

# Diagnostic Performance of Optical Coherence Tomography and Nonspecialist Gonioscopy to Detect Angle Closure

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## ABSTRACT

**Aim:** To compare the usefulness of gonioscopy performed by general ophthalmologists (GO) and anterior segment optical coherence tomography (AS-OCT) in detecting angle closure in patients with a shallow anterior chamber.

**Methods:** Forty-four patients with a shallow anterior chamber (defined by a ratio of peripheral anterior chamber depth to peripheral corneal thickness lower than 1/2) were included in this cross-sectional study. Gonioscopy was performed in all subjects by two glaucoma experts (GE1 and GE2) and one GO. Anterior segment imaging was performed using Visante® OCT (Carl Zeiss Meditec Inc.). Agreement between examiners was assessed with first-order agreement coefficients (AC1). Diagnostic accuracies of GO gonioscopy and AS-OCT were evaluated using sensitivity, specificity, and area under the receiver operating characteristic (AROC) curves.

**Results:** For static gonioscopy, the agreement between GE1 and GE2 was substantial (AC1 = 0.65), and that between GE1 and GO was moderate (AC1 = 0.50). For indentation gonioscopy, the agreement between GE1 and GE2 was slightly lower (AC1 = 0.55); however, the agreement between GE1 and GO showed a larger reduction (AC1 = 0.12). GO's gonioscopy presented a low specificity (25%) and the AROC to angle closure detection was lower than AS-OCT (0.56–0.73). Combined information of GO gonioscopy and AS-OCT improved specificity (85.7%) and AROC (0.77) of angle closure evaluation.

**Conclusion:** Agreement between GO and glaucoma experts was moderate for static gonioscopy and slight for indentation gonioscopy. AS-OCT performed better than GO gonioscopy in detecting angle closure in patients with a shallow anterior chamber. The addition of AS-OCT to clinical information in patients with GO positive gonioscopy improved the specificity and AROC of gonioscopy test.

**Keywords:** Angle-closure, Anterior segment optical coherence tomography, Gonioscopy, Primary angle-closure glaucoma.

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## INTRODUCTION

Primary angle-closure glaucoma (PACG) accounts for one-third of glaucoma cases worldwide. However, half of the glaucoma-related blindness cases are caused by PACG. Early identification and prevention of angular closure could prevent progression to blindness in approximately 70% of cases.<sup>1</sup>

Patients showing a shallow anterior chamber during slit-lamp biomicroscopy by Van Herick method (VHM) should be evaluated by gonioscopy due to the risk of PACG development.<sup>2,3</sup> However, VHM fails to detect 21% to 42% of patients who show closed angles by gonioscopy.<sup>4</sup> Gonioscopy is the gold standard to evaluate anterior chamber angle status and detect iridotrabecular contact signs such as synechiae or imprints. These findings, in association with both intraocular pressure (IOP) measurement and optic nerve head (ONH) evaluation, can help classify the stage of the disease and define the therapeutic approach to be adopted.<sup>5</sup>

Despite its importance in the management of shallow anterior chamber patients, gonioscopy presents several limitations: it is a subjective evaluation, grading may vary among clinicians, it requires a gonioscopic lens, and considerable training is required to identify the angle structures during static gonioscopy, perform indentation, detect imprints or synechiae, and grade trabecular meshwork pigmentation. An automated gonioscopy technique was developed recently (NGS-1; Nidek Co. Gamagori, Japan), but it showed only slight agreement with manual gonioscopy.<sup>6</sup>

Anterior segment optical coherence tomography (AS-OCT) uses the principle of low-coherence interferometry

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to obtain cross-sectional images of the entire anterior chamber.<sup>7</sup> It is a semiautomatic in vivo imaging examination that does not require any contact with the eye and has good reproducibility.<sup>8,9</sup> Moreover, AS-OCT shows a higher sensitivity to detect angular closure when compared to gonioscopy performed by well-trained physicians.<sup>10–12</sup>

The learning curve for successful gonioscopy is slightly steep, and a non-glaucoma-trained ophthalmologist may occasionally not perform the examination with adequate accuracy. AS-OCT can help general ophthalmologists (GOs) establish the diagnosis of angle closure. This study aims to compare the usefulness of AS-OCT and gonioscopy performed by glaucoma-trained and GOs in detecting angle closure in patients with a shallow anterior chamber.

