Comparison of Gonioscopy and Anterior Segment Ocular Coherence Tomography in Detecting Angle Closure in Different Quadrants of the Anterior Chamber Angle

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Purpose: To compare the performance of gonioscopy and anterior segment (AS) optical coherence tomography (OCT) in detecting angle closure in the different quadrants of the anterior chamber angle (ACA).

Design: Cross-sectional observational study.

Participants: Five hundred two consecutive subjects more than 50 years of age with no previous ophthalmic problems recruited from a community clinic in Singapore.

Methods: All subjects underwent gonioscopy and AS OCT imaging in the dark. Using gonioscopy, the ACA was graded using the Scheie system by a single examiner masked to AS OCT findings.

Main Outcome Measures: The ACA in a particular quadrant was classified as closed if the posterior trabecular meshwork could not be seen on gonioscopy. A closed ACA on AS OCT imaging was defined by the presence of any contact between the iris and angle wall anterior to the scleral spur.

Results: After excluding eyes with poor image quality, a total of 423 right eyes were included in the analysis. A closed angle in at least 1 quadrant was observed in 59% of the eyes by AS OCT and in 33% of the eyes by gonioscopy ($P<0.001$), with fair agreement between the two methods ($\kappa = 0.40$). The frequency of closed angles by AS OCT and gonioscopy were 48% versus 29% superiorly, 43% versus 22% inferiorly, 18% versus 14% nasally, and 12% versus 20% temporally, respectively. Of the 119 of 1692 quadrants that were closed on gonioscopy but open on AS OCT, a steep iris profile was present in 61 (51%) of 119 quadrants on AS OCT, and of the 276 of 1692 quadrants that were open on gonioscopy but closed on AS OCT, 196 (71%) of 276 quadrants showed short iridoangle contact on AS OCT.

Conclusions: The highest rates of closed angles on gonioscopy and AS OCT images were observed in the superior quadrant. Anterior segment OCT tended to detect more closed ACAs than gonioscopy, particularly in the superior and inferior quadrants. Variations in the iris profile and level of iridoangle contact also may explain some of the differences seen between gonioscopy and AS OCT. *Ophthalmology 2008;115:769–774 © 2008 by the American Academy of Ophthalmology.*

Primary angle-closure glaucoma is a visually destructive type of glaucoma[1–3] in which the closure of the anterior chamber angle (ACA) leads to intraocular pressure increase and glaucomatous optic neuropathy.[4] The current reference standard for evaluating the ACA configuration is gonioscopy, an examination that can be performed quickly but that involves contact with the cornea and often is considered a cumbersome examination in a busy clinical practice. Furthermore, gonioscopic findings may be affected by inadvertent pressure on the gonioscopy lens and by increased illumination (which tends to open the ACA) during the examination. Previous studies have shown that even experienced, cross-trained examiners have only moderate agreement in determining angle width.[5,6]

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Anterior segment (AS) optical coherence tomography (OCT) uses a 1093-nm diode laser to obtain real-time images of the ACA and provides a rapid noncontact method for the detection of angle closure.[7–9] The aim of this study was to compare the performance of gonioscopy and AS OCT in detecting angle closure in a cohort of patients attending a community clinic for nonophthalmic care and to investigate variations in findings between the two methods in the different quadrants of the ACA.

Patients and Methods

Subjects for this study were a subset of participants of a larger study being conducted to evaluate new imaging devices for angle closure and were recruited from attendees seeking treatment for nonophthalmic reasons at a community clinic in Singapore. Informed consent was obtained from all participants, the Institutional Review Board of the Singapore National Eye Center approved the protocol, and the study adhered to the tenets of the Declaration of Helsinki.

After an interview to obtain previous medical and ophthalmic history, each subject underwent the following examinations on the same day: visual acuity, anterior segment imaging by AS OCT (Visante; Carl Zeiss Meditec, Dublin CA), anterior chamber depth and axial length measurements (IOL Master; Carl Zeiss Meditec), slit-lamp biomicroscopy, Goldmann applanation tonometry, and indirect gonioscopy. Only subjects 50 years of age and older were included. Subjects were excluded if they had a history of intraocular surgery or penetrating trauma in either eye, previous anterior segment laser treatment, or a history of glaucoma.

