Diagnostic accuracy of AS-OCT vs gonioscopy for detecting angle closure: a systematic review and meta-analysis

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Abstract

Purpose This study aims to review the literature that compares the accuracy of Anterior Segment-Optical Coherence Tomography (AS-OCT) against gonioscopy in detecting eyes with angle closure. It is currently unclear how AS-OCT fits into clinical practice for detecting angle closure. This is a systematic review and meta-analysis.

Methods A literature search was performed on Medline, Embase, Scopus and the Cochrane Central Register of Controlled Trials to identify studies that investigated the diagnostic accuracy of AS-OCT in detecting eyes with angle closure as diagnosed by gonioscopy. Eligible studies included in the analysis met stringent inclusion criteria determining the sensitivity and specificity of AS-OCT.

Results The initial search identified 727 studies, of which 23 were included in the final analysis. We found substantial variation in the parameters being studied and methodologies. The sensitivity of AS-OCT ranged from 46 to 100% (median 87%). Twenty-one studies identified parameters that showed sensitivity above 80%. The specificity ranged from 55.3 to 100% (median 84%).

Conclusion AS-OCT demonstrates good sensitivity for detecting angle closure. It may provide an avenue to address high rates of undiagnosed angle closure, such as found in developing Asian countries. However, AS-OCT is not yet able to replace gonioscopy. Clinicians should consider whether the diagnostic accuracy of AS-OCT is acceptable for their specific clinical use before adopting it. More studies are needed to determine the utility of AS-OCT, including longitudinal studies to determine the significance of eyes classified to have closed angles by AS-OCT but open on gonioscopy.

Keywords Anterior segment optical coherence tomography · OCT · Glaucoma · Narrow angle · Gonioscopy · Screening
Introduction

Primary angle closure glaucoma (PACG) affects an estimated 23 million people worldwide, with over 80% of cases found in Asia [1]. PACG is a more aggressive form of glaucoma, and despite accounting for only around 26% of glaucoma cases, it causes almost half of the blindness [2]. It confers a three times higher risk of blindness compared to primary open angle glaucoma (POAG) [2–4]. Angle closure disease is significantly underdiagnosed worldwide, particularly in rural or developing areas, causing a significant burden of blindness. In China, over 90% of primary angle closure cases were undiagnosed in 2010 [5]. PACG is also frequently misdiagnosed, with up to two-thirds of cases misdiagnosed as POAG in one Indian study [6].

Identifying eyes with angle closure, including primary angle closure suspects (PACS), is critical for several reasons. Firstly, PACG is a more aggressive disease than POAG and there is a greater risk of vision loss if left untreated [2]. Almost 30% of eyes with angle closure and peripheral anterior synechiae or high pressures will progress to PACG within 5 years [7]. Secondly, the treatment for PACG is different to POAG. Treatment can effectively reduce the intraocular pressure and reduce risk of glaucomatous progression. Finally, it may identify eyes at higher risk of acute angle closure with mydriatic agents [8].

Fig. 1 Angle opening distance at 500 μm (AOD500)—the distance between the corneal endothelium and iris along a line drawn perpendicularly from a point on the corneal endothelium 500 microns anterior to the scleral spur. Trabecular-iris space area at 500 μm (TISA500)—the area enclosed by the AOD500 line, the anterior iris surface, the corneal endothelium/trabecular meshwork and a line drawn perpendicular from the scleral spur. Angle recess area at 500 μm (ARAS500)—the area enclosed by the AOD500 line, anterior iris surface and the corneal endothelium/trabecular meshwork/ciliary body. Anterior chamber angle (ACA)—this may be formally defined using the trabecular-iris angle at 500 μm (TIA500). The angle subtended by the AOD500 line from the apex of the iris recess. Lens vault (LV)—the perpendicular distance between the anterior apex of the lens and the line that joins the two opposite scleral spurs. Anterior chamber depth (ACD)—the distance between the corneal endothelium and anterior surface of the lens along the central axis. Anterior chamber volume (ACV)—the volume of the anterior chamber. Iridotrabecular contact index (ITC index)—a parameter that reflects the circumferential extent of anterior angle with iridocorneal touch. Iridotrabecular contact length (ITC length)—the distance between the scleral spur and the anterior extent of iridocorneal touch. Iridotrabecular contact area (ITC area)—the total area of ITC in the eye, determined by ITC length around the circumference of the eye. Trabecular-iris circumference volume at 500 μm (TICV500)—the total volume of trabecular-iris space in the eye, determined by TISA500 around the circumference of the eye.
Detection of angle closure relies on careful assessment of the anterior chamber angles. The gold standard method is gonioscopy [9]. This can be performed with basic equipment and allows 360-degree visualisation of the anterior chamber angle. However, it has several downsides including that it requires a significant amount of skill from the practitioner, compliance from the patients, contact with the eye and only fair repeatability [10]. The skill required is a significant barrier to effective detection of angle closure. Very few clinicians can perform gonioscopy well, contributing to the high rate of undiagnosed angle closure disease. In a USA-based study, optometrists were 46% less likely to diagnose angle closure disease than ophthalmologists [11]. Poorer countries are even less likely to have skilled clinicians and the equipment needed for assessment by gonioscopy. For these reasons, gonioscopy is not suitable for large scale screening. There is a need for better screening tools to improve detection rates of angle closure, especially in rural areas or developing countries [12].

Anterior segment optical coherence tomography (AS-OCT) is a computerised imaging technology that provides optical cross-sectional images of ocular structures. It has become an invaluable tool for assessing the anterior segment as it provides high-resolution visualisation of the cornea and anterior chamber as well as objective measures of anterior eye parameters (Fig. 1).

Although AS-OCT can provide excellent data on the structure of the anterior chamber angle, it remains unclear how it fits into clinical practice for detecting angle closure. The largest review by the American Academy of Ophthalmology was conducted on studies up from 2005 to 2011 and concluded that AS-OCT could provide useful supplemental information when used alongside gonioscopy [13]. A review by Porporato et al. (2018) found that AS-OCT had good sensitivity and diagnostic accuracy but did not include several studies of lower level of evidence [14]. Both reviews did not focus on collating sensitivity and specificity data to compare AS-OCT against gonioscopy. A review by Chansangpetch et al. (2018) did not conduct the review systematically [15]. A Cochrane review by Jindal et al. (2020) assessed non-contact tests for angle closure but did not compare against gonioscopy as a reference standard [16].

This study aimed to systematically review the literature investigating the diagnostic accuracy AS-OCT in the detection of angle closure, thus determining the utility of AS-OCT in clinical practice. This systematic review was conducted with a focus on reviewing the sensitivity and
specificity of parameters that can be measured with AS-OCT when compared against gonioscopy as the reference standard (Fig. 2).

