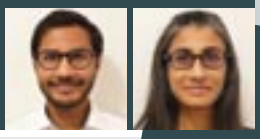

COMPETENCIES COVERED

DISPENSING OPTICIANS
Standards of Practice, Methods of Ocular Examination

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This CET has been approved for one point by the GOC. It is open to all FBDO members, and associate member optometrists. The multiple-choice questions (MCQs) for this month's CET are available **online only**, to comply with the GOC's Good Practice Guidance for this type of CET. Insert your answers to the six MCQs online at www.abdo.org.uk. After member login, go into the secure membership portal and CET Online will be found on the L menu.
Questions will be presented in random order. Please ensure that your email address and GOC number are up-to-date. The pass mark is 60 per cent. The answers will appear in the May 2021 issue of *Dispensing Optics*. The closing date is 9 April 2021.

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C-76735 Approved for one CET Point

Getting to grips with OCT Part 1

By Prashant Shah BSc(Hons) MCOptom PGDipOphth DipClinOptom and Yashita Shah BSc(Hons) PGDipOphth

Optical coherence tomography (OCT) is a quick, non-contact, non-invasive and reliable imaging technique, which has transformed ophthalmology and optometry practice. OCT provides both qualitative and quantitative (thickness and volume) analysis of the optic disc, macula and retina – and can be used to evaluate the anterior segment of the eye. It uses low coherence interferometry to produce a 3D image of the retina and can be performed with or without pupil dilation. OCT has been commercially available since 1996[1]. As its use is increasing in primary eyecare settings, this article explores the benefits, limitations and history of OCT and its applications in practice.

APPLICATION OF OCT IN PRACTICE

OCT is currently being used for research, screening, diagnosing and monitoring pathology of the macula, retinal nerve fibre layer, optic nerve and anterior segment. It can be used to quantify structures and lesions and monitor progression over time. Treatment planning and response to treatment is another feature of OCT use; for example, if patients need additional therapy, OCT imaging can assist in clinical decision making.

Anterior segment OCT has a wide variety of clinical applications, including diagnosing and managing conditions such as ocular surface disease, keratoconus, corneal dystrophies and glaucoma. Other uses are for anterior chamber angle assessment, central corneal thickness measurement and contact lens assessment[2,3].

One of the more recent developments in OCT technology is OCT angiography. It is used to visualise the retinal and choroidal vasculature, which is useful in conditions such as diabetic retinopathy[4]. Unlike fluorescein angiography and indocyanine green angiography, it does not require the injection of contrast dye – so it is particularly beneficial in cases when a patient may have an allergy to the dye or in those with severe renal impairment[4].

This article focuses primarily on OCT application for common eye conditions encountered in everyday clinical practice. Therefore, anterior segment OCT and OCT angiography will not be discussed further as it is beyond the scope of this article.

ROLE OF A DISPENSING OPTICIAN

As more optical practices are utilising OCT, optical assistants and dispensing opticians may be requested to take OCT images as part of the initial screening – as well as to promote the service to

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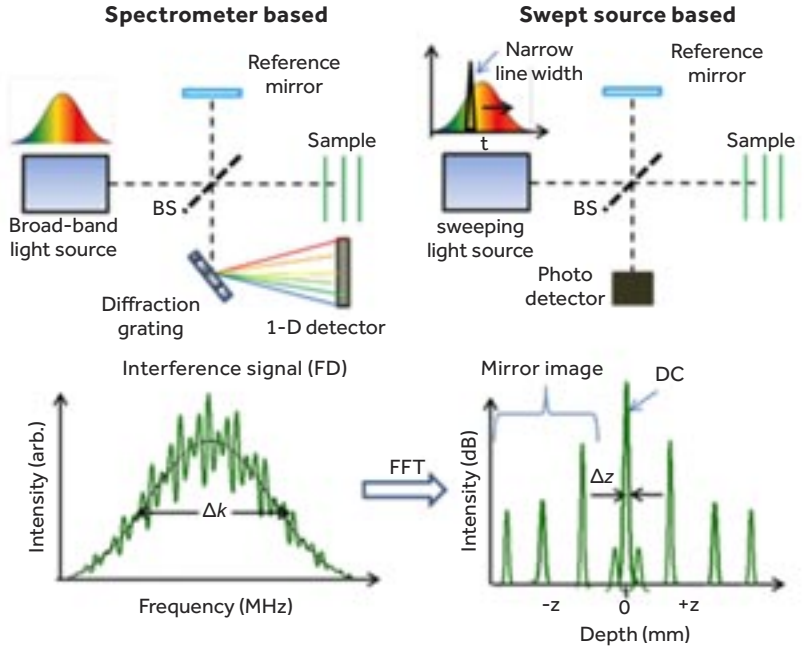