## MATERIALS AND METHODS

This cross-sectional study was approved by the Institutional Ethics Committee of the Federal University of São Paulo, Brazil. It was performed in accordance with the ethical standards laid down in the Declaration of Helsinki and the International Conference on Harmonization Guidelines for Good Clinical Practice. Written informed consent was obtained from all individual participants before inclusion in the study.

All subjects underwent a comprehensive ophthalmologic examination, including a review of medical history, best-corrected visual acuity (BCVA) measurement, manifest refraction, slit-lamp biomicroscopy, Goldmann applanation tonometry, gonioscopy, and non-dilated fundoscopic examination with a 90D fundus lens (Volk; Mentor, OH, USA). Axial length (AXL) and anterior chamber depth (ACD) were measured with IOL Master 500 (Carl Zeiss Meditec Inc., Dublin, CA, USA). All subjects were consecutive evaluated and were referred to the glaucoma division for angle-closure evaluation. Only subjects with a peripheral ACD to peripheral corneal thickness (PACD:PCT) ratio lower than 1/2 were included and divided into the following groups: lower than 1/4 (grade 1); and from 1/4 to less than 1/2 (grade 2). Subjects with a history of ocular trauma or previous intraocular surgery, including laser peripheral iridotomy or iridoplasty, were excluded.

### Gonioscopy

Gonioscopy was performed by two glaucoma experts (GEs) and one GO masked to AS-OCT findings. A GE was considered as an ophthalmologist who completed at least a 1-year glaucoma fellowship and was attending at the institution glaucoma service. GE1 and GE2 were the first and second experts to perform the gonioscopy examinations. The GO was a board-certified physician attending fellowship programs other than that for glaucoma at the institution. The examinations were noted in separate forms, and the examiners did not have access to them. Only the first examined eye was included in this protocol.

All subjects were evaluated in a darkened room with a Sussman 4-mirror lens (Ocular Inst., Bellevue, WA, USA) at high magnification (16x), with the eye in the primary gaze position. A 1-mm beam of light was reduced to a narrow slit to evaluate the anterior chamber angle. Care was taken to avoid directing the beam of light at the pupil. Gonioscopy results were recorded according to the visibility of the angle anatomical landmarks (Schwalbe's line, non-pigmented trabecular meshwork, pigmented trabecular meshwork, scleral spur, and ciliary body band) during static (without indentation) and dynamic gonioscopy. The presence of iridotrabecular contact signs (imprints or synechiae) in quadrants was also recorded.

### AS-OCT

Anterior segment imaging was performed using Visante® OCT (Carl Zeiss Meditec Inc., Dublin, CA, USA) under dark ambient lighting. All scans were centered on the pupil and acquired using the Enhanced Anterior Segment Scan protocol on the horizontal axis (3 h–9 h) to evaluate the nasal and temporal quadrants, and the vertical axis (12 h–6 h) to evaluate the superior and inferior quadrants. Care was taken to avoid inadvertent pressure on the eye when the upper and lower eyelids were displaced to acquire vertical axis images.

All images were exported to ImageJ® software (V.1.50i) and analyzed by an examiner masked to gonioscopy results. Only images with a clearly discernible scleral spur (SS) and correctly

centered on the pupil at the vertical and horizontal axes were analyzed. After manually marking SS, the angle variables were quantified. The parameters measured were defined as follows. The angle opening distance (AOD) represents the perpendicular distance between the cornea and iris at 250 (AOD250) and 500 (AOD500) micrometers (μm) from the SS. The trabecular-iris space area (TISA500) represents the trapezoidal area lying between the inner corneoscleral wall, the line of the AOD500 track, the anterior iris surface, and the perpendicular line drawn from the SS to the opposing point of the iris. The trabecular-iris angle (TIA) represents the angle between the point 500 μm anterior to SS and the point perpendicular to the iris surface, with the apex at the angle recess. The trabecular-iris contact length (TICL) represents the linear distance of the corneoscleral surface from the SS at the end of the appositional or synechial angle closure. Lens vault (LV) was defined as the perpendicular distance from a plotted line between the opposed SS and the anterior lens capsule. Pupillary distance (PD) was the internal diameter of the pupil during the exam. Iris thickness (IT) was measured from the point at the anterior surface of the iris located 750 μm (IT750) and 2000 μm (IT2000) from SS. The iris curvature (ICURVE) represents the distance of a perpendicular line extending from a line drawn from the most peripheral to the most central point of the posterior iris to the iris pigment epithelium at the point of greatest convexity. The iris area (IAREA) was the cross-sectional area of the full length of the iris on the image scan.<sup>13</sup>

### Main Outcome Variables

An anterior chamber angle quadrant was considered closed on gonioscopy when the pigmented trabecular meshwork could not be identified during static gonioscopy evaluation and on AS-OCT when any contact between the iris and corneoscleral surface anterior to the SS could be detected and measured (TICL > 0).

