IOP

LOWESS and change-point analyses were repeated for AS-OCT and adjusted IOP measurements in the light for angle closure eyes after adjusting IOP for age, sex, systolic blood pressure (SBP), diagnosis of diabetes mellitus (DM), body mass index (BMI), and

central corneal thickness (CCT) (Supplemental Figure 3). These data were similar to the data based on unadjusted IOP (Supplemental Table 2).

There was no significant difference ($p > 0.07$, Wilcoxon rank sum test) between adjusted IOP values for angle closure eyes with measurements above the change-points or for open angle eyes.

Relationship between AS-OCT measurements and IOP under dissimilar lighting conditions

LOWESS and change-point analyses were repeated using AS-OCT measurements obtained in the dark and IOP measurements obtained in the light (Figure 4, ARA750; Supplemental Figure 4). In general, correlations were weaker than for AS-OCT measurements obtained in the light (Supplementary Table 3). For measurements below the change-points, correlation coefficients ranged from -0.04 (TIA500) to -0.306 (SSA750). This relationship was significant ($p < 0.05$) for AOD750, ARA500, ARA750, TISA500, and SSA750. For measurement above the change-points, correlation coefficients ranged from -0.02 (ARA500) to 0.07 (TISA750). This relationship was not significant ($p > 0.15$) for any parameter.

Discussion

In this cross-sectional study, we examined the relationship between angle configuration measured by AS-OCT and IOP in a cohort of Chinese Americans. Our data show that in subjects with untreated PACD, IOP tends to increase as angle width decreases. In addition, our data show that there is a strong correlation between angle configuration and IOP among eyes with AS-OCT measurements below parameter-specific threshold values. This correlation does not exist among angle closure and open angle eyes with AS-OCT measurements above the threshold values. To our knowledge, this is the first study to demonstrate an anatomical threshold below which the structural configuration of the angle and IOP, an indirect measure of trabecular outflow, are correlated. We believe these findings have important implications for the diagnosis and management of patients with PACD.

Primary angle closure represents a continuous spectrum of disease even though the current classification of PACD divides it into three discrete categories: PACS, PAC, and PACG. We elected to analyze angle configuration and IOP as continuous variables based on the widely-held theory that angle closure leads directly to elevation of IOP, which then contributes to increased risk of glaucomatous optic neuropathy.¹⁷ Despite the prevalence of this theory, a strong correlation between angle configuration and IOP had not been demonstrated using any angle assessment method. Gonioscopic studies of angle width and extent of PAS reported weak associations with IOP.^{18,19} One previous study found a weak association between AS-OCT measurements of angle width and IOP when subjects were grouped based on measurement quartiles or presence of iridotrabecular contact (ITC).²⁰ By performing a continuous assessment of angle configuration, we identified a subset of eyes with gonioscopic angle closure in which angle width and IOP were strongly correlated. This finding demonstrates one potential benefit of assessing the angle with quantitative AS-OCT measurements over qualitative gonioscopic descriptions of angle configuration.

There is currently no standardized definition of angle closure based on AS-OCT measurements that can be used to guide clinical management of patients with angle closure. ITC and PAS are qualitative anatomical findings that are sometimes used to define angle closure in AS-OCT images, but it is unclear to what degree ITC and PAS are necessary to be of clinical significance.²² The threshold values identified in this study derive their significance from quantifiable relationships with IOP, a key risk factor for developing glaucoma. We postulate that individuals with AS-OCT measurements approaching or below threshold may have higher risk for elevation of IOP. These threshold values could provide a more specific method than gonioscopy for identifying patients who warrant closer monitoring for the development of elevated IOP and glaucomatous damage. These patients may also be better candidates for interventions that alleviate angle closure and lower IOP, such as LPI and cataract surgery.^{23,24}

Our findings raise concerns regarding the staging and management of PACD based on current definitions. Firstly, there is a wide range of angle configurations (measurements greater than threshold values) with no relationship to IOP among subjects with gonioscopic angle closure. While these eyes qualify as angle closure based on gonioscopic definitions, their angle function appears similar to open angle eyes, at least in the light. This highlights the somewhat arbitrary anatomical distinction between eyes with and without PACD and emphasizes the need for improved methods to identify which patients with angle closure will go on to develop elevated IOP. Secondly, once the relationship between angle configuration and IOP emerges (measurements less than threshold values), there is a continuous rise in IOP from baseline. Currently, PAC is diagnosed when IOP is 21 mmHg or greater in an eye with gonioscopic angle closure. This definition of PAC resists trends moving away from IOP-based definitions of glaucoma and ignores the increased risk for glaucoma conferred by incremental increases in IOP in cases where IOP is below 21 mmHg. It also ignores the possibility that elevated IOP can occur in the presence of angle closure even if it is not resultant from the angle closure.