**Methods**

This paper was written in accordance with the 1964 Declaration of Helsinki and its later amendments. The University of Sydney ethics committee waived the need for ethics approval due to this paper being a literature review. Data was gathered by electronic searches of MEDLINE, EMBASE, Scopus and the Cochrane Central Register of Controlled Trials (CENTRAL). Search terms included, ‘gonio*’, ‘optical coherence tomography’, ‘angle closure’, ‘narrow angle’, ‘diagnos*’, ‘identif*’, ‘screen*’ and ‘detect*’. The literature search was performed in April 2020. The reference lists of included studies were reviewed to search for any papers that may have been missed during this search. Only papers written in English were included in this review. Only studies performed on humans were included. Abstracts, case studies and expert opinions were excluded from this review.

Selection criteria included any trial that investigated the diagnostic accuracy of AS-OCT in detecting eyes with angle closure as diagnosed by gonioscopy. Only papers that provided enough data to determine the sensitivity and specificity of AS-OCT were included. Only papers that assessed the ability to detect an eye with angle closure (as opposed to a quadrant or individual with angle closure) were included.

After the literature search was performed, study selection, extraction of data and assessment of risk of bias were independently performed by two key investigators (TD and VT). For any papers with missing data, the corresponding author would be contacted to find the missing data. If no reply was received 2 weeks after initial contact, then the study would be excluded. An assessment of each studies risk of bias was performed using the QUADAS-2 tool [17]. We modified the QUADAS-2 tool to also consider whether each study analysed the Cochrane Central Register of Controlled Trials (CENTRAL). Search terms included, ‘gonio*’, ‘optical coherence tomography’, ‘angle closure’, ‘narrow angle’, ‘diagnos*’, ‘identif*’, ‘screen*’ and ‘detect*’. The literature search was performed in April 2020. The reference lists of included studies were reviewed to search for any papers that may have been missed during this search. Only papers written in English were included in this review. Only studies performed on humans were included. Abstracts, case studies and expert opinions were excluded from this review.

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Data was entered into Revman 5.4 [18] to create the forest plots presented in this review. We performed a meta-analysis of the sensitivity and specificity data when there were data from 3 or more studies available for an index parameter. This was performed using a hierarchical summary receiver operator curve (ROC) model for each index parameter [19]. Results were calculated using the MetaDAS macro [20] in SAS for Windows, version 9.4 [21] and presented as an estimated summary ROC curve. The Cochrane Handbook outlines how estimation of a summary ROC curve is the most appropriate form of meta-analysis given the studies included in our review [19]. Unfortunately, it was not appropriate to calculate summary sensitivity and specificity points for any index parameters because there were few studies available or there was large heterogeneity in gonioscopy criteria and/or positivity threshold. If we were to calculate summary sensitivity and specificity values, they would represent diagnostic accuracy at an indeterminate average positivity threshold and be unusable in clinical practice [19].

Some studies provided data on more than one index parameter or at more than one positivity threshold. Our analysis only included a single data set per index parameter per study. When there was more than one data set available for an index parameter in a study, such as when multiple positivity thresholds were tested, the single data set with the highest Youden’s J statistic was selected for analysis [22].

Comparison between index parameters was made directly by analysing studies that assessed more than one index parameter. Takwoingi et al. (2013) [23] showed that this approach is more reliable than indirect comparisons. We extended this to allow for direct comparison between studies by the same researchers that used the exact same patients and study design and only differed in the index parameter being studied. It was not possible to perform a formal statistical comparison between index parameters due to the small number of studies for each index parameter.

It was not possible to perform a quantitative heterogeneity analysis for any index parameter due to a small number of studies. Instead, we have presented a narrative description of the contributors to heterogeneity, aided by graphical presentation on the relevant summary ROC plot.

**Results**

The initial search gave 727 papers across the 4 databases. After removing duplicates, there were 373 papers to be reviewed. These papers were screened based on their title and abstract and after removing unsuitable studies, there
were 76 papers remaining for a full text screen. Twenty-five papers were found to be suitable for inclusion after full appraisal. Two further studies were excluded. One for missing data and the authors not contactable [24], and the other because there was a more in-depth reanalysis of the same data in another later study [25, 26].

Seven studies were performed by the same research group and used a common set of patients, labelled as Population A [26–32]. Another two studies used another common set of patients, labelled as Population B [33, 34]. These studies tested different index parameters; therefore, it was not necessary to entirely exclude any of the studies. Occasionally, some data were presented in more than one study. Accordingly, subsets of data from two studies were excluded to avoid double reporting of the data [27, 33].

A total of 5663 patients were included across all studies, excluding the duplicate patients that appeared in more than one study. Eighteen studies (78%) were based out of Asia, 3 out of the USA (13%), and 2 out of the UK (9%). Ten studies (43%) were conducted in a community setting, 12 (52%) were conducted in a secondary care setting, and in 1 study, it was unclear (4%). Two studies were longitudinal in nature and investigated the accuracy of AS-OCT in predicting eyes that would develop angle closure 4 years later [32]. Results from 7 different OCT devices were analysed between the included studies. Characteristics of each study are outlined in Table 1.

Gonioscopy criteria for diagnosing angle closure varied between studies. Non-visibility of posterior trabecular meshwork (PTM) was used as gonioscopy criteria for diagnosing angle closure in most studies. Non-visibility of ≥1, 2, 3 and 4 quadrants of PTM was used as a threshold in 5, 13, 6 and 1 studies, respectively. Six studies did not directly assess for visibility of PTM and used the Spaeth grading system or a modified Shafer grading system instead [37, 40]. One study analysed only three quadrants in each eye to determine angle closure by gonioscopy [47].