An eye was defined as showing angle closure on gonioscopy when two or more quadrants were classified as closed.

### Statistical Analyses

All statistical analyses were performed with Stata® software (Stata version 15; StataCorp, College Station, TX, USA). Student's *t*-test was used to compare age, BCVA, spherical equivalent (SE), IOP, AXL, ACD, and all angle variables between eyes with and without angle closure.

The first-order agreement coefficient (AC1) statistic was used to assess the agreement between categorical variables. We preferred AC1 statistics over Kappa statistics since the prevalence of positive classification (presence of trabecular-iris contact, for example) was low.<sup>14</sup> Qualitative ratings of agreement statistics were used based on the definitions proposed by Landis and Koch: poor (<0), slight (0–0.2), fair (0.2–0.4), moderate (0.4–0.6), substantial (0.6–0.8), and almost perfect (0.8–1.0) agreement.<sup>15</sup>

Sensitivity, specificity, and the area under the receiver operating characteristic (AROC) curve was used to compare the diagnostic accuracies of GO gonioscopy and AS-OCT to detect angle closure, using gonioscopy performed by GE1 as the reference.<sup>16</sup>

The alpha level (type I error) was set at 0.05.

## RESULTS

Forty-four eyes of 44 patients were enrolled in this cross-sectional study. Thirty-seven (84%) subjects were female, and 34 (77%) self-declared themselves as Caucasians. Eleven (25%) subjects referred a relative with glaucoma, and 14 (32%) patients were

using hypotensive drops. Nine (20%) subjects presented a vertical cup-disc ratio higher than 0.6. The PACD:PCT was grade 1 in 26 (59%) and grade 2 in 18 (41%) subjects.

The mean age was  $65.8 \pm 9.2$  years, ranging from 46.2 to 83.6 years. Mean BCVA was  $0.14 \pm 0.22$  logMAR, and SE was  $+0.91 \pm 2.06$  D. Mean IOP was  $15.61 \pm 3.85$  mm Hg. AXL and ACD were  $22.4 \pm 0.9$  mm and  $2.6 \pm 0.3$  mm, respectively.

### Gonioscopy

We evaluated 176 quadrants (superior, nasal, inferior, and temporal) of all included eyes. GE1 classified 132 quadrants as closed; in 85 (64%) quadrants, only Schwalbe's line was observed, while in 47, both Schwalbe's line and non-pigmented trabecular meshwork were seen. A closed-angle was detected at the superior, nasal, inferior, and temporal quadrants in 75%, 75%, 82%, and 68% of the evaluated patients, respectively. During dynamic gonioscopy, 167 quadrants were considered open, and it was possible to identify the pigmented trabecular meshwork in 17 quadrants, the scleral spur in 100, and the ciliary body band in 50 quadrants. We detected peripheral anterior synechiae in 28 quadrants, imprints in 21, and both in eight quadrants.

Considering all included quadrants during static gonioscopy, the general agreement between GE1 and GE2 was substantial ( $AC1 = 0.65$ ), and that between GE1 and GO was moderate ( $AC1 = 0.50$ ). In the analysis of indentation gonioscopy, we observed a reduction

in agreement both for GE1 vs GE2 ( $AC1 = 0.55$ ) and GE1 vs GO ( $AC1 = 0.12$ ). However, during dynamic gonioscopy, and using the answer if the quadrant was open or closed as the clinical surrogate endpoint, GE1 and GE2 showed a substantial agreement ( $AC1 = 0.76$ ), and the agreement between GE1 and GO was fair ( $AC1 = 0.39$ ).

Agreement on the identification of iridotrabecular contact signs was moderate for both comparisons (GE1 vs. GE2- $AC1 = 0.46$ ; GE1 vs GO- $AC1 = 0.55$ ; Table 1).