Gonioscopy

Gonioscopy was performed in the dark in all cases by a single examiner (RL) masked to AS OCT findings. The examiner was a trained ophthalmologist with extensive experience in performing gonioscopy in a research setting. A 1-mm light beam was reduced to a very narrow slit and the vertical beam was offset horizontally for assessing superior and inferior angles and was offset vertically for nasal and temporal angles. Static and dynamic gonioscopy was performed using a Goldmann 2-mirror lens and a Sussman 4-mirror lens, respectively, at high magnification (×16), with the eye in the primary position of gaze. Care was taken to avoid light falling on the pupil and to avoid accidental indentation during the examination. Slight tilting of the gonioscopy lens was permitted in an attempt to gain a view over the convexity of the iris. The ACA in each quadrant was graded using the Scheie grading system (grade I, visible ciliary body; grade II, visible scleral spur; grade III, visible anterior trabecular meshwork; grade IV, angle structures not visible) according to the anatomic structures observed during gonioscopy.[10]

Anterior Segment Optical Coherence Tomography

Anterior segment imaging was obtained using a commercially available AS OCT (Visante; Carl Zeiss Meditec). The details of AS OCT imaging technology have been described previously.[7,8] Briefly, this technology permits image acquisition at a rate of 8 frames per second (2000 A scans per second) with a transverse resolution of 60 μm, and an axial resolution of 10 to 20 μm. Furthermore, the use of wide-field scanning optics (16 mm) and deep axial scan range (8 mm) allows AS OCT to image a cross section of the anterior chamber in 1 image frame. After acquisition, the scanned images have to be processed by customized software (dewarping software), which compensates for index of refraction transition at the air–tear interface and the different group indices in air, cornea, and aqueous to correct the physical dimensions of the images.[11]

Seated subjects were examined by a single examiner who was masked to other test results before any procedure that involved contact with the eye. Three AS OCT images of the ACA of each eye were obtained in dark conditions: 1 image scanning the angle at the 3- and 9-o'clock hour positions, 1 scanning the superior angle at 12 o'clock, and 1 scanning the inferior angle at 6 o'clock. Because the eyelids may interfere with AS OCT image acquisition of the ACA at 6 and 12 o'clock, the lower lid was pulled down gently by the operator to image the inferior angle, and the upper lid was elevated gently to image the superior angle, taking care to avoid inadvertent pressure on the globe. The AS OCT image files were exported to a personal computer and were evaluated for the presence of a closed or open ACA by 2 examiners with glaucoma subspecialty training (LMS and TA working together) who were masked to other test results.

Main Outcomes Variables

An ACA quadrant was considered to be closed on gonioscopy if the posterior trabecular meshwork could not be seen in the primary position without indentation (Scheie grade III or IV). A quadrant was considered to be closed on AS OCT imaging if any contact between the iris and angle wall anterior to the scleral spur was noted (Fig 1).

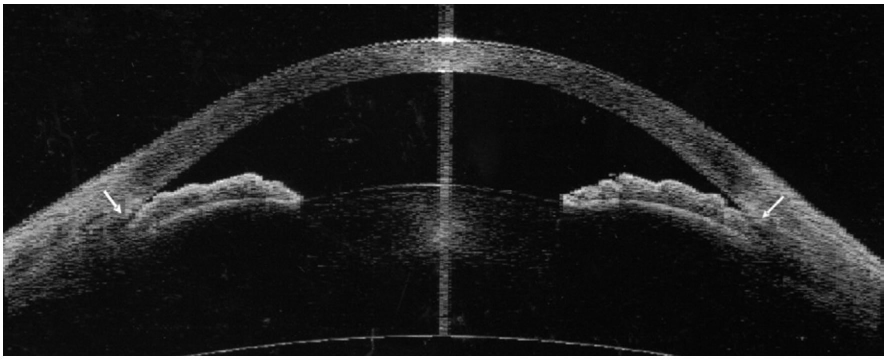

Figure 1. Anterior segment ocular coherence tomography image showing a closed anterior chamber angle with contact between the iris and angle wall anterior to the scleral spur (arrows).