The risk of bias was found to be variable amongst the studies and summarised in Figs. 3 and 4. We identified two areas of study design that were frequently performed in a way that are likely to introduce bias. Eight studies did not avoid a case–control study design which falls under the ‘Patient Selection domain’. Nine studies did not pre-specify a threshold for diagnosis of angle closure which falls

| Study characteristics |
|------------------------|
| First Author | Date | No. of eyes | Location | Setting | Angle closure prevalence by gonioscopy (%) | Type of OCT |
| Porporato [34] | 2019 | 1865 A | Singapore | Community | 7.5 | CASIA SS-1000, Tomey |
| Li [35] | 2019 | 252 | China | Secondary | N/A | CASIA SS-1000, Tomey |
| Porporato [33] | 2018 | 1857 A | Singapore | Community | 5.17 | CASIA SS-1000, Tomey |
| Nongpiur [32] | 2017 | 342 A | Singapore | Community | N/A | Visante, Carl-Zeiss |
| Tun [36] | 2017 | 202 | Singapore | Secondary | 24.8 | CIRRUS 5000, Carl-Zeiss |
| Melese [37] | 2016 | 189 A | USA | Secondary | N/A | CASIA SS-1000, Tomey |
| Baskaran [31] | 2015 | 342 A | Singapore | Community | N/A | Visante, Carl-Zeiss |
| Dabasia [38] | 2015 | 78 | UK | Secondary | N/A | Visante, Carl-Zeiss |
| Campbell [39] | 2015 | 78 | UK | Community | 15 | 3D OCT-2000, Topcon |
| Qin [40] | 2013 | 65 | USA | Secondary | N/A | RTVue, Optovue |
| Nongpiur [26] | 2013 | 1368 A | Singapore | Community | 21.6 | Visante, Carl-Zeiss |
| Baskaran [41] | 2013 | 140 | Singapore | Secondary | 22.9 | CASIA SS-1000, Tomey |
| Baskaran [42] | 2012 | 97 | Singapore | Secondary | 39.8 | Visante, Carl-Zeiss |
| Tan [30] | 2012 | 1465 A | Singapore | Community | 21.5 | Visante, Carl-Zeiss |
| Grewal [43] | 2011 | 265 | India | Secondary | 10.6 | RTVue 100, Optovue |
| Chang [27] | 2011 | 2047 A | Singapore | Community | 19.3 | Visante, Carl-Zeiss |
| Narayanaswamy [29] | 2010 | 1465 A | Singapore | Community | 21.5 | Visante, Carl-Zeiss |
| Khor [28] | 2010 | 1853 A | Singapore | Community | 16.4–28.2 | Visante, Carl-Zeiss |
| Hong [44] | 2009 | 73 | Korea | Unclear | N/A | SL-OCT, Heidelberg |
| Sakata [45] | 2009 | 83 | Singapore | Secondary | 36.1 | Visante and SL-OCT |
| Wong [46] | 2009 | 153 | Singapore | Secondary | 30.1–33.3 | Visante, Carl-Zeiss |
| Nolan [47] | 2006 | 342 | Singapore | Secondary | 44.4 | Prototype OCT, Carl-Zeiss |
| Radhakrishnan [48] | 2005 | 31 | USA | Secondary | N/A | Prototype OCT, Carl-Zeiss |

aSeventy-five eyes in validation set. bSixty-nine eyes in validation set. ^Shared population A. §Shared population B
under the ‘Index Test’ domain. Instead, they determined an ideal threshold to fit to the data after it had been collected.

Between all 23 studies, the sensitivity ranged from 46 to 100% (median 87%) and the specificity ranged from 55.3 to 100% (median 84%). There were 21 (91%) and 17 (74%) studies that identified a parameter that had sensitivity and specificity over 80%, respectively. The four studies that showed the best diagnostic accuracy for AS-OCT all used a case–control study design [37, 35–48]. It is likely that this artificially improved their results. Summarised data from all 23 studies was collated and presented in Table 2 (available online).

### AOD and TISA

AOD and TISA are two parameters that were often analysed together. Six studies assessing AOD were included in the analysis for a total of 1970 participants (Figs. 5 and 6). Five studies assessing TISA were included in the analysis for a total of 1905 participants (Figs. 7 and 8).

The largest study to analyse AOD and TISA was performed by Narayanaswamy et al. in 2010 [29]. They reported that the most powerful parameters were AOD750 nasally (sensitivity 82.5%, specificity 84.0%) and AOD750 temporally (sensitivity 90.2%, specificity 77.4%). This study reported the lowest specificity for AOD and was the only study conducted in a community setting.

We considered 4 studies to be at high risk of bias in the patient selection domain for not avoiding a case–control design [37, 40, 35, 48]. This includes the 3 studies with the highest reported sensitivity for AOD and TISA. We considered 4 studies to be at high risk of bias in the index test domain because they did not pre-specify a positivity threshold [29, 40, 48, 43]. We also considered two studies to be at increased risk of bias for analysing more than one eye per patient [40, 48].

### Iridotrabecular touch

Seven studies assessing the presence of iridotrabecular touch were included in analysis for a total of 2808 participants (Figs. 9 and 10). The best evidence comes from a study by Khor et al. (2010)[28]. They found that it was most effective when assessing for touch in the inferior quadrant, reaching a sensitivity as high as 87.8%. However, specificity was less than 73%. The results for this study sit directly on the summary ROC curve. The risk of bias amongst the studies was generally low. All of the studies avoided a case–control design, apart from one study by Campbell et al. (2015) where it is uncertain [39]. The study by Nolan et al. (2006) was considered to be at an increased risk of bias for including more than one eye per patient [47].

### ITC index

Three studies assessing ITC index were included in the analysis for a total of 2074 patients (Figs. 11 and 12). One study does not appear in the analysis as data from the same patients were also presented in an earlier study [33, 34]. The data from the later study were essentially identical but used different gonioscopy criteria and had a lower Youden’s J statistic.

Porporato et al. (2018) assessed ITC index in a community based study and showed a NPV of over 96% for all tested thresholds [33, 34]. Baskaran et al.(2013) used a hospital-based population which generally showed similar specificity but higher sensitivity [41]. Melese et al. (2016) showed an improved result over both other studies (sensitivity 93%, specificity 84%) [37].

The studies by Porporato et al. (2018) and Baskaran et al.(2013) were both considered to have low risk of bias in all domains. The study by Melese et al. (2016) used a
Fig. 4  Risk of bias and applicability concerns summary

| Study               | Patient Selection | Index Test | Reference Standard | Flow and Timing | Applicability Concerns |
|---------------------|-------------------|------------|--------------------|-----------------|------------------------|
| Baskaran 2012       |                   |            |                    |                 |                        |
| Baskaran 2013       |                   |            |                    |                 |                        |
| Baskaran 2015       |                   |            |                    |                 |                        |
| Campbell 2015       |                   |            |                    |                 |                        |
| Chang 2011          |                   |            |                    |                 |                        |
| Dabasia 2015        |                   |            |                    |                 |                        |
| Grewal 2011         |                   |            |                    |                 |                        |
| Hong 2009           |                   |            |                    |                 |                        |
| Khor 2010           |                   |            |                    |                 |                        |
| Li 2019             |                   |            |                    |                 |                        |
| Melese 2016         |                   |            |                    |                 |                        |
| Narayanaswamy 2010  |                   |            |                    |                 |                        |
| Nolan 2006          |                   |            |                    |                 |                        |
| Nongpiur 2013       |                   |            |                    |                 |                        |
| Nongpiur 2017       |                   |            |                    |                 |                        |
| Porporato 2018      |                   |            |                    |                 |                        |
| Porporato 2019      |                   |            |                    |                 |                        |
| Qin 2013            |                   |            |                    |                 |                        |
| Radhakrishnan 2005  |                   |            |                    |                 |                        |
| Sakata 2009         |                   |            |                    |                 |                        |
| Tan 2012            |                   |            |                    |                 |                        |
| Tun 2017            |                   |            |                    |                 |                        |
| Wong 2009           |                   |            |                    |                 |                        |

