Country	CET/CPD information	Audience	Competencies	MCQs
UK	This article offers 1 non-interactive CET point (C-73783)	General Optical Council Approved CET For Optometrists	STANDARDS OF PRACTICE; OCULAR EXAMINATION; OCULAR DISEASE	6
ROI	All articles are CPD accredited in the Republic of Ireland			6

Anterior Segment OCT

by **William Lok** BSc MCOptom FBDO Dip Tp (IP)
and **Mike Horler** BSc(Hons) MCOptom Cert Oc Pharm Oc Therapeutics

Outline

This article examines how practitioners can make effective use of OCT images in the diagnosis and management of a range of anterior chamber structures and conditions.

About the authors

William is dual qualified as a dispensing optician and optometrist as wells as clinical director of Lok Optometric Consultants Ltd, a company which develops and delivers training materials for optical conferences. He qualified as a dispensing optician in October 2005, an optometrist in August 2010 and was awarded independent prescriber status in June 2014. William has considerable experience of developing and delivering CET peer discussion sessions at regional and national training events.

Mike is the Ophthalmic Director and Clinical Lead at Specsavers Brighton. Alongside this varied role, Mike also works as a specialist optometrist in the macula clinic at Sussex eye hospital and is an AMD Community Optometrist with Special Interest in Brighton & Hove. He offers support for other practitioners in his role as Head of Enhanced Optical Services in the South East. This role involves furthering clinical scope, development and professional standards. Mike is also a WOPEC lead assessor and sits on Specsavers Professional Leadership Council. Mike has lived and practiced overseas in New Zealand, where he gained full therapeutics endorsement and worked with ophthalmologists in co-management. He has delivered and examined on various CPD courses for students and optometrists and acted as an OCANZ examiner there. He has delivered a number of CET-accredited lectures and workshops including the Optometry Tomorrow Conference and Specsavers Professional Advancement Conferences.

GOC's Enhanced CET Scheme

CET and CPD regulators require practitioners to reflect on their learning. Additional activities are required to gain CET for distance learning.

Log into your CET dashboard via iLearn. On the menu you reach you will find non-interactive CET for this unit of learning.

For 'non-interactive' CET you have to pass (>60%) a six-question multiple-choice quiz.

The learning objectives for this article are:

2.7.2 Optometrists will have an enhanced understanding of the use of OCT for anterior chamber assessment in glaucoma monitoring and refractive surgical pathways

3.1.1 Optometrists will have an evidence-based understanding of assessment of the dimensions and curvature of the cornea and other anterior chamber structures using OCT

6.1.8 Optometrists will have an enhanced understanding of the assessment of the anterior chamber angle and other anterior segment structures using OCT and gonioscopy

Introduction

Optical coherence tomography (OCT) is a high resolution cross-sectional imaging technique that was initially developed for retinal imaging. In 1994, Izatt et al. first described anterior segment OCT (ASOCT) imaging using the same wavelength of light as retinal OCT (i.e. 830nm).[1] However, a wavelength of 830nm is not ideal for imaging the angle due to inadequate penetration through the sclera and other light scattering tissue. OCT imaging of the anterior segment using a longer wavelength of 1310nm was later developed. The advantages of using 1310nm include:

- Better penetration through the sclera
- Real-time imaging (eight frames per second)[2]

There are many varied applications of ASOCT, each requiring different scan protocols. The two main scanning protocols used for anterior segment imaging are:

- Radial OCT scans — consisting of 12 B-scans in a radial pattern, usually used to assess the corneal curvature and thickness (Figure 1)
- High-resolution single line B-scans — usually used when a high-quality image of an anterior structure is required (Figure 2)

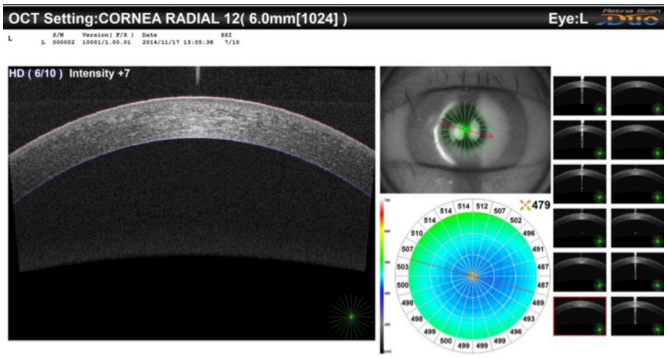

Figure 1: A corneal scan output displaying corneal thickness, curvature values and pachymetry readings