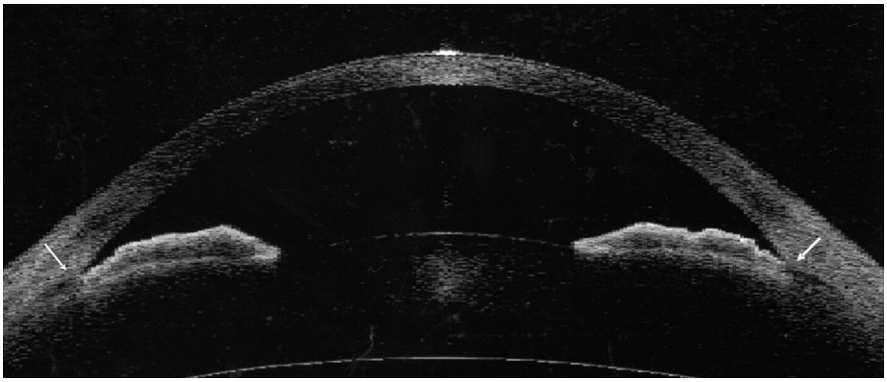

Figure 2. Anterior segment ocular coherence tomography image demonstrating short iridoangle contact of the iris just anterior to the scleral spur (arrows, location of the scleral spur).

Two additional parameters were graded in the AS OCT images: short iridoangle contact and steep iris profile. Short iridoangle contact was present when there was contact between the iris and angle wall just above the scleral spur, but the contact distance was short (Fig 2). A steep iris profile was present when there was a pronounced convex profile of the anterior surface of the iris with an open ACA (Fig 3). The graders subjectively compared AS OCT images with a set of standard AS OCT images illustrating these 2 categories.

Statistical Analysis

Parametric and nonparametric tests were used to compare continuous variables, according to data distribution. The chi-square test was used to compare categorical data. The McNemar test was used to compare differences in distribution of a categorical variable between 2 dependent samples. The κ statistic was used to assess the agreement between categorical variables. However, the κ statistic has limitations, such as being affected by trait prevalence (distribution) and base rates.[12–15] In an attempt to deal with these well-known limitations, using AC1 statistics to assess the agreement between raters in situations where the prevalence of positive classifications may lead to inconsistent results has been proposed,[15] with results interpreted in a similar way as κ statistics.[12–15] The AC1 statistic is quite similar to the κ statistic (the formula is essentially identical, but the probability of agreement by chance is calculated in a different fashion). A P value less than 0.05 was considered to be statistically significant. Statistical analyses were performed using JMP 5 (SAS Institute, Inc., Cary, NC) and MedCalc (MedCalc Software, Mariakerke, Belgium).

Results

Five hundred four consecutive subjects were included in this study, of whom 274 (54.6%) were female. Most subjects were Chinese (n = 463 [92%]), the others being Malay (n = 9 [2%]), Indian (n = 20 [4%]), and other races (n = 12 [2%]). The mean age (±standard deviation [SD]) was 61.3±7.6 years (range, 51–93 years). The mean AC depth of subject's right eyes was 3.12 mm (SD, 0.36 mm), and the mean axial length was 23.71 mm (SD, 3.25 mm).

Anterior segment OCT images of all 4 quadrants could be obtained in 502 patients, because it was not possible to obtain superior scans in both eyes of 2 patients. In quadrant-by-quadrant comparison, the frequency of a closed ACA observed in the right eye was not significantly different from the frequency of a closed ACA observed in the corresponding quadrants of the left eye ($P = 0.08$, data not shown). Results from right eyes were used in the analyses below. The ACA could not be classified in the AS OCT images of 79 right eyes (16%) because of poor quality of the image or poor definition of the scleral spur. Further analysis considered only the 423 eyes (84% of total) in which the ACA status on AS OCT imaging could be assessed in all 4 quadrants. There were no differences in the mean age, gender, or race distribution between the 79

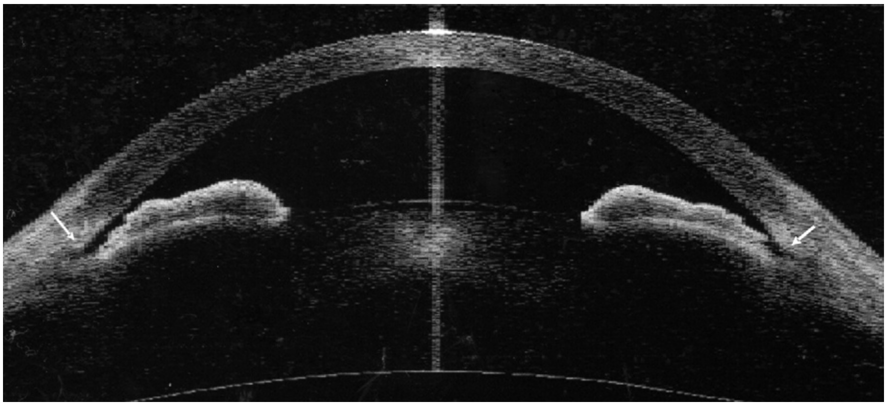

Figure 3. Anterior segment ocular coherence tomography image demonstrating a steep iris profile and an open angle (arrows, location of the scleral spur).