- **High**
- **Unclear**
- **Low**
| First author | Gonioscopy criteria | AS-OCT criteria | Threshold value | Sensitivity | Specificity | PPV | NPV |
|--------------|---------------------|-----------------|-----------------|-------------|------------|-----|-----|
| Porporato [34] | Posterior PTM not visible in ≥ 2 quadrants | ITC index | ≥ 35% | 82.1 (74.8–88.1) | 78.4 (76.4–80.4) | 23.6 (21.5–25.8) | 98.2 (97.4–98.7) |
|              |                     |                 | ≥ 50% | 75.7 (67.8–82.6) | 84.2 (82.4–85.9) | 28.0 (25.2–31.0) | 97.7 (97.0–98.3) |
|              |                     |                 | ≥ 75% | 60.7 (52.1–68.9) | 90.8 (89.3–92.1) | 34.8 (30.5–39.5) | 96.6 (95.9–97.2) |
| Li [35]      | Posterior PTM not visible in > 180 degrees | AOD500 @ Temporal (mm) | 0.221 (0.215, 0.270) | 97.5 | 65.7 |
|              |                     | AOD500 @ Nasal (mm) | 0.192 (0.184, 0.213) | 97.4 | 80.0 |
| Tun [36]     | Posterior TM not visible in ≥ 2 quadrants | LV | > 0.56 mm | 64.6 (49.5–77.8) | 78.3 (73.0–83.0) |
|              |                     | AOD750 | ≤ 0.31 mm | 95.8 (85.7–99.5) | 60.1 (54.2–65.9) |
|              |                     | Angle closure score as defined by Nongpiur et al | abs value > 3.11 | 79.2 (65.0–89.5) | 73.2 (67.6–78.3) |
| First author | Gonioscopy criteria | AS-OCT criteria | Threshold value | Sensitivity | Specificity | PPV | NPV |
|--------------|---------------------|----------------|----------------|------------|------------|-----|-----|
| Melese [37] | Spaeth grade A or B. Clinical judgement used for Spaeth grade C | AOD500 @ Temporal (mm) | 0.28 (0.17–0.39) | 1.00 (1.00, 1.00) | 0.79 (0.58, 0.97) |     |     |
|             |                     | AOD500 @ Nasal (mm) | 0.23 (0.14–0.32) | 1.00 (1.00, 1.00) | 0.87 (0.69, 1.00) |     |     |
|             |                     | AOD500 @ Superior (mm) | 0.15 (0.08–0.21) | 0.87 (0.61, 1.00) | 0.92 (0.71, 1.00) |     |     |
|             |                     | AOD500 @ Inferior (mm) | 0.24 (0.21–0.26) | 1.00 (1.00, 1.00) | 0.84 (0.65, 1.00) |     |     |
|             |                     | AOD750 @ Temporal (mm) | 0.37 (0.29–0.46) | 0.97 (0.82, 1.00) | 0.84 (0.66, 0.97) |     |     |
|             |                     | AOD750 @ Nasal (mm) | 0.39 (0.33–0.46) | 1.00 (1.00, 1.00) | 0.79 (0.58, 0.95) |     |     |
|             |                     | AOD750 @ Superior (mm) | 0.24 (0.19–0.29) | 0.97 (0.84, 1.00) | 0.87 (0.66, 1.00) |     |     |
|             |                     | AOD750 @ Inferior (mm) | **0.31 (0.25–0.37)** | **1.00 (1.00, 1.00)** | **0.92 (0.76, 1.00)** |     |     |
|             |                     | TISA500 @ Temporal (mm^2) | 0.079 (0.045–0.113) | 0.97 (0.85, 1.00) | 0.76 (0.58, 0.96) |     |     |
|             |                     | TISA500 @ Nasal (mm^2) | 0.070 (0.037–0.103) | 0.87 (0.59, 1.00) | 0.84 (0.68, 1.00) |     |     |
|             |                     | TISA500 @ Superior (mm^2) | 0.028 (0.012–0.043) | 0.87 (0.61, 1.00) | 0.87 (0.68, 1.00) |     |     |
|             |                     | TISA500 @ Inferior (mm^2) | 0.054 (0.045–0.064) | 1.00 (1.00, 1.00) | 0.84 (0.65, 1.00) |     |     |
|             |                     | TISA750 @ Temporal (mm^2) | 0.162 (0.031–0.101) | 0.97 (0.85, 1.00) | 0.79 (0.58, 0.97) |     |     |
|             |                     | TISA750 @ Nasal (mm^2) | 0.134 (0.079–0.190) | 0.94 (0.70, 1.00) | 0.84 (0.66, 0.98) |     |     |
|             |                     | TISA750 @ Superior (mm^2) | 0.073 (0.042–0.103) | 0.87 (0.61, 1.00) | 0.89 (0.68, 1.00) |     |     |
|             |                     | TISA750 @ Inferior (mm^2) | **0.120 (0.098–0.142)** | **1.00 (1.00, 1.00)** | **0.84 (0.65, 1.00)** |     |     |
|             |                     | TICV500 (microL) | 1.92 (1.26–2.57) | 1.00 (1.00, 1.00) | 0.87 (0.70, 1.00) |     |     |
|             |                     | TICV750 (microL) | **4.00 (2.95–5.06)** | **1.00 (1.00, 1.00)** | **0.87 (0.70, 1.00)** |     |     |
|             |                     | ITC length @ Temporal (mm) | 0.030 (0.000–0.112) | 0.80 (0.56, 1.00) | 0.84 (0.66, 0.98) |     |     |
|             |                     | ITC length @ Nasal (mm) | 0.017 (0.000–0.089) | 0.61 (0.35, 0.90) | 0.94 (0.82, 1.00) |     |     |
|             |                     | ITC length @ Superior (mm) | 0.159 (0.067–0.250) | 0.80 (0.45, 1.00) | 0.79 (0.43, 0.95) |     |     |
|             |                     | ITC length @ Inferior (mm) | **0.054 (0.000–0.112)** | **0.87 (0.58, 1.00)** | **0.79 (0.56, 0.95)** |     |     |
|             |                     | ITC index (%) | **36.9 (23.1–51.1)** | **0.93 (0.73, 1.00)** | **0.84 (0.63, 0.98)** |     |     |
|             |                     | ITC area (mm^2) | **3.27 (1.40–5.15)** | **0.93 (0.73, 1.00)** | **0.87 (0.68, 1.00)** |     |     |
