Dynamic Gonioscopy Using Optical Coherence Tomography

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BACKGROUND AND OBJECTIVE: To describe the use of anterior segment optical coherence tomography (AS-OCT) in studying the dynamic changes of the anterior chamber angle by corneal indentation.

PATIENTS AND METHODS: In a prospective observational study, the anterior segments of 21 eyes were imaged using AS-OCT. After the initial scan, a second scan was executed on the same areas with a central corneal indentation. An evaluation of the reopening of the angle and its measurement were performed.

RESULTS: With AS-OCT, the indirect signs were accurate enough to guide the diagnosis in all plateau iris confirmed by ultrabiomicroscopy. The angle widths were significantly increased after indentation.

CONCLUSION: This method would appear to offer a convenient and rapid method of assessing the configuration of the anterior chamber; it may help during the routine clinical assessment and treatment of patients with narrow or closed angles, particularly when gonioscopy is difficult to interpret.


INTRODUCTION

Glaucoma is the second most prevalent cause of irreversible blindness worldwide, affecting nearly 66 million people. Approximately half have primary angle-closure glaucoma, especially in East and South Asia, where this form of glaucoma affects 75%. The angle configuration must be systematically checked at least one time and on each first clinical examination of patients presenting with raised intraocular pressure or glaucoma.

Dynamic indentation gonioscopy with a gonioprism is the current reference standard for clinically
assessing anterior chamber angle structures and their configuration; however, the interpretation of gonioscopic findings is subjective and only semiquantitative. With the development of new imaging techniques of the anterior segment, new analysis methods have also been developed. Ultrabiomicroscopy (UBM) was the first method of analyzing the anterior segment and is still the only imaging technique for all anterior segment structures (especially the ciliary body). Another method is optical coherence tomography (OCT), a non-contact technique feasible in a sitting patient and therefore more physiologic than the UBM examination, for which the patient is supine. Anterior segment assessment is accessible by numerous practitioners but limited by the optic wall represented by iris, which most often prevents viewing of the ciliary body.

We describe a new modified method using anterior segment OCT (AS-OCT) to perform dynamic gonioscopy.

**PATIENTS AND METHODS**

In a prospective observational study, the anterior segments of 21 eyes of 16 patients were imaged using the 3D OCT-1000 (Topcon, Tokyo, Japan) and Lin50 UBM Aviso (Quantel Medical, Les Ulis, France) after a complete ophthalmic examination, including slit-lamp biomicroscopy and gonioscopy. All patients were informed appropriately about the procedure, and signed informed consent statements and institutional ethics committee approval were obtained.

Seventeen eyes of 12 patients with narrow or closed angles as determined by gonioscopy were compared with 4 eyes of 4 patients with open-angle glaucoma (primary open-angle glaucoma, juvenile glaucoma, and pigmentary glaucoma). The angle was defined as open when graded on gonioscopy as 3 or 4 over 180° according to the Shaffer grading system. Then dynamic indentation gonioscopy was performed to assess the possibility of reopening the angle to determine whether closure was definitive (peripheral anterior synechiae, peripheral iris apposition) and to evaluate the configuration of the iris root. All patients had UBM examination to confirm the clinical analysis.

**Acquisition by OCT**

The same examiner (FM) took all images of the anterior chamber angle in a masked fashion. Topical anesthesia by oxybuprocaine hydrochloride 0.4% drops (Novesine; Merck Sharp & Dohme-Chibret, Paris, France) was applied to the corneal surface. To acquire images, patients had to look straight forward using the internal fixation target of the 3D OCT-1000. This OCT instrument has a scanning speed of 20,000 A-scans per second with an axial resolution of 6 µm. The superluminescent diode light source used is centered at 850 nm with a bandwidth of 50 nm; this is more specific for retinal imaging but is usable for the anterior segment. It has a limited penetration compared with a dedicated anterior segment instrument such as the Visante OCT (1,310 nm) (Carl Zeiss Meditec, Inc., Dublin, CA).

Focus was adjusted manually on the limbus, and then two scans were oriented horizontally on the limbus and covered the anterior chamber angle in the nasal and temporal edge. Scans were parameterized as follows. Each was a line-scan of 6 mm length with four passes for each scan (overlapping mode). All were of satisfactory quality (signal strength > 50) (Table 1). In case of movement artifacts or blinking that caused a shadow across part of the scan, the scans had to be retaken. After the initial scan (Figure 1A), the second scan was executed on the same areas during a central corneal indentation (Figure 1B) performed using a sterile cotton-tipped applicator (Figure 1C). Sufficient pressure was applied to force aqueous peripherally into the drainage angle, which displaces the iris posteriorly from the trabecular meshwork to reopen the anterior chamber angle (Figure 1B).

The patient then sat back from the machine for 5 minutes before being repositioned. The second series of scans was performed by the same examiner.