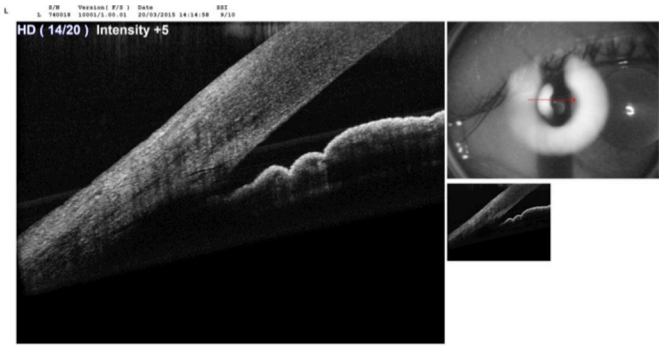

Figure 2: A high quality image of the anterior chamber

ASOCT offers the ability to non-invasively image the anterior chamber angle and, depending on the scan resolution and the wavelength of light used, it can also be used to visualise the angle structures. Furthermore, an automated measurement of central corneal thickness can be obtained, using a radial scan protocol.

Clinical applications

In addition to its use in glaucoma practice, ASOCT can be used to assist in cataract and refractive practice. Preoperative evaluation of refractive patients with ASOCT can provide intricate detail of the anterior segment, specifically the cornea, iris, and anterior chamber angle. Cross-sectional images are most frequently used in the evaluation of these structures. Images of the angle are commonly captured to quantify the angle for angle closure glaucoma and identify the following:

- Scleral spur
- Schlemm's canal
- Schwalbe's line
- Trabecular meshwork

The pachymetry feature of an ASOCT can be used to quantify the degree of corneal oedema over time. Thus, it is useful in pre- and post-operative assessment of patients with Fuchs endothelial dystrophy and can be helpful in explaining to patients why their vision is affected.

In endothelial keratoplasty, the "flap tool" may also be used to measure pre-cut endothelial keratoplasty buttons as well as in vitro during the post-operative course. Limbus-to-limbus pachymetry can deliver significant information regarding the suitability of a patient for surgery. Knowledge of residual bed thickness will provide the surgeon with valuable information to avoid ectasia. Therefore, the "flap tool" may be used to measure the flap and residual stromal bed thickness in post-operative LASIK patients.

Anterior chamber biometry is helpful for refractive surgery as the strength of an ASOCT is the characterisation of the anterior chamber dimensions in phakic refractive implant and glaucoma patients. The distances from the endothelium to the anterior lens surface, anterior chamber angle width, white-to-white measurement, and sulcus-to-sulcus measurement can be performed.

Differentiation of iris lesions such as pigment epithelial cysts, iris nevus, iris melanoma and iridoschesis may also be viewed with ASOCT.

Due to the limitations of light, imaging the lens, posterior to the iris and ciliary body, can be difficult. Images of anterior segment cysts and tumours are sometimes possible, but are generally imaged with ultrasound biomicrscopy (UBM).

Corneal thickness

ASOCT measurement of corneal thickness has been shown to have comparable repeatability to that of ultrasound pachymetry (currently the gold standard technique). However, due to differences in the way corneal thickness is measured, OCT assessment of corneal thickness consistently measures 16µm thinner than ultrasound.

As mentioned earlier, an ASOCT output of the corneal scan automatically provides pachymetry readings. These not only highlight the thinnest point of the cornea, but also present a very useful pachymetry map. Although this does not provide true topography data, it can help to understand a lot about the shape and health of the cornea.

Qualitative assessment

When interpreting ASOCT images, it is essential that the scleral spur is correctly identified. The scleral spur is viewed as an inward projection of the sclera at the junction between the inner scleral and corneal curvatures (Figure 3).