### Quantitative Analysis

The SS was not identified in 18 (10%) quadrant scans of nine eyes due to poor-quality images, and these were excluded from the quantitative analysis. The remaining 28 eyes were classified as showing angle closure and seven as open angles, according to gonioscopy status.

At the nasal and temporal quadrants, angles classified as closed in gonioscopy presented lower AOD250, AOD500, TISA500, TIA, and higher TICL. At the superior quadrant, closed angles presented lower AOD500. No differences between closed and open angles were observed in the inferior quadrant. Moreover, there were no significant differences in IT750, IT2000, ICURVE, and IAREA in the evaluated quadrants (Table 2).

The LV ( $882.49 \pm 222.45$   $\mu$ m vs  $680.69 \pm 298.38$  mm,  $p = 0.13$ ) and PD at the horizontal axis ( $4.09 \pm 0.82$  mm vs  $3.99 \pm 1.28$  mm,

**Table 1:** Glaucoma experts and general ophthalmologist agreement on static and dynamic gonioscopy plus signs of iridotrabecular contact

Quadrant	GE1 vs GE2		GE1 vs GO	
	AC1 (95% CI)	Ratings	AC1 (IC 95%)	Ratings
<i>Static gonioscopy (*)</i>				
All quadrants	0.65 (0.56–0.73)	Substantial	0.50 (0.41–0.60)	moderate
Superior	0.61 (0.41–0.80)	Substantial	0.59 (0.43–0.75)	moderate
Nasal	0.64 (0.49–0.80)	Substantial	0.58 (0.40–0.77)	moderate
Inferior	0.71 (0.58–0.84)	Substantial	0.31 (0.09–0.54)	fair
Temporal	0.64 (0.45–0.83)	Substantial	0.52 (0.33–0.71)	moderate
<i>Dynamic gonioscopy (*)</i>				
All quadrants	0.55 (0.46–0.65)	Moderate	0.12 (0.00–0.24)	slight
Superior	0.55 (0.34–0.76)	Moderate	0.07 (-0.18–0.33)	slight
Nasal	0.52 (0.32–0.72)	Moderate	0.10 (-0.14–0.34)	slight
Inferior	0.57 (0.38–0.76)	Moderate	0.29 (0.05–0.53)	fair
Temporal	0.59 (0.41–0.78)	Moderate	0.03 (-0.19–0.25)	slight
<i>Dynamic gonioscopy (open vs closed)</i>				
All quadrants	0.76 (0.67–0.86)	Substantial	0.39 (0.24–0.54)	fair
Superior	0.76 (0.55–0.96)	Substantial	0.39 (0.09–0.70)	fair
Nasal	0.71 (0.49–0.93)	Substantial	0.30 (-0.03–0.62)	fair
Inferior	0.78 (0.60–0.96)	Substantial	0.59 (0.34–0.84)	moderate
Temporal	0.81 (0.63–0.98)	Almost perfect	0.25 (-0.09–0.58)	fair
<i>Iridotrabecular contact (PAS, imprints or both)</i>				
All quadrants	0.46 (0.36–0.57)	Moderate	0.55 (0.45–0.64)	moderate
Superior	0.69 (0.51–0.87)	Substantial	0.70 (0.53–0.86)	substantial
Nasal	0.37 (0.15–0.59)	Fair	0.52 (0.33–0.72)	moderate
Inferior	0.50 (0.28–0.71)	Moderate	0.52 (0.33–0.72)	moderate
Temporal	0.29 (0.06–0.51)	Fair	0.44 (0.24–0.64)	moderate

AC1, first-order agreement coefficient; 95% CI, 95% Confidence Interval; PAS, peripheral anterior synechiae; GE1, glaucoma expert 1; GE2, glaucoma expert2; GO, general ophthalmologist

(\*) all landmarks of gonioscopy were considerate as surrogate endpoint to weighted analysis

**Table 2:** Anterior segment optical tomography quantitative angle parameters in open and closed quadrants by gonioscopy