**Data Analysis**

For static acquisitions, visibility of the scleral spur and trabecular meshwork was checked for all patients (angle closure and open angle) (Table 1) according to the reflectivity and contrast of each structure compared to the background. The shape of the iris and its root and apparent insertion (when it was possible) were evaluated.

For dynamic acquisitions, the reopening of the anterior chamber angle was also assessed with measurement of the angle (degree) before and during (Figure 2) indentation using 3D OCT-1000 software.

Because the scleral spur is not seen in all cases in
OCT imaging (Figure 1) in contrast to UBM, the possible landmark used in AS-OCT is the trabecular meshwork seen as a triangular body. The anterior part of the trabecular meshwork is 500 to 750 µm anterior to the scleral spur. \(^7\)

The apex of the angle measured was the crossing between two lines: the first was parallel to the inner corneoscleral junction passing by the anterior part of the trabecular meshwork and the second was a line parallel to the iris passing by a mirror point of the anterior part of the trabecular meshwork on the iris. The line between these two points was perpendicular to the corneoscleral plane.

The agreement between the two examinations and then repeatability was determined using intraclass correlation coefficients (ICCs): ICC = (within variance + between variance) / (within variance + between variance). A higher ICC indicates better reproducibility of the method.

Angle measures were compared before and after indentation for temporal angle alone, nasal angle alone, or both together, and for open angles and closed angles groups.

### Table 1

<table>
<thead>
<tr>
<th>Pathology</th>
<th>No. (n = 21)</th>
<th>Before Gonioscopy</th>
<th>After Gonioscopy</th>
<th>Image Quality</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>SS</td>
<td>TM</td>
<td>SS</td>
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<td>Controls</td>
<td></td>
<td></td>
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<td>POAG</td>
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<td>+++</td>
<td>++</td>
<td>++</td>
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<td>++</td>
<td>++</td>
<td>++</td>
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<tr>
<td>PG</td>
<td>1</td>
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<td>++</td>
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<tr>
<td>Narrow and closed angle</td>
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<td></td>
<td></td>
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<td>Iris plateau</td>
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<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
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<td>–</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>NVG</td>
<td>1</td>
<td>–</td>
<td>+</td>
<td>–</td>
</tr>
<tr>
<td>Pupil block</td>
<td>7</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>

SS = scleral spur; TM = trabecular meshwork; POAG = primary angle-closure glaucoma; JG = juvenile glaucoma; PG = pigmentary glaucoma; MG = malignant glaucoma; NVG = neovascular glaucoma; +++ = excellent visibility; ++ = good visibility; + = mild visibility; – = non-visibility.

**Figure 1.** Analysis of anterior chamber angle in a patient with iris plateau (A) before and (B) during (C) corneal indentation (thin arrows: scleral spur; large arrows: “double hump aspect”).
Statistical analysis was performed using SPSS software version 13.0 for Windows (SPSS, Inc., Chicago, IL). Statistical significance was defined as a *P* value of less than .05. Because of the small sample size, non-parametric tests were applied and 95% confidence intervals were given in descriptive distribution analysis of the parameter. The Mann–Whitney *U* test was then used to compare groups pairwise.

RESULTS

In all 21 eyes of 16 patients (mean age: 52.1 ± 13.5 years), AS-OCT provided high-resolution information regarding iris configuration. Seventeen eyes of 12 patients (mean age: 52.3 ± 13.7 years) had narrow or closed angles as determined by gonioscopy and 4 eyes of 4 patients (mean age: 51.2 ± 14.9 years) had open-angle glaucoma (primary open-angle glaucoma, juvenile glaucoma, and pigmentary glaucoma). All were of satisfactory quality with minor issues identified, including movement artifacts that required the scan to be retaken.

Even if a good analysis of the anterior chamber angle was possible, the visualization of the scleral spur and the trabecular meshwork showed a high variability (Table 1). The indentation did not dramatically increase visibility of the scleral spur and was of a moderate effect concerning exposition of the trabecular meshwork, but imaging of the angle and iris configuration was still possible with minimal image degradation. For the 8 cases of plateau iris, the indirect signs were accurate enough to guide the diagnosis in all plateau iris and then easily confirmed by UBM.8

In the angle closed by peripheral anterior synechiae, there was no reopening of the anterior chamber angle. For the reopenable angle, the measures were significantly increased after indentation. In non-indented angles (nasal and temporal), the mean angle was 9.8 ± 5.8 degrees) and increased to 16.4 ± 4.6 degrees (*P* < .0001, Mann–Whitney *U* test) after indentation. This increase was also significant between non-indented and indented angles in nasal (10 to 16.2 degrees, *P* = .013, Mann–Whitney *U* test) and temporal (9.6 to 16.6 deg-
Significant difference was not achieved between nasal and temporal angles before \((P = .885, \text{Mann–Whitney } U\text{ test})\) and after \((P = .623, \text{Mann–Whitney } U\text{ test})\) indentation. The average values of non-indented nasal and temporal anterior chamber angle found in our study are comparable to those measured by AS-OCT and reported in the literature.\(^9\) Moreover, the nasal edge was more open than the temporal edge, but not statistically significant.