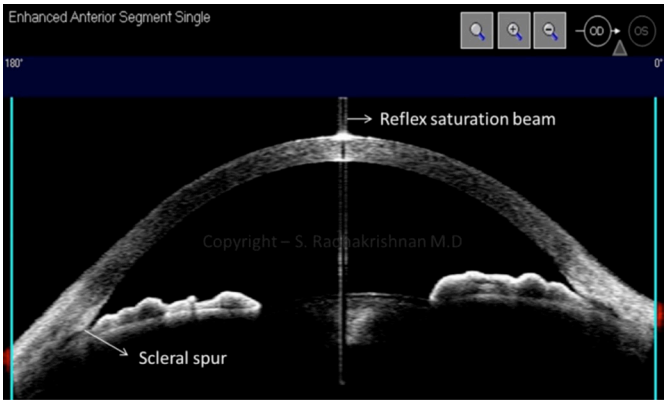

Figure 3: Anterior segment scan depicting the location of the scleral spur

The position between the iris and the inner corneoscleral wall can be used as a qualitative method of detecting angle closure.[3,4] However, the amount of apposition may be variable (Figures 4 and 5) and does not correlate exactly as defined by gonioscopy.

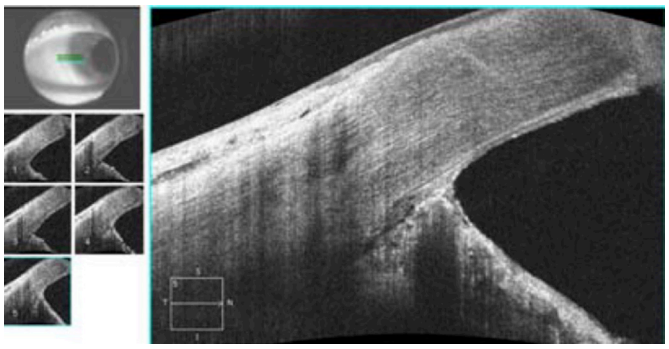

Figure 4: ASOCT depicting an open anterior chamber angle

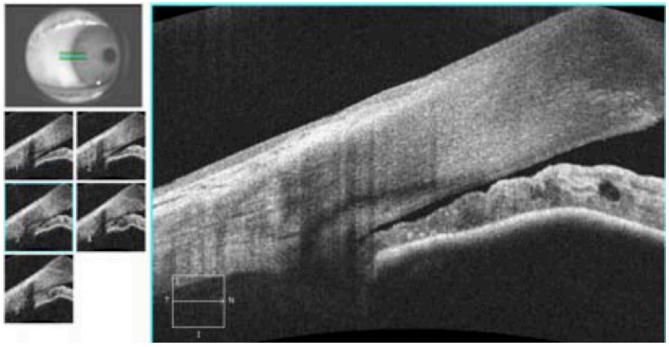

Figure 5: ASOCT depicting a narrow anterior chamber angle

Gonioscopy remains the gold standard for assessing anterior chamber angle. With gonioscopy, any abnormalities within the angle (e.g. pigment deposition, neovascular growth etc.) can be detected and the width of the angle can be graded depending on which structures are visible (Table 1). However, as this is a subjective technique, it can be affected by several factors including:

- Patient cooperation
- Examiner's skill
- Type of lens used
- Direction of gaze
- Unintentional pressure on the cornea
- Environmental illumination

Two of the common flaws in the performance of clinical gonioscopy (the placement of pressure on the cornea and the use of excessive amounts of light) can affect the examination outcome. Both of these factors characteristically result in the illusion of an open angle in a patient who otherwise may have narrow, or even appositionally closed, angles.

ASOCT is a non-invasive aide to gonioscopy, providing a direct measurement of the iridocorneal angle. For patients with narrow anterior chamber angles, ASOCT can help determine whether the patient is at risk for angle closure, which may necessitate laser iridotomy. Furthermore, the location and patency of the drainage device may be determined by ASOCT in patients with more advanced glaucoma.

Imaging of the anterior segment of the eye can therefore offer an objective method for visualising the angle and neighbouring anatomical structures.

Grade	Structures visible	Probability of closure	Van Herrick equivalent
0	None	Closed	0
1	Only Schwalbe's line visible	Very likely	1
2	Trabecular meshwork visible	Possible	2
3	Scleral spur visible	Unlikely	3
4	Ciliary body visible	Impossible	4

Table 1: Gonioscopy grading of the anterior chamber angle

Quantitative assessment

While simply viewing the B-scan images can help to determine whether there is suitable space to allow aqueous drainage through the trabecular meshwork, it is sometimes useful to be able to quantify the angle.