| First author | Gonioscopy criteria | AS-OCT criteria | Threshold value | Sensitivity | Specificity | PPV | NPV |
|--------------|---------------------|----------------|----------------|-------------|------------|-----|-----|
| Baskaran [31] | Posterior TM not visible in ≥ 2 quadrants | ≥ 1 quadrant with any iridotrabecular contact anterior to scleral spur | 100.0 (92.6–100.0) | 22.1 (17.4–27.4) |
| | | ≥ 2 quadrants with any iridotrabecular contact anterior to scleral spur | 75.0 (60.4–86.4) | 56.5 (50.5–62.3) |
| | | ≥ 3 quadrants with any iridotrabecular contact anterior to scleral spur | 41.7 (27.6–56.8) | 89.1 (84.9–92.5) |
| | | 4 quadrants with any iridotrabecular contact anterior to scleral spur | 16.7 (7.48–30.2) | 97.2 (94.5–98.8) |
| Posterior TM not visible in ≥ 3 quadrants | | | 100.0 (87.7–100) | 20.7 (16.3–25.6) |
| | | ≥ 1 quadrants with any iridotrabecular contact anterior to scleral spur | 82.1 (63.1–93.9) | 55.1 (49.3–60.8) |
| | | ≥ 2 quadrants with any iridotrabecular contact anterior to scleral spur | 50.0 (30.7–69.4) | 87.9 (83.7–91.3) |
| | | 4 quadrants with any iridotrabecular contact anterior to scleral spur | 25.0 (10.7–44.9) | 97.1 (94.5–98.6) |
| Dabasia [38] | Posterior TM not visible in ≥ 270 degrees | ACA (°) | ≤ 20.7 | 87.2 (72.6–95.7) | 86.8 (71.9–95.6) |
| | Expert opinion after dynamic gonio assessment | | ≤ 18.6 | 100 (80.5–100.0) | 66.7 (53.3–78.3) |
| | Posterior TM not visible in ≥ 270 degrees | ACD (mm) | ≤ 2.50 | 71.8 (55.1–85.0) | 84.6 (69.5–94.1) |
| | Expert opinion after dynamic gonio assessment | | ≤ 2.38 | 82.3 (56.6–96.2) | 83.6 (71.9–91.8) |
| Campbell [39] | Posterior TM visible for less than 270 degrees | Iridotrabecular touch in nasal or temporal quadrant | Visit 1 | 46 (17—77) | 87 (76—94) | 36 | 90 |
| | | | Visit 2 | 25 (6—57) | 89 (79—96) | 31 | 86 |
| Qin [40] | Modified Shaffer grade ≤ 1 in all quadrants | AOD-Schwalbe’s Line @ Nasal (mm) | 0.29 | 80 | 87 |
| | | AOD-Schwalbe’s Line @ Temporal (mm) | 0.29 | 85 | 77 |
| First author | Gonioscopy criteria | AS-OCT criteria | Threshold value | Sensitivity | Specificity | PPV | NPV |
|--------------|---------------------|-----------------|-----------------|------------|------------|-----|-----|
| Nongpiur [26] | Posterior PTM not visible in ≥ 180 degrees | Stepwise logistic regression model | 0.5 | 0.26 | 89 | 89 | 69 | 97 |
| Baskaran [41] | Posterior PTM not visible in ≥ 1 quadrants | ITC index | > 35% | 69.1 (52.9–82.4) | 88.8 (80.8–94.3) | 72.5 (55.9–85.5) | 87.0 (78.8–92.9) |
| | | | ≥ 50% | 42.9 (27.7–59.0) | 94.9 (88.5–98.3) | 78.3 (55.7–92.8) | 79.5 (71.0–86.4) |
| | | | > 70% | 21.4 (10.3–36.8) | 99.0 (94.4–100.0) | 90.0 (55.5–99.7) | 74.6 (66.2–81.8) |
| | Posterior PTM not visible in ≥ 2 quadrants | | > 35% | 71.9 (53.3–86.3) | 84.3 (76.0–90.6) | 57.5 (40.9–73.0) | 91.0 (83.6–95.8) |
| | | | ≥ 50% | 43.8 (26.4–62.3) | 91.7 (84.8–96.1) | 60.9 (38.5–80.3) | 84.6 (76.7–90.6) |
| | | | > 70% | 25.0 (11.5–43.4) | 98.1 (93.5–99.8) | 80.0 (42.2–97.9) | 81.5 (73.8–87.8) |
| | Posterior PTM not visible in ≥ 3 quadrants | | > 35% | 71.0 (52.0–85.8) | 83.5 (75.2–89.9) | 55.0 (38.5–70.7) | 91.0 (83.6–95.8) |
| | | | ≥ 50% | 45.2 (27.3–64.0) | 91.7 (84.9–96.2) | 60.9 (38.0–80.7) | 85.5 (77.8–91.3) |
| | | | > 70% | 25.8 (11.9–44.6) | 98.2 (93.5–99.8) | 80.0 (44.4–97.5) | 82.3 (74.6–88.4) |
| | Posterior PTM not visible in ≥ 4 quadrants | | > 35% | 92.3 (64.0–99.8) | 78.0 (69.7–84.8) | 30.0 (16.6–46.5) | 99.0 (94.5–100.0) |
| | | | ≥ 50% | 76.9 (46.2–95.0) | 89.8 (83.1–94.4) | 43.5 (23.2–65.5) | 97.4 (92.7–99.5) |
| | | | > 70% | 46.2 (19.2–74.9) | 96.9 (92.1–99.1) | 60.0 (26.2–87.8) | 94.6 (89.2–97.8) |
| Baskaran [42] | Posterior PTM not visible in ≥ 2 quadrants | Any iridotrabecular touch anterior to the SS in ≥ 1 quadrants | 95 | 95 | 61 | 61.7 | 94.9 |
| | | Any iridotrabecular touch anterior to the SS in ≥ 2 quadrants | 92 | 65 | 63.5 | 92.5 |
| | | Any iridotrabecular touch anterior to the SS in ≥ 3 quadrants | 84 | 75 | 68.1 | 88.0 |
| | | Any iridotrabecular touch anterior to the SS in ≥ 4 quadrants | 77 | 76 | 68 | 83.3 |
| Tan [30] | Posterior TM not visible in ≥ 180 degrees | LV (mm) | ≥ 0.576 | 85.7 | 77.5 | 51 | 95.2 |
| Grewal [43] | Shaffer grade ≤ 1 in all quadrants | AOD500 @ Nasal (mm) | ≤ 0.34 | 78.6 (59.0–91.7) | 71.3 (65.1–77.0) | 19.5 (11.3–30.1) | 97.1 (93.4–99.0) |
| | | AOD500 @ Temporal (mm) | ≤ 0.32 | 67.9 (47.7–84.1) | 88.2 (83.4–92.0) | 33.3 (18.6–51.0) | 96.3 (92.8–98.4) |
| | | TISA500 @ Nasal (mm^2) | ≤ 0.20 | 64.3 (44.1–81.3) | 78.7 (72.8–83.8) | 18.3 (9.50–30.4) | 95.3 (91.2–97.8) |
| | | TISA500 @ Temporal (mm^2) | ≤ 0.21 | 71.4 (51.3–86.7) | 81.0 (75.4–85.8) | 22.8 (12.8–35.8) | 96.4 (92.7–98.5) |
| Chang [27] | Shaffer grade ≤ 1 in ≥ 2 quadrants | AOD750 if SS visible. If not, subjective assessment (mm) | ≤ 0.258 | 83.0 (78.9–86.5) | 78.2 (76.1–80.2) | 48.4 (44.6–52.3) | 94.9 (93.6–96.0) |
Table 2 (continued)