Table 1. Number of Quadrants with Closed Anterior Chamber Angles Observed on Gonioscopy Examination and Anterior Segment Optical Coherence Tomography Images of the 4 Quadrants of 423 Eyes

Quadrant	No. Closed on Anterior Segment Optical Coherence Tomography (%, 95% Confidence Interval)	No. Closed on Gonioscopy (%, 95% Confidence Interval)	*P* Value*
Superior	205 (48, 44–53)	122 (29, 25–33)	<0.001
Inferior	184 (43, 39–48)	93 (22, 18–26)	<0.001
Nasal	76 (18, 15–22)	61 (14, 11–18)	0.11
Temporal	51 (12, 9–15)	83 (20, 16–24)	<0.001
Total	516 (30, 28–33)	359 (21, 19–23)	<0.001

*McNemar test.

excluded patients and 423 included patients ($P>0.40$, data not shown), nor were there any significant differences in the mean anterior chamber depth and axial length between the 2 groups ($P>0.33$). There was also no difference in mean Scheie grade (2.15±0.42 vs. 2.28±0.57, respectively; $P = 0.35$, Mann–Whitney U test) or the proportion of eyes with at least 1 quadrant with closed ACA on gonioscopy (27.8% vs. 32.6%, respectively; $P = 0.48$).

The superior quadrant had the highest frequency of closed ACA, followed by the inferior quadrant both by gonioscopy and AS OCT imaging (Table 1). With gonioscopy, the number of persons with a closed ACA was significantly greater in the superior quadrant than in any other quadrant of the eye ($P<0.03$). With AS OCT imaging, the number of persons with closed ACA quadrants was greater for the superior and inferior quadrants than for the temporal and nasal quadrants ($P<0.001$). When comparing the 2 techniques, the frequency of a closed superior or inferior quadrant was significantly greater using AS OCT, whereas the frequency of a closed temporal quadrant was greater using gonioscopy (Table 1).

A closed angle in at least one quadrant was observed in 249 eyes (59%) by AS OCT, and in 138 eyes (33%) by gonioscopy ($P<0.001$, McNemar test). Ninety eyes (21%) were identified as having closed angles by both techniques. In eyes with only 1 closed quadrant, the superior quadrant was the most commonly affected quadrant. In eyes with 2 closed quadrants, the superior and inferior quadrants were the most commonly closed quadrants (Table 2). The overall agreement between AS OCT and gonioscopy in detecting angle closure in all quadrants was fair ($\kappa = 0.40$; 95% confidence interval, 0.35–0.45). The agreement between AS OCT and gonioscopy in detecting angle closure in the superior, inferior, nasal, and temporal quadrants were as follows: based on κ statistics, 0.41, 0.40, 0.31, and 0.33, respectively; and based on AC1 statistics, 0.45, 0.51, 0.74, and 0.75, respectively. Because the 2 techniques agreed on the ACA status in 71%, 72%, 81%, and 82% of cases in the superior, inferior, nasal, and temporal quadrants, respectively (data not shown), it seems that the AC1 statistics provided more consistent results of the agreement between the 2 techniques. Thus, the results of AC1 statistics suggest that the agreement between the 2 techniques was greater in the temporal and nasal quadrants than in the superior and inferior quadrants.

Of the 1333 quadrants with an open ACA on gonioscopy (Scheie grading I or II), 21% (276) of them were classified as being closed by AS OCT. Most of this type of disagreement between the 2 techniques occurred in the superior and inferior quadrants (Table 3). One third (n = 119) of the 359 quadrants that were closed on

Table 2. Distribution of Closed Anterior Chamber Angle by Quadrants among Eyes with 1, 2, 3, or 4 Closed Anterior Chamber Angle(s) on Anterior Segment Optical Coherence Tomography Images and Gonioscopy