Quantitative measurement of the anterior chamber angle is possible with in-built software in most of the anterior segment devices and requires the identification of the scleral spur. Several parameters have been described and previous studies have shown good reproducibility.[5–7] To gain a repeatable measurement, the angle should be measured from 500µm anterior to the scleral spur, to a point perpendicularly opposite on the iris. However, there are limitations in the routine use of quantitative measurement for angle assessment, these include:

- The visibility of scleral spur
- Natural variation in angle anatomy within the same eye, and between eyes

Several other quantitative parameters can also be used in the assessment of the anterior chamber angle. These include:

- Iris thickness[8]
- Anterior chamber width[9]
- Lens vault[10]

Excessive vaulting of a posterior chamber (i.e. long axial length), may cause the iris diaphragm to bulge forward, leading to narrowing of the anterior chamber angle. Similarly, the lack of vaulting of a posterior chamber lens (i.e. short axial length), may result in an anterior subcapsular cataract. The ideal vault height for a posterior chamber refractive implant is approximately 350µm in myopia and 250µm in hyperopia[10]; these dimensions can accurately be determined with ASOCT. By imaging the lens, the surgeon is able to ascertain the location of intraocular lenses.

Anterior chamber angle measurements with ASOCT can give further information on the relationship between the iris and cornea. The commonly used quantitative parameters are as follows (Figures 6 and 7):

1. Angle opening distance (in mm): Perpendicular distance between a point 500µm (AOD 500) or 750µm (AOD750) anterior to the scleral spur and the opposing iris
2. Angle recess area (in mm^2): The triangular area (ARA 500 or 750) bounded by the AOD 500 or 750, the anterior iris surface and the inner corneoscleral wall
3. Trabecular space area (in mm^2): Trapezoidal area (TISA 500 or 750) bounded by the AOD 500 or 750, the anterior iris surface, the inner corneoscleral wall and the perpendicular distance between the scleral spur and the opposing iris

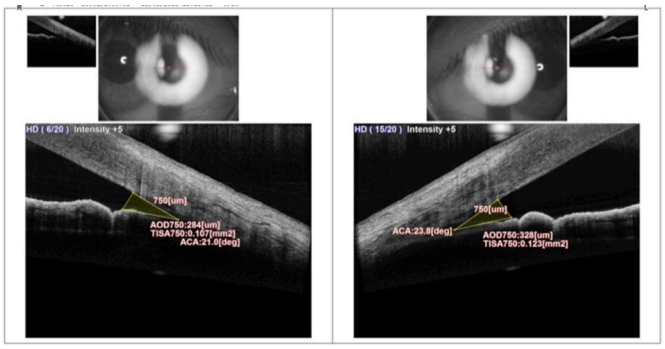

Figure 6: Image of the anterior chamber with quantitative measurements

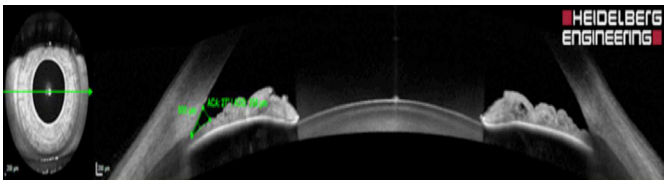

Figure 7: Visualisation of both angles with measuring tool

ASOCT can quantitatively measure the exact angle recess as well as provide an insight into the possible mechanism of the angle's narrowing or closure, including:

- A primarily lens-related mechanism
- Plateau iris
- Combined lens rise and plateau iris
- Malignant glaucoma

Classically, in plateau iris, the central anterior chamber is deep, but the peripheral anterior chamber is shallow, leading to the illusion of an open angle on examination. However, with gonioscopy, the iridotrabecular proximity can be identified along with the 'double hump' sign upon light compression. This finding occurs where it is thought the ciliary body is more anteriorly positioned or relatively enlarged, thus propping up the peripheral iris and resulting in the narrow angle. Although ASOCT provides key information and numerous signs, clinicians must remember that plateau iris, or any ciliary body mediated posterior pushing of the peripheral iris (i.e. a cyst or tumour), cannot be diagnosed using ASOCT alone as the ASOCT is unable to image any tissues posterior to the iris due to its pigmentation. Clinicians should therefore use UBM for definitive documentation and evaluation of the ciliary processes.