	<i>All quadrants Mean (SD)</i>	<i>Open quadrants Mean (SD)</i>	<i>Closed quadrants Mean (SD)</i>	<i>p-value</i>
<i>Superior</i>	<i>n = 35</i>	<i>n = 9</i>	<i>n = 26</i>	
AOD250, mm	0.04 (0.06)	0.07 (0.07)	0.03 (0.06)	0.15
AOD500, mm	0.07 (0.09)	0.14 (0.11)	0.04 (0.07)	0.03*
TISA500, mm <sup>2</sup>	0.02 (0.03)	0.03 (0.04)	0.01 (0.02)	0.16
TIA, degrees	5.07 (8.20)	10.12 (12.09)	3.32 (5.69)	0.14
TICL, mm	0.54 (0.46)	0.31 (0.39)	0.61 (0.46)	0.08
IT750, mm	0.44 (0.09)	0.47 (0.07)	0.43 (0.10)	0.21
IT2000, mm	0.49 (0.08)	0.50 (0.11)	0.48 (0.07)	0.64
ICURVE, mm	0.27 (0.06)	0.23 (0.08)	0.29 (0.05)	0.11
IAREA, mm <sup>2</sup>	1.81 (0.28)	1.94 (0.35)	1.76 (0.24)	0.19
<i>Nasal</i>	<i>n = 35</i>	<i>n = 8</i>	<i>n = 27</i>	
AOD250, mm	0.11 (0.08)	0.17 (0.05)	0.09 (0.08)	0.01*
AOD500, mm	0.13 (0.11)	0.24 (0.11)	0.10 (0.10)	0.01*
TISA500, mm <sup>2</sup>	0.05 (0.04)	0.09 (0.02)	0.04 (0.04)	<0.001*
TIA, degrees	12.69 (10.72)	22.90 (10.15)	9.67 (9.01)	0.007*
TICL, mm	0.26 (0.41)	0 (0)	0.34 (0.44)	<0.001*
IT750, mm	0.46 (0.09)	0.42 (0.06)	0.47 (0.10)	0.13
IT2000, mm	0.47 (0.09)	0.43 (0.09)	0.48 (0.09)	0.19
ICURVE, mm	0.26 (0.07)	0.26 (0.08)	0.27 (0.07)	0.95
IAREA, mm <sup>2</sup>	1.61 (1.53)	1.61 (0.30)	1.62 (0.24)	0.93
<i>Inferior</i>	<i>n = 35</i>	<i>n = 6</i>	<i>n = 29</i>	
AOD250, mm	0.07 (0.10)	0.13 (0.15)	0.06 (0.08)	0.31
AOD500, mm	0.11 (0.12)	0.20 (0.19)	0.09 (0.10)	0.23
TISA500, mm <sup>2</sup>	0.03 (0.05)	0.06 (0.07)	0.02 (0.04)	0.26
TIA, degrees	7.57 (10.60)	14.99 (17.91)	6.03 (8.06)	0.28
TICL, mm	0.43 (0.47)	0.23 (0.35)	0.48 (0.48)	0.17
IT750, mm	0.46 (0.09)	0.40 (0.08)	0.48 (0.09)	0.08
IT2000, mm	0.44 (0.07)	0.41 (0.08)	0.45 (0.06)	0.31
ICURVE, mm	0.29 (0.07)	0.27 (0.09)	0.30 (0.06)	0.49
IAREA, mm <sup>2</sup>	1.72 (0.26)	1.73 (0.38)	1.72 (0.23)	0.96
<i>Temporal</i>	<i>n = 35</i>	<i>n = 13</i>	<i>n = 22</i>	
AOD250, mm	0.08 (0.09)	0.14 (0.08)	0.04 (0.06)	<0.001*
AOD500, mm	0.12 (0.11)	0.22 (0.09)	0.07 (0.07)	<0.001*
TISA500, mm <sup>2</sup>	0.04 (0.04)	0.08 (0.04)	0.02 (0.03)	<0.001*
TIA, degrees	10.62 (10.56)	20.17 (9.12)	4.98 (6.58)	<0.001*
TICL, mm	0.31 (0.35)	0.04 (0.11)	0.47 (0.36)	<0.001*
IT750, mm	0.41 (0.08)	0.39 (0.09)	0.43 (0.07)	0.30
IT2000, mm	0.46 (0.09)	0.42 (0.07)	0.48 (0.09)	0.06
ICURVE, mm	0.29 (0.08)	0.30 (0.08)	0.29 (0.08)	0.50
IAREA, mm <sup>2</sup>	1.64 (0.27)	1.66 (0.30)	1.63 (0.26)	0.77

SD, standard deviation; AOD250, angle opening distance at 250  $\mu$ m of scleral spur; AOD500, angle opening distance at 500  $\mu$ m of scleral spur; TISA, trabecular iris space area; TIA, trabecular iris angle; TICL, trabecular-iris contact length; IT750, iris thickness at 750  $\mu$ m of scleral spur; IT2000, iris thickness at 2000  $\mu$ m of scleral spur; ICURVE, iris curvature; IAREA, iris area



$p = 0.24$ ) were not significantly different between angle-closure and open-angle eyes.