| First author | Gonioscopy criteria | AS-OCT criteria | Threshold value | Sensitivity | Specificity | PPV    | NPV    |
|--------------|---------------------|-----------------|-----------------|-------------|------------|--------|--------|
| Narayanaswamy [29] Posterior PTM not visible in ≥ 180 degrees | AOD250 @ Temporal (mm) | 0.144 | 77.1 (72.5–81.8) | 68.2 (65.6–70.9) | 37.7 (33.8–41.6) | 92.2 (90.4–94.0) |
| | AOD250 @ Nasal (mm) | 0.138 | 75.6 (70.8–80.3) | 70.6 (68.0–73.2) | 39.1 (35.1–43.1) | 92.0 (90.2–93.8) |
| | AOD500 @ Temporal (mm) | 0.191 | 88.9 (85.4–92.3) | 74.6 (72.1–77.1) | 46.6 (42.5–50.7) | 96.4 (95.1–97.6) |
| | AOD500 @ Nasal (mm) | 0.177 | 85.1 (81.1–89.0) | 76.1 (73.7–78.6) | 47.1 (42.8–51.3) | 95.3 (93.9–96.6) |
| | AOD750 @ Temporal (mm) | 0.258 | 90.2 (86.9–93.4) | 77.4 (74.9–79.8) | 49.9 (45.6–54.2) | 96.9 (95.8–98.0) |
| | AOD750 @ Nasal (mm) | 0.225 | 82.5 (78.3–86.7) | 84.0 (81.9–86.2) | 56.3 (51.6–61.0) | 95.0 (93.7–96.3) |
| | TISA500 @ Temporal (mm^2) | 0.103 | 88.2 (84.7–91.8) | 59.1 (56.3–62.0) | 35.0 (31.6–38.5) | 95.2 (93.6–96.7) |
| | TISA500 @ Nasal (mm^2) | 0.076 | 73.3 (68.4–78.2) | 75.2 (72.7–77.7) | 42.4 (38.1–46.7) | 91.8 (90.0–93.5) |
| | TISA750 @ Temporal (mm^2) | 0.151 | 83.5 (79.4–87.6) | 76.7 (74.3–79.2) | 47.3 (43.0–51.6) | 94.8 (93.4–96.2) |
| | TISA750 @ Nasal (mm^2) | 0.134 | 80.3 (75.9–84.7) | 77.5 (75.1–79.9) | 47.2 (42.8–51.8) | 94.0 (92.5–95.5) |
| | ARA750 @ Temporal (mm^2) | 0.191 | 84.1 (80.1–88.2) | 69.2 (66.5–71.9) | 40.6 (36.7–44.4) | 94.5 (93.0–96.0) |
| | ARA750 @ Nasal (mm^2) | 0.154 | 74.0 (69.1–78.8) | 75.8 (73.3–78.3) | 43.2 (38.9–47.5) | 92.0 (90.3–93.7) |
| Khor [28] | Any iridotrabecular touch anterior to the SS in ≥ 1 quadrants of quadrants tested | | | | | |
| | Posterior TM not visible in ≥ 1 quadrants | Inferior only | 79.5 | 72.7 | 53.4 | 90.0 |
| | | Inferior, nasal and temporal | 82.2 | 68.3 | 50.5 | 90.7 |
| | | Nasal and temporal only | 40.8 | 89.0 | 59.3 | 79.3 |
| | Posterior TM not visible in ≥ 2 quadrants | Inferior only | 83.9 | 68.8 | 41.0 | 94.3 |
| | | Inferior, nasal and temporal | 87.4 | 64.8 | 39.0 | 95.2 |
| | | Nasal and temporal only | 46.8 | 87.6 | 49.3 | 86.5 |
| | Posterior TM not visible in ≥ 3 quadrants | Inferior only | 87.8 | 67.0 | 34.3 | 96.6 |
| | | Inferior, nasal and temporal | 90.8 | 62.8 | 32.4 | 97.2 |
| | | Nasal and temporal only | 49.2 | 86.4 | 41.5 | 89.7 |
| Hong [44] | TM visible in < 90 degrees | ACA (°) | 31.8 | 75.0 | 97.6 | |
| | | ACD (mm) | 2.45 | 87.5 | 97.6 | |
| Sakata [45] | Posterior TM not visible in ≥ 1 quadrants | Any iridotrabecular touch anterior to the SS in ≥ 1 quadrants of quadrants tested | | | | |
| | Visante data | | 97 (83–100) | 51 (37–65) | 53 (46–60) | 96 (79–99) |
| | SL-OCT data | | 90 (73–98) | 64 (50–77) | 59 (49–68) | 92 (79–97) |
| First author | Gonioscopy criteria | AS-OCT criteria | Threshold value | Sensitivity | Specificity | PPV | NPV |
|--------------|---------------------|-----------------|----------------|-------------|------------|-----|-----|
| Wong [46]    | Posterior TM not visible in ≥ 1 quadrants | Any iridotrabecular touch anterior to the SS in ≥ 1 quadrants | 84 | 58 | 50 | 88 |
|              |                     | Any iridotrabecular touch anterior to the SS in ≥ 2 quadrants | 68 | 75 | 58 | 82 |
|              |                     | Any iridotrabecular touch anterior to the SS in ≥ 3 quadrants | 43 | 86 | 61 | 75 |
| Nolan [47]a | Spaeth 0° in ≥ 1 quadrants, assessing temporal, nasal and inferior quadrants only | Any iridotrabecular touch anterior to the SS in ≥ 1 quadrants out of the 3 temporal, nasal and inferior quadrants | 94.1 (88.7–97.1) | 55.3 (47.9–62.4) | 62.7 (58.8–66.4) | 92.1 (85.4–95.7) |
| Radhakrishnan [48] | Shaffer grade ≤ 1 in 4 quadrants | AOD500 (mm) | 0.191 | 100.0 | 87.5 |
|              |                     | ARA500 (mm²) | 0.12 | 87.0 | 100 |
|              |                     | ARA750 (mm²) | 0.17 | 91.3 | 87.5 |
|              |                     | TISA500 (mm²) | 0.11 | 87.0 | 100 |
|              |                     | TISA750 (mm²) | 0.17 | 91.3 | 87.5 |