The relative variations in the measurements between the two successive examinations were small, and the ICCs calculated for this group were always larger than 0.91. Reproducibility of angle measurements was good for non-indented \((\text{ICC } = 0.979)\) and indented \((\text{ICC of } 0.913)\) angles. This difference was due to small changes in the strength of indentation, but this was not a problem for good reproducibility. Furthermore, it should be noted that all angles with appositional closure observed with AS-OCT could be opened by corneal indentation. The only difference was on reopening the angle.

Two descriptive cases illustrating typical examples of angle closure are presented below.

**Case 1: Plateau Iris Syndrome**

A 56-year-old woman presented to the ophthalmology department with a red, painful right eye, blurred vision, and headache. Intraocular pressure was 54 mm Hg in the right eye and 22 mm Hg in

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**Figure 3.** Right eye of case 1. Narrow angle with partial opening during indentation due to peripheral anterior synechiae predominantly on nasal angle.

**Figure 4.** Left eye of case 1. Narrow angle partially reopened by corneal indentation.
the left eye. Right acute angle-closure glaucoma was diagnosed. Following administration of topical and systemic treatment, a laser peripheral iridotomy was performed on the right eye. The intraocular pressure decreased to 25 mm Hg despite a patent laser peripheral iridotomy. Imaging of the anterior chamber by OCT showed that the iris root was angulated and iris configuration was compatible with that of plateau iris aspect in both eyes (Figures 3-4). Dynamic gonioscopy with OCT was performed and showed a narrow angle in the right eye with an incomplete aperture essentially in the nasal part secondary to peripheral anterior synechiae due to acute crisis (Figure 3). A narrower angle with a better aperture during indentation (Figure 4) without peripheral anterior synechiae was observed in the left eye. UBM confirmed the diagnosis already made by OCT. Iridoplasty was performed, with normalization of intraocular pressure and resolution of symptoms in both eyes.

**Case 2: Creeping Angle-Closure Glaucoma**

A 31-year-old man with a history of intermittent angle-closure episodes underwent anterior chamber examination and UBM, which revealed bilateral creeping angle-closure glaucoma with iris plateau configuration. The right eye was more symptomatic and showed wide iridocorneal synechiae. The angle was shortened with iris stuck to the cornea (Figures 5-6), which brings the peripheral iris close to the external angle wall. Dynamic gonioscopy with OCT did not permit reopening of the angle because of the peripheral anterior synechiae.
DISCUSSION

Gonioscopy is an essential step during clinical examination of a patient presenting with raised intraocular pressure or glaucoma. When assessing a patient with a narrow angle for occludability, it is important to perform gonioscopy with no indentation on the cornea and in a room with dim illumination using the smallest square of light for a slit beam set off the pupil to avoid stimulating the pupillary light reflex. The aim of these strict conditions is to prevent artifacts that could create a pseudo open angle on examination. However, this technique is not easy to perform and requires some training to be efficient and reproducible. Thus, AS-OCT is a good alternative or supplement to complete anterior chamber angle assessment.

With AS-OCT, use of the infrared laser and the non-contact technique during examination allows capturing of the angle morphology in the dark. Moreover, AS-OCT has the potential to provide valuable quantitative and spatial information regarding dynamic changes of the angle configuration not provided by standard gonioscopy. Compared to other diagnostic techniques that analyze the anterior segment, such as UBM, dynamic gonioscopy by AS-OCT has advantages for the patient because it is a non-invasive, reproducible, fast, and well-tolerated method.

With our technique, it is now possible to distinguish between appositional closure and synechial closure by AS-OCT. However, it is necessary to clarify that even if our technique is useful in exploring the anterior segment, only a few meridians could be checked easily, especially horizontals, and some experience is required to perform it well. Furthermore, superior and inferior meridians are difficult to assess and their examination only permits less reproducible examinations. It might be interesting to use AS-OCT with an eye-tracker system to improve the quality of vertical meridian images and more widely for all examinations.

Even if dynamic indentation gonioscopy with a goniprism is the current reference standard for clinically assessing anterior chamber angle structures and their configuration, dynamic gonioscopy with OCT is a technique for completing the clinical examination that could provide more than simple qualitative information and, when associated with optic nerve and retinal thickness assessment, allows a broader assessment of a clinical state. This method would appear to offer a convenient and rapid method of assessing the configuration of the anterior chamber and may help during routine clinical assessment and treatment of patients with narrow or closed angles, particularly when gonioscopy is difficult to interpret, as in highly pigmented angle. With the development of a new generation of OCT and the emergence of three-dimensional acquisition, dynamic gonioscopy with OCT would allow imaging of the entire circumference of the angle rather than one meridian, making this technique clinically more accomplished.

REFERENCES