Anterior chamber angle

Currently, the number of people with glaucoma worldwide is estimated to be 64.3 million. Studies have revealed that 10% of glaucoma cases have closed angles, with 75% of these being wrongly diagnosed with primary open angle glaucoma. Examination of the anterior chamber angle is essential in determining the possibility of angle closure. Currently, gonioscopy is the gold standard in anterior chamber angle assessment. However, the assessment is subjective and highly reliant on the assessor's judgment.

When gonioscopy is not feasible due to corneal pathology or lack of patient cooperation, ASOCT can be useful as an assistant or substitute to gonioscopy in clinical glaucoma practice. When compared to gonioscopy, OCT has the advantages of:

- Being non-contact
- Quick and easy to perform
- Can be performed under dark conditions allowing angle assessment during physiological mydriasis

Based on the iris profile and position of the lens with respect to anterior segment structures, mechanisms of angle closure such as pupillary block and anterior lens vault can be distinguished. It is important to note that structures behind the iris cannot be visualised with OCT, thus diagnosis of angle closure due to posterior mechanisms of such as iridociliary lesions and plateau iris must be confirmed with UBM. ASOCT is also more useful than UBM for consecutive monitoring of the angle since approximate alignment with ocular landmarks (e.g. iridotomies, iris nevi, conjunctival blood vessels etc.) can be performed with ASOCT. OCT may also be used to image the trabeculectomy blebs and anterior segment implants (e.g. drainage devices and keratoprosthesis).

Summary

Technology cannot substitute a thorough clinical examination and the diagnostic and therapeutic decision-making of an experienced clinician. Furthermore, as ASOCT has its limitations, most notably its inability to image through pigmented tissue, it is inadequate for the assessment of the ciliary body, zonules, posterior chamber, or anterior vitreous.

However, as ASOCT produces exceptional cross-sectional views of the anterior segment, and it has the capacity to accurately measure various spaces and angles between tissues, this technology can be a powerful tool for verifying disease and providing diagnostic signs. It can also be used for monitoring changes and progression of the tissue's position over time. As ASOCT provides excellent high-resolution images, is non-contact in nature and possess a rapid scanning rate, it is an excellent tool for both the clinician and the patient to help with diagnosis and management of anterior eye anomalies.

References

1. Izatt JA, Hee MR, Swanson EA et al. Micrometer-scale resolution imaging of the anterior eye in vivo with optical coherence tomography. *Arch Ophthalmol* 1994;112:1584–9

2. Radhakrishnan S, Rollins AM, Roth JE et al. Real-time optical coherence tomography of the anterior segment at 1310 nm. *Arch Ophthalmol* 2001;119:1179–85.

3. Nolan WP, See JL, Chew PT et al. Detection of primary angle closure using anterior segment OCT in Asian eyes. *Ophthalmology* 2007;114:33–9.

4. Lavanya R, Foster PJ, Sakata LM et al. Screening for narrow angle s in the Singapore population: evaluation of new non-contact screening methods. *Ophthalmology* 2008;115:1720–7.

5. Radhakrishnan S, Goldsmith J, Westphal V et al. Comparison of coherence tomography and ultrasound biomicroscopy for detection of narrow anterior chamber angles. *Arch Ophthalmol* 2005;128:1053–9.

6. Fukuda S, Kawana K, Yasuno Y et al. Repeatability and reproducibility of anterior ocular biometric measurements with 2-D and 3-D optical coherence tomography. *J Cataract Refract Surg* 2010;36:1867–73.

7. Tan AN, Sauren LD, de Brabander J et al. Reproducibility of anterior chamber angle measurements with anterior segment OCT. *Invest Ophthalmol Vis Sci* 2011;52:2095–9.

8. Wang B, Sakata LM, Friedman DS et al. Quantitative iris parameters and association with narrow angles. *Ophthalmology* 2010;117:11–7.

9. Nongpiur ME, Sakata LM, Friedman DS et al. Novel association of smaller anterior chamber width with angle closure in Singaporeans. *Ophthalmology* 2010;117:1967–73.

10. Tan GS, He M, Zhao W et al. Determinants of lens vault and association with narrow angles in patients from Singapore. *Am J Ophthalmol* 2012;154:39–46.