While an assortment of AS-OCT parameters exist that describe the angle, it is not clear which of these parameters is best for quantifying its configuration. There is currently no gold standard for measuring angle configuration. Therefore, previous studies have assessed the diagnostic performance of angle parameters based on their agreement with gonioscopy.²⁴ Among the angle parameters that we examined, ARA500, ARA750, TISA500, and TISA750 measurements were most strongly correlated with IOP below their threshold values. Conversely, TIA500 and TIA750 measurements were not correlated with IOP at any point. The strength of correlation between AS-OCT measurements and IOP provides a new method to evaluate the performance of angle parameters based on physiologic measures that are independent of gonioscopic findings and definitions.

Our results demonstrate the dynamic relationship between AS-OCT and IOP measurements based on changes in the lighting environment: correlations were stronger when both were measured under the same lighting conditions compared to when lighting conditions differed. This is unsurprising given that changes in lighting can induce significant changes in angle configuration.²⁶ However, this highlights an important point in the evaluation of patients with angle closure: IOP should be measured under dark lighting conditions that confer the

greatest risk for appositional closure. Unfortunately, we are unable to comment on the dynamic change in IOP induced by dark-light changes in angle configuration since IOP in CHES was only measured in the light, consistent with current clinical convention. The lack of IOP measurements in the dark somewhat limits the generalizability of our results since gonioscopy and AS-OCT are most commonly performed in the dark. It is possible that with a change in lighting conditions, a different set of threshold values and correlations between angle configuration and IOP would be identified.

Our study has several strengths. The majority of CHES subjects with angle closure were undiagnosed and untreated, which allowed us to study the natural relationship between angle configuration and IOP without the influence of prior treatment or knowledge of disease status. We also took into account a number of factors that are known to influence IOP, including age, sex, body mass index, central corneal thickness (CCT), systolic blood pressure, and diabetes.²¹ When we controlled for these variables, there was minimal impact on the results of our analyses, which suggests that the influence of angle closure on IOP greatly outweighs the influence of other variables. We elected not to control for pupil size or extent of PAS since these variables are strong determinants of angle configuration and directly affect angle measurements.²⁶ In addition, while PAS is an important determinant of clinical management of PACD, its static effects on angle configuration are reflected in AS-OCT measurements. Finally, we repeated our analyses using one eye per subject in order to ensure that no biases were introduced by analyzing data from both eyes of some subjects. We took this approach rather than correct for inter-eye correlations in our regression analysis since this could have reduced or even negated the effects of angle configuration on IOP. The results from both sets of data were similar, suggesting that there is minimal contribution of inter-eye correlations to the observed relationship between angle configuration and IOP.

Our study has several limitations. CHES was a cross-sectional study and our results are based on population-based data from a single time point rather than longitudinal single-eye data. Therefore, we are unable to comment on the variability of threshold values in individual eyes or their change over time. There was also a significant loss of subjects in this study, most of whom were excluded due to missing images and lid artifacts. There was little difficulty in identifying the scleral spur when images were properly acquired. Thirdly, IOP measurements were obtained at all times of day. While IOP varies throughout the day, this variation is typically only a few mmHg and is small compared to the IOP effects described in this study.²⁷ Fourthly, AS-OCT imaging was performed after GAT and gonioscopy, both of which are contact assessments and may have affected the angle configuration. Finally, we only examined AS-OCT parameters that directly measured angle configuration. Parameters such as lens vault and iris curvature contribute to the development of angle closure and could be correlated with IOP.^{10,28,29} However, these parameters do not directly reflect angle configuration and ultimately fell outside the scope of this study.