95% Confidence intervals indicated in brackets
Parameter with the highest Youden-J value in bold
a Excluded duplicate data from Porporato (2019)
b Data from validation set only
c Excluded per individual analysis
d PPV/NPV values given for 20% prevalence
e Excluded per individual analysis
Fig. 5 Forest plot for studies investigating AOD

Fig. 6 Summary ROC plot for studies investigating AOD

Fig. 7 Forest plot for studies investigating TISA
case–control design so we considered it to be at high risk of patient selection bias.

**ACD**

Three studies assessing ACD have been included in the analysis for a total of 226 participants (Figs. 13 and 14) [35, 44, 38]. Overall, the evidence investigating ACD is weak due to all 3 studies using a case–control design and small sample sizes. Results showed variable sensitivity (ranging from 71.8 to 92.5%) and specificity (ranging from 83.6 to 97.6%).

**Remaining index parameters**

The remaining index parameters had few studies to draw data from as shown in the forest plot in Fig. 15. Data has

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**Fig. 8** Summary ROC plot for studies investigating TISA

**Fig. 9** Forest plot for studies investigating Iridotrabeccular touch
not been shown on a summary ROC plot to avoid facilitating an inappropriate indirect comparison between index parameters. Li et al. (2019) found that ACV showed a sensitivity of 90.0% and specificity of 97.1% [35]. ACA was analysed in two studies and the results varied significantly [44, 38] with sensitivity ranging from 75.0 to 100.0% and specificity ranging from to 66.7 to 97.6%. LV has been assessed in a single community based study by Tan et al. (2012) with 1465 eyes [30]. The results showed a reasonable ability to detect angle closure (sensitivity 85.7%, specificity 77.5%, PPV 51.0%, NPV 95.2%). TICV, ITC area and ITC length were analysed by Melese et al. (2016) [37]. TICV achieved 100% specificity and 87% specificity. ITC area had good results (sensitivity 93%, specificity 87%). The results for ITC length were more the modest. ARA has only been assessed in two studies with variable sensitivity (range 74.0–91.3) and specificity (range 69.2–100).

Nongpiur et al. (2013) assessed a stepwise logistic regression model that uses multiple parameters to determine an angle closure score and estimate a probability of angle closure [25, 26, 32]. Data for two different thresholds were presented, with one weighted toward a higher sensitivity of
96% (NPV 99%) and the other weighted toward a higher specificity of 89% (PPV 69%).

**Ability to predict development of angle closure at 4 years**

Nongpiur et al. (2017) and Baskaran et al. (2015) assessed models that use baseline AS-OCT measurements to predict angle closure by gonioscopy four years later (Fig. 16) [31, 32]. The two studies were conducted at the same community clinic in Singapore and used the exact same participants (n = 342). The participants were limited to those that did not have angle closure by gonioscopy at baseline. Nongpiur et al. (2017) showed the sensitivity of LV and AOD750 to be 64.6% and 95.8% respectively. Baskaran et al. (2015) assessed for the number of quadrants with presence of iridotrabecular touch. When 1 quadrant was used as the threshold, the sensitivity was 100%. When 4 quadrant was used as the threshold, the specificity was above 97%.

**Comparisons between index parameters**

In the paired studies by Narayanaswamy et al. (2010) [29] and Tan et al. (2012) [30], AOD, TISA and LV were shown...
to be significantly more specific than ARA (AOD: 0.77 (95% CI 0.75–0.80), TISA: 0.77 (95% CI 0.74–0.79), LV: 0.77 (95% CI 0.75–0.80), ARA: 0.69 (95% CI 0.66–0.72)). The two longitudinal studies showed that LV was more specific than all other tested parameters, but it was less sensitive than AOD and a stepwise logistic model. However, Nongpiur et al. (2017) did not find a significant difference between parameters when comparing AUC values. These conclusions are only applicable at the specific positivity thresholds used in the studies. There is not enough information to make any further conclusions about the relative accuracy of index parameters.

**Discussion**

Optical coherence tomography has made an incredible impact in the field of ophthalmology. It is proven to be cost-effective and has become a key imaging modality for many eye conditions including glaucoma and neovascular age-related macular degeneration [49, 50]. Our systematic review focused on the evidence of the diagnostic accuracy of AS-OCT in detecting angle closure. We were able to produce summary ROC curves and show that AS-OCT may reach above 90% in sensitivity or specificity for detecting angle closure as defined by gonioscopy. However, the studies that showed the best results for AS-OCT were at often high risk of bias due to their study design. There is not enough evidence to conclude that any individual parameter is significantly better or worse for detecting angle closure. Similarly, there is not enough evidence to conclude that horizontal, vertical or circumferential AS-OCT scans perform differently.

AS-OCT allows excellent visualisation of the anterior angle and has several key advantages over gonioscopy. It is non-contact, more comfortable for the patient and requires little training to use. The objective measurements are ideal for ongoing monitoring of glaucoma patients and suspects. However, AS-OCT cannot replace gonioscopy which remains the reference standard as it is useful for
purposes other than detecting angle closure including assessment of neovascularisation, peripheral anterior synechiae, pigment dispersion syndrome and angle recession. A dynamic assessment with indentation is also only possible with a gonioscopy lens. Furthermore, gonioscopy facilitates 360-degree visualisation of the anterior angle, whereas AS-OCT often only provides a small number of axis scans, preventing a complete assessment.