### Closed Quadrant Detection

One hundred and fifty-eight quadrants were analyzed by AS-OCT and gonioscopy performed by GE1 and GO. Sixty quadrants were classified as closed and 18 as open by both examiners and AS-OCT. GE1 detected more closed quadrants ( $n = 115$ , 73%) than GO ( $n = 103$ , 65%) and AS-OCT ( $n = 90$ , 57% - Fig. 1).

Considering GE1's gonioscopy findings as a reference standard to angle-closure detection, GO's gonioscopy presented a higher sensitivity but lower specificity and AROC than AS-OCT. If the AS-OCT test was included only to patients with an angle-closure diagnosis on GO's gonioscopy, this combined information presented a higher specificity and AROC than gonioscopy and AS-OCT alone (Table 3 and supplemental figure). Supplemental table presents the cross-tabulation of the index test results by the results of the reference standard.

### DISCUSSION

The agreement between GO and GE was moderate for static gonioscopy and slight for indentation gonioscopy, and this imbalance could impact the correct therapeutics for patients at risk of PACG. Moreover, GO specificity was very low in our cohort with shallow anterior chamber patients. The use of AS-OCT in patients with positive diagnoses by GO, could reduce the number of false-positive results.

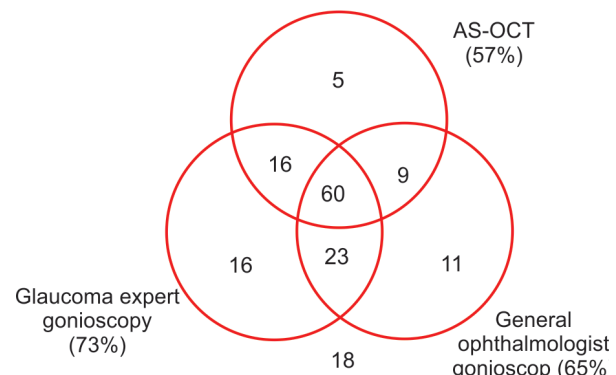
In populations with a low prevalence of PACG, the use of AS-OCT for angle-closure screening is not cost-effective. However, this technology could help GOs make an early diagnosis of a potential sight-threatening problem.

Gonioscopy findings are used to classify the anterior chamber angle status and define the management of eyes with angle closure. The absence of visualization of the pigmented trabecular meshwork over 180° or more, during static gonioscopy, is used to define suspected primary angle closure. If, besides these findings, 'peripheral anterior synechiae or imprints were identified, the subject was classified as showing primary angle-closure, or PACG when glaucomatous optic neuropathy was also detected. GE1 and GE2s showed substantial agreement in static gonioscopy evaluations ( $AC1 = 0.65$ , 95% CI 0.56–0.73), and the agreement between GE1 and GO was moderate (0.50, 95% CI 0.41–0.60). We observed a significant reduction in the agreement of GE1 and GO during indentation ( $AC1 = 0.12$ , 95% CI = 0.00–0.24), which could be justified by the difficulty with the maneuver. Johnson et al. detected an excellent agreement between ophthalmology residents and

GE-attending physicians ( $k = 0.84$ ,  $p < 0.01$ ). In their sample, the majority of patients presented with an open-angle status, and this condition could favor the agreement between examiners; moreover, the authors attributed the high agreement to adequate training of their residents on gonioscopy skills.<sup>4</sup>

The identification of iridotrabecular contact possibly presents a more challenging clinical situation, and, therefore, agreement in detecting peripheral anterior synechiae, imprints, or both was only moderate in both comparisons (0.46 for GE1 and GE2; and 0.40 for GE1 and GO). Although OCT helps in angle-closure detection, it is not capable of detecting or differentiating synechiae and imprints or other causes of angle closure.