In summary, we studied a population of Chinese Americans with untreated gonioscopic angle closure and identified a subset of eyes that demonstrate a strong correlation between angle parameters measured by AS-OCT and IOP. These findings support a reconsideration of current definitions of PACD and development of a classification system in which angle configuration is assessed as a continuous risk factor for elevated IOP and glaucoma, rather

than as discrete categories of disease. These findings also support an expanded role for AS-OCT in the clinical management of angle closure patients as a complement or possibly even replacement to gonioscopy. We hope that this study will encourage further efforts to elucidate mechanisms by which a more detailed delineation of angle structures can help guide the management of patients at risk for elevated IOP and glaucoma from angle closure.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Relationship between AS-OCT and IOP measurements in the light for angle closure eyes in. AS-OCT measurement values for each of 10 angle parameters were divided into deciles. Bar plots and error bars show the mean and standard deviation of IOP for each decile. Numbers above each plot indicate the number of subjects per decile. Asterisks (*) indicates the decile/s with distribution of IOP that differs significantly from the others. Angle opening distance (AOD), angle recess area (ARA), trabecular iris space area (TISA), trabecular iris angle (TIA), and scleral spur angle (SSA). 500/750 denote measurement at 500 μm or 750 μm from the scleral spur.

Figure 2. Change-points in the relationship between AS-OCT and IOP measurements in the light for angle closure eyes. LOWESS plots with 95% confidence intervals (shaded bars) of IOP plotted against AS-OCT measurements for 10 angle parameters. Solid triangles (▼) indicate change-point values.

Figure 3. LOWESS plot of the relationship between ARA750 and IOP measurements in the light for open angle eyes. Conventions same as Figure 2.

Figure 4. Change-point in the relationship between ARA750 measurements in the dark and IOP measurements in the light for angle closure eyes. Conventions same as Figure 2.

Table 1.

Characteristics of angle closure, open angle, and all subjects.

	Angle Closure	Open Angle	All
Subjects (N)	235	320	555
Eyes (N)	382	320	702
Sex (male/female)	59/176	124/196	183/372
Age (years)	62.6± 8.2	59.6± 7.9	61.0± 7.9
IOP (mmHg)	16.3± 3.9	15.3± 2.7	15.9± 3.7
Mean gonioscopy grade	0.74 ± 0.49	3.03 ± 0.67	1.72 ± 1.33
CCT (μm)	560± 33	560± 32	560± 33

Data are expressed as mean ± SD. IOP, intraocular pressure. CCT, central corneal thickness.

Table 2.

Statistical measures of correlation between IOP and AS-OCT measurements for eyes with measurement values below and above each parameter-specific change-point value.

Parameter	Change-point	Angle Closure Measurement Change- point			Angle Closure Measurement > Change- point			Angle Closure All Measurements			Open Angle All Measurements		
		Eyes (N)	Rho	P Value	Eyes (N)	Rho	P Value	Eyes (N)	Rho	P Value	Eyes (N)	Rho	P Value
AOD500	0.104 mm	33	-0.416	0.016	349	0.001	0.987	382	-0.096	0.061	320	0.018	0.762
AOD750	0.205 mm	118	-0.213	0.021	264	0.058	0.347	382	-0.045	0.381	320	0.045	0.433
ARA500	0.047 mm ²	23	-0.669	< 0.001	359	-0.045	0.396	382	-0.149	0.003	320	-0.049	0.396
ARA750	0.085 mm ²	28	-0.68	< 0.001	354	-0.03	0.57	382	-0.121	0.018	320	-0.014	0.815
TISA500	0.046 mm ²	33	-0.655	< 0.001	349	-0.058	0.281	382	-0.167	0.001	320	-0.049	0.401
TISA750	0.081 mm ²	28	-0.641	< 0.001	354	-0.039	0.462	382	-0.129	0.011	320	0.000	0.995
TIA500	15.26 degrees	103	-0.074	0.455	279	0.08	0.185	382	-0.042	0.412	320	0.001	0.992
TIA750	13.96 degrees	93	-0.01	0.925	289	0.089	0.131	382	0.012	0.810	320	0.045	0.442
SSA500	11.18 degrees	28	-0.538	0.003	354	-0.021	0.693	382	-0.096	0.060	320	-0.006	0.914
SSA750	15.30 degrees	123	-0.208	0.021	259	0.056	0.369	382	-0.045	0.378	320	0.041	0.491

Angle opening distance (AOD), angle recess area (ARA), trabecular iris space area (TISA), trabecular iris angle (TIA), and scleral spur angle (SSAngle). 500 or 750 denotes distance in μm from the scleral spur.

Boldface values indicate statistical significance of Spearman correlation coefficient at $P < 0.05$.