Time for data acquisition using the AS-OCT varies with different anterior angle parameters and is an important factor for clinicians from a practical perspective. AOD and TISA currently require manual input from the clinician to locate the scleral spur which may slow down the testing procedure, especially if multiple quadrants are assessed. This requirement for subjective input may also introduce error. The practicality of AOD and TISA is further reduced by frequently poor visualisation of the scleral spur. The largest study by Narayanaswamy had to exclude 25% of eyes from their analysis for this reason [29]. However, the OCT device software is improving over time and it may

Fig. 15 Forest plot for studies investigating remaining parameters
soon be possible that results for all parameters are generated automatically.

The two included longitudinal studies showed that iridotrabecular touch and AOD750 have sensitivity above 95% for detecting eyes that would develop closed angles by gonioscopy 4 years later [31, 32]. However, they reported a high false-positive rate, leading to poor specificity. The longitudinal design allows us to analyse the natural history of eyes that are classified to have closed angles by AS-OCT but open by gonioscopy. These eyes correspond to false-positive data points in other studies. The results suggest that the eyes determined to have angle closure by AS-OCT should be carefully monitored as they are at higher risk of developing angle closure on gonioscopy.

Our review gives insight into possible clinical applications for AS-OCT in detecting angle closure. The good sensitivity corresponds to a strong NPV (reaching above 95%) and suggests that there might be a place for AS-OCT in ruling out angle closure. A negative result could be very reassuring in situations where a practitioner skilled in gonioscopy is not available. Potential use cases include telehealth consultations or in primary care practice. These situations are particularly relevant in the context of the COVID-19 pandemic when this review was written.

When the condition being tested for has a low prevalence in the population being tested, it is ideal if the specificity is high otherwise the PPV will be low. Despite AS-OCT generally showing specificity above 80%, the prevalence of angle closure is low enough that the PPV was often less than 50%. A positive result becomes difficult to interpret and would necessitate further testing.

We do not currently know if these false-positive errors are truly errors or if they represent eyes at greater risk of angle closure and glaucomatous damage. This uncertainty is partially caused by using gonioscopy to define angle closure. Nolan et al. (2006) have argued that gonioscopy may not be the most appropriate reference standard as it may miss cases of angle closure [47]. That if gonioscopy was being tested against AS-OCT as the reference standard, it would be shown to have low sensitivity and high specificity.

Another possible interpretation of the false-positive errors is that they represent pre-gonioscopic angle closure; that the eyes only determined to have angle closure by AS-OCT are at higher risk of glaucoma but have not yet progressed to angle closure by gonioscopy. Specifically, AS-OCT could allow for early detection of angle closure. This is supported by the two longitudinal studies that showed AS-OCT was very sensitive in detecting eyes that would progress from open to closed on gonioscopy [31, 32]. More longitudinal studies are needed to better determine the long-term risk of glaucoma and angle closure for patients that are deemed to be closed on AS-OCT but open by gonioscopy.

Due to its strong NPV, ease of use, objective measurements and possibility for earlier detection, AS-OCT may be ideal for initial assessment of patients at higher risk of angle closure. This may include patients from higher risk populations such as Asians, or those with structural risk factors. As an added benefit, AS-OCT gives information on iris configuration and anterior eye structure. This enables assessment of structural risk factors including pupillary block, large lens vault and large iris area [51–53].
When assessing the utility of AS-OCT for detecting angle closure, we should consider the shortcomings of our current tools. Many eyes with angle closure disease go unrealised in developed countries and the rates are even worse in developing Asian countries. There are not enough clinicians skilled in gonioscopy to adequately assess for angle closure on a large scale. In this context, AS-OCT provides a tool for screening where there is very little else available. This provides an avenue to detect currently undiagnosed angle closure and reduce the long-term burden of blindness. Unfortunately, developing countries are currently unlikely to have access to an OCT device due to the prohibitive cost. However, this may change as the cost of technology decreases with time. Clinicians should consider the strengths and limitations of AS-OCT to determine how it may be safely used for their specific clinical needs.

Our review has been the first to perform a meta-analysis of data that assesses the accuracy of AS-OCT for detecting angle closure against gonioscopy as a reference standard. A review by the American Academy of Ophthalmology (2013) identified that AS-OCT may provide supplemental information when used alongside gonioscopy [13], whereas we found that AS-OCT has a strong NPV and may have a place in screening for angle closure. We found that AS-OCT may have specificity above 80% when certain parameters and thresholds are used. This contrasts with a review by Porporato et al. (2018) that reported the specificity to be low [14]. Despite this, we agreed that the PPV was often poor. It remains to be seen how the clinical utility of AS-OCT compares against other anterior chamber analysis modalities including Scheimpflug photography and Scanning Peripheral Anterior Chamber Depth Analyser.

There were several limitations of our review. There was substantial variation between studies in areas including gonioscopy criteria, AS-OCT positivity threshold and OCT device being used. We were therefore limited in what statistical analyses we were able to perform, making it difficult to draw firm conclusions on the utility of AS-OCT. We were unable to determine summary sensitivity and specificity values for each index parameter. We were also unable to perform a quantitative analysis of heterogeneity or quantitative comparison between index parameters.

To reduce heterogeneity, future studies should consider using non-visibility of 2 quadrants of PTM as the gonioscopy criterion if it matches clinical practice. Another approach would be to include results for several gonioscopy criteria as some studies have done. Future studies should analyse data using positivity thresholds established in previous studies if possible. If a new threshold is established, they should also validate their results using a separate population or by using a cross-validation procedure. Future studies should also avoid a case-control design.

**Conclusion**

Although the current literature is heterogenous in methodology, AS-OCT demonstrates good sensitivity and NPV. There are not enough clinicians skilled in gonioscopy to adequately assess for angle closure on a large scale, particularly in developing Asian countries. In this context, AS-OCT allows for earlier detection and provides a tool for screening where there is very little else available. This provides an avenue to detect currently undiagnosed angle closure and reduce the long-term burden of blindness. However, AS-OCT is not yet able to replace gonioscopy. Clinicians should consider whether the diagnostic accuracy of AS-OCT is acceptable for their specific clinical use before adopting it. More studies are needed to determine the utility of AS-OCT, including longitudinal studies to determine the significance of eyes classified to have closed angles by AS-OCT but open on gonioscopy.

**Appendix 1**

Full search strategy for Medline database.o

1. gonio*.mp. or exp Gonioscopy/
2. exp Tomography, Optical Coherence/ or optical coherence tomography.mp.
3. OCT.mp.
4. 2 or 3
5. narrow angle.mp.
6. closed angle.mp.
7. angle closure.mp.
8. Glaucoma, Angle-Closure/
9. 5 or 6 or 7 or 8
10. detect*.mp.
11. diagnos*.mp.
12. identif*.mp.
13. screen*.mp.
14. 10 or 11 or 12 or 13
15. 1 and 4 and 9 and 14

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s00417-021-05271-4.
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