In contrast to previous reports, in the present study, gonioscopy detected more closed angles than AS-OCT. Sakata et al. described closed-angle detection in at least one quadrant in 59% of the eyes evaluated by AS-OCT and 33% of those evaluated by gonioscopy, in a large cohort of Chinese subjects with mean ACD of  $3.12 \pm 0.36$  mm and AXL of  $23.71 \pm 3.25$  mm.<sup>12</sup> In our study, AS-OCT detected a closed quadrant in 57% of the evaluated quadrants in patients with mean AXL and ACD values of  $22.4 \pm 0.9$  mm and  $2.6 \pm 0.3$  mm, respectively. Nolan et al. also detected more quadrants closed by AS-OCT than gonioscopy (66.7% vs 44.4%, in the nasal, temporal, and inferior quadrants in dark conditions), in a cohort including primary angle-closure suspects, PACG, primary open-angle glaucoma, and normal subjects.<sup>11</sup> In our study, we included only patients with a shallow anterior chamber at slit-lamp biomicroscopy, and gonioscopy performed by GE1 detected 73% (115/158) while AS-OCT detected 57% (90/158) of closed quadrants in all evaluated scans.



**Fig. 1:** Venn diagram showing agreement between gonioscopy and anterior segment optical coherence tomography (AS-OCT) in detecting closed quadrants. One hundred fifty-eight quadrants were evaluated by gonioscopy (glaucoma experts and general ophthalmologists) and AS-OCT

**Table 3:** Diagnostic accuracy of gonioscopy performed by general ophthalmologist, Visante® OCT and combined information for positive response of gonioscopy

Index test	Sensitivity (95% CI)	Specificity (95% CI)	AROC (95% CI)
GO	86.1% (70.5–95.3%)	25.0% (3.2–65.1%)	0.56 (0.39–0.73)
AS-OCT	75.0% (55.1%–89.3%)	71.4% (29–96.3%)	0.73 (0.53–0.93)
GO and AS-OCT	67.9% (47.6–84.1%)	85.7% (42.1–99.6%)	0.77 (0.60–0.93)

GO, general ophthalmologist; AS-OCT, anterior segment optical coherence tomography; 95% CI, 95% confidence interval; AROC, area under the receiver operating characteristic curve

Gonioscopy performed by glaucoma expert 1 was considered the reference standard.

In our sample, patients with closed nasal and temporal quadrants presented with significantly narrower angle parameters (AOD250, AOD500, TIA, and TISA 500) than those with open quadrants. Moghimi et al. studied fellow eyes of acute primary angle-closure and phacomorphic angle-closure eyes and found that  $AOD750 < 161 \mu\text{m}$  and  $LV > 768.6 \mu\text{m}$  could distinguish between these two mechanisms of angle closure.<sup>17</sup> In our study, we did not observe a statistically significant difference between the LV parameter among patients with a shallow anterior chamber who presented open-angle and angle-closure ( $882.49 \pm 222.45 \mu\text{m}$  vs  $680.69 \pm 298.38 \mu\text{m}$ ,  $p = 0.13$ ). In agreement with previous reports, we also found that superior quadrants had a narrower angle than the other ones.<sup>18,19</sup>

Our study had several limitations. First, we evaluated a small sample with different angle-closure mechanisms. A shallow anterior chamber was the main inclusion criterion; therefore, this information could influence examiners to detect more angle-closure quadrants. We cannot affirm that the GO who participated in this study was representative of physicians without expertise in glaucoma. Moreover, only one grader evaluated all AS-OCT scans using the ImageJ® software, and manually marked the scleral spur before angle parameter measurements were performed. Furthermore, the gonioscopic diagnosis was based on visual inspection of the entire quadrant, while the tomographic evaluation was based on the analysis of only one point per quadrant, which could justify some disagreement between the methods used herein.

In conclusion, GO presented a moderate agreement with GE during static gonioscopy of eyes with a shallow anterior chamber, but a slight agreement during the indentation maneuver. AS-OCT in darkroom conditions showed better diagnostic performance than gonioscopy performed by a GO to detect angle closure in patients with a shallow anterior chamber; however, it could detect fewer closed angles than GE. Therefore, AS-OCT could be useful for GOs without daily practice in gonioscopy to detect angle closure in patients with the shallow anterior chamber by slit-lamp biomicroscopy.

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