Closed Quadrant(s)	Anterior Segment Optical Coherence Tomography (%, 95% Confidence Interval)	Gonioscopy (%, 95% Confidence Interval)
1 closed quadrant		
Superior	46 (19, 14–24)	30 (22, 17–27)
Inferior	32 (13, 9–17)	8 (6, 3–9)
Nasal	4 (2, 0–4)	3 (2, 0–4)
Temporal	2 (1, 0–2)	3 (2, 0–4)
2 closed quadrants		
Superior/inferior	75 (30, 24–36)	8 (6, 3–9)
Superior/nasal	10 (4, 2–6)	1 (1, 0–2)
Superior/temporal	2 (1, 0–2)	4 (3, 1–5)
Inferior/nasal	3 (1, 0–2)	0 (0, 0–0)
Inferior/temporal	1 (0, 0–0)	1 (1, 0–2)
Nasal/temporal	1 (0, 0–0)	0 (0, 0–0)
3 closed quadrants		
Superior/inferior/nasal	28 (11, 7–15)	5 (3, 1–5)
Superior/inferior/temporal	15 (6, 3–9)	22 (16, 10–22)
Inferior/temporal/nasal	1 (0, 0–0)	3 (2, 0–4)
Superior/temporal/nasal	0 (0, 0–0)	3 (2, 0–4)
4 closed quadrants		
Superior/inferior/nasal/temporal	29 (12, 8–16)	47 (34, 28–40)
Total no. of eyes	249 (100%)	138 (100%)

Table 3. Number of Quadrants with Closed Angles Detected on Anterior Segment Optical Coherence Tomography Images According to Closed or Open Anterior Chamber Angle Status on Gonioscopy

	Closed on Gonioscopy (n = 359 Quadrants)		Open on Gonioscopy (n = 1333 Quadrants)	
Quadrant	*Closed on Anterior Segment Optical Coherence Tomography (%, 95% Confidence Interval)*	*Open on Anterior Segment Optical Coherence Tomography (%, 95% Confidence Interval)*	*Closed on Anterior Segment Optical Coherence Tomography (%, 95% Confidence Interval)*	*Open on Anterior Segment Optical Coherence Tomography (%, 95% Confidence Interval)*
Superior	102 (84, 76–89)	20 (16, 11–24)	103 (34, 29–40)	198 (66, 60–71)
Inferior	80 (86, 78–92)	13 (14, 8–22)	104 (32, 27–37)	226 (68, 63–73)
Nasal	29 (48, 35–60)	32 (52, 40–64)	47 (13, 10–17)	315 (87, 83–90)
Temporal	29 (35, 26–46)	54 (65, 54–74)	22 (6, 4–10)	318 (94, 90–96)
Total	240 (67, 62–71)	119 (33, 28–38)	276 (21, 19–23)	1057 (79, 77–81)

gonioscopy were classified as open using AS OCT. Most of this type of disagreement between the two techniques occurred in the nasal and temporal quadrants (Table 3).

A total of 259 quadrants (15% of all quadrants) were classified as having short iridoangle contact on AS OCT (Fig 2). Of the 276 quadrants that were open on gonioscopy but closed on AS OCT, 196 (71%) had short iridoangle contact. Sixty-three other quadrants had this finding that were graded as having a closed ACA on both gonioscopy and AS OCT imaging (representing 26% of the 240 quadrants graded as closed by both methods).

A total of 101 quadrants (6% of all quadrants) were graded as having steep iris profiles (Fig 3). Among the 119 quadrants that were closed on gonioscopy but open on AS OCT, a steep iris profile was present in 61 (51%) of 119 quadrants. Another 40 quadrants with steep iris profiles were graded as having an open ACA on both gonioscopy and AS OCT.

Discussion

Confirming a previous report,[10] this study found that the ACA is most frequently closed in the superior quadrant on gonioscopy. In a recent population-based study in China, He et al[16] found that the superior quadrant had the narrowest ACA, and the proportion of angles with a closed angle on gonioscopy differed by quadrant (superior > nasal = temporal > inferior).[16,17] Kunimatsu et al[17] investigated the ACA of 80 patients with a shallow peripheral anterior chamber using ultrasound biomicroscopy and reported that the highest rates of closed angles were found on the superior quadrant (79%), followed by the inferior (64%), nasal (33%), and temporal (26%) quadrants. The current study confirms these findings using the AS OCT. A closed ACA was observed more frequently in the superior quadrant, followed closely by the inferior quadrant. In eyes with only 1 or 2 quadrants of closed ACA, the superior and inferior quadrants were the most commonly affected quadrants. The relatively high prevalence of angle closure in the superior and inferior quadrants has implications for AS OCT imaging protocols that aim to determine angle closure. If these quadrants are not imaged, many eyes with angle closure would be missed.

Overall, the agreement in detecting a closed ACA quadrant using AS OCT and gonioscopy was fair with a κ of 0.4, and as in a previous study,[9] AS OCT tended to detect more closed ACAs than gonioscopy. When the 2 techniques differed, the AS OCT tended to image the temporal angles as open when gonioscopically they appeared closed, and the gonioscopist tended to see inferior and superior angles as open when the AS OCT images showed them to be closed. The differing findings between AS OCT and gonioscopy in the various quadrants may be the result of technical difficulties of performing each technique. For example, viewing the temporal (and nasal) angles can be difficult with gonioscopy. Imaging the superior and inferior quadrants with AS OCT can be difficult because of the eyelid, and manipulations to move the lid out of the way may have altered the appearance of the angle on AS OCT. Nolan et al[9] hypothesized that the disagreement between these 2 techniques may be explained partially by the fact that AS OCT uses infrared light and does not require contact with the eye, whereas inadvertent indentation and excessive light during gonioscopy may open the ACA artificially. It is also possible that the discrepant findings between gonioscopy and AS OCT may be the result of the different anatomic landmarks and levels of iridoangle contact used to define a closed angle. Based on subjective grading, short iridoangle contact just above the scleral spur on AS OCT was observed in 71% of quadrants with an ACA graded as open by gonioscopy and closed on AS OCT (Fig 2), as opposed to 26% of quadrants graded as closed by both methods. On AS OCT, this short iridoangle contact is considered to be angle closure, because this was defined as the presence of any contact between the iris and the angle wall anterior to the scleral spur. However, because this apposition may not have occurred up to the level of the posterior trabecular meshwork, the quadrant may not have been graded as closed on gonioscopy, because the gonioscopist graded the ACA based on a view of most of the posterior trabecular meshwork in the entire quadrant.

Among the cases with ACA judged to be closed on gonioscopy but open on Visante OCT, the presence of a steep, so-called over-the-hill iris configuration on Visante OCT was determined subjectively in 51% of these quadrants. We hypothesize that, in such cases, the pronounced convexity of the iris might have blocked the indirect view of angle structures with a gonioscopy lens, regardless of the attempt to gain view over the convexity of the iris, leading to a closed ACA appearance as seen with gonioscopy (particularly when using a grading system based on the angle structures visible during the examination). An alternative hypothesis is that, during the attempt to gain view over the convexity of the iris, accidental pressure on the edge of the gonioscope might have resulted in inadvertent mechanical distortion of the cornea, making the drainage angle appear artificially narrower.[10,18] However, it is important to note that 40 of the quadrants with a steep iris profile were graded as having an open ACA on both gonioscopy and AS OCT. It is possible that in these cases, the gonioscopist was able to identify an open angle despite the steep iris profile or that excessive light or inadvertent indentation during the gonioscopy might have opened the ACA artificially.

This study has some limitations. The analysis of the ACA in each quadrant by AS OCT was based on only a cross-sectional image of the angle, and there may be variations in the quadrant that may be missed by this image. Although this study demonstrated that most of the ACA imaged by the AS OCT could be graded, the number of images in which the ACA status cannot be determined may be higher in clinical practice, especially if performed by inexperienced technicians or if the images are qualitatively assessed by individual observers with less expertise. The use of a single observer could result in a systematic bias of the gonioscopy findings and is a weakness of the study. Another limitation relates to the fact that the reproducibility of detecting a closed ACA in AS OCT images was not assessed in this study. Future studies must evaluate the factors related to the reproducibility of the qualitative assessment of ACA in images obtained with Visante OCT, including variations related to image acquisition and those related to the subjective grading of the ACA. In addition, studies comparing AS OCT with a more comprehensive gonioscopic grading system such as the Spaeth system, or with other imaging methods of assessing the ACA such as ultrasound biomicroscopy, may provide further insights to the discrepancies between gonioscopy and AS OCT.

In summary, this study demonstrated that the superior quadrant showed the highest rates of closed angles on both gonioscopy and AS OCT imaging and the relative rates of closed angles among the different quadrants differed between each technique. Particularities in the methods of assessing and interpreting the ACA configuration of each technique may account for some of these discrepancies. Longitudinal prospective studies are required to determine the value of AS OCT findings in the management of patients with angle closure.

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