Figure 1. Upper left shows the optical set up of SD-OCT and upper right shows SS-OCT. SD-OCT uses a spectrometer to separate wavelengths, whereas SS-OCT uses a light source which sweeps the wavelength in time. Bottom left of the image is the interference signal produced (FD). Bottom right of the image is the A-scan produced using Fourier Transformation (FFT) of the interference pattern/signal. Sample: Object of interest such as the retina (figure taken from: Drexler W, et al. Optical coherence tomography today: speed, contrast, and multimodality. J. Biomed Opt. 2014;19(7):071412)

patients and the general public before the sight test takes place.

Whilst it is beyond the scope of a dispensing optician to interpret and analyse images in detail, it is advantageous for them to have some background knowledge of the retinal anatomy and to be able to recognise a normal scan from an abnormal one, thereby allowing them to flag any concerns directly to the optometrist. A basic understanding will also enable the dispensing optician to understand and relate patient symptoms to the OCT scan results.

BENEFITS OF OCT

There are clear benefits to having an OCT in practice:

- It has a high degree of sensitivity and specificity in detecting ocular pathology[5-10], such as early stage primary open angle glaucoma or pathology not immediately visible on ophthalmoscopy such as cystoid macula oedema. Early pathology detection leads to better clinical decision making and prognosis for the patient
- False positive referrals can be avoided, giving the optometrist more confidence in managing patients. It also allows referral refinement so that the patient can be seen by the hospital eye service within the appropriate time scale
- Optometrists who become confident in interpreting and analysing images can become involved in shared care schemes, which expands the scope of their clinical work and builds relationships with other healthcare workers
- All-in-one devices, which incorporate retinal imaging with OCT, save space and time. They allow practitioners to compare a lesion on the OCT image to that on the fundus image
- Patients appreciate and like new technology as this makes them feel that they are having a more thorough test. It also allows them to become more involved in their management and gain a better understanding of their eyes

HISTORY AND SCIENCE BEHIND OCT

Low coherence interferometry is the underlying principle for all OCT designs[1-2, 11-13] as shown in **Figure 1**. A laser diode (broad band light source in spectral domain OCT or sweeping light source in swept source OCT) emits low coherent near infrared light (840nm) that travels to an interferometer. Here, the beam of light is split into two equal parts by a beam splitter (BS): one part travels through the ocular media to the retina (known as the measurement beam); and the other part travels to a reference mirror (known as the reference beam).

The difference between the reflected light from the tissue being imaged and the light from the reference mirror, interact to produce an interference pattern, which is converted into a signal by a photosensitive detector (I-D detector or photodetector). These interference patterns give information about the intensity and depth of the reflected light from the measurement beam[11-13].

Fourier transformation (FFT) converts the interference pattern/signal into an A-scan. A-scans are stacked together either in a line or circle to form a 2D cross-sectional B-scan. B-scans can be stacked together to form a 3D image.

Optical surfaces absorb, reflect and transmit the infrared signal. Differences in refractive index and scattering properties of the various different retinal layers produce the contrast on the images, which resemble a histological section. Tissue structures are represented in greyscale or in colour. Digital processing corrects eye movements and digital smoothing techniques are used to further reduce image noise[11].

Time domain OCT (TD-OCT) was the earliest system used, where a moveable reference mirror produced interference patterns as a function of time. It wasn't ideal because the scanning speed was very slow at approximately 400 A-scans per second and it gave a poor resolution of 10 to 15 microns[1,2,13].

This led to the evolution of the second generation system: spectral/Fourier domain OCT (SD-OCT) which was demonstrated in 2003[1,2,13] (**Figure 1**, upper left image). Most OCT machines used in current practice are of this type. A spectrometer measures the interference patterns as a function of frequency whilst the reference mirror is kept stationary. The whole A-scan is generated at once based on Fourier transformation of the interference patterns[1,2]. Scanning speeds are significantly improved to approximately 50,000 A-scans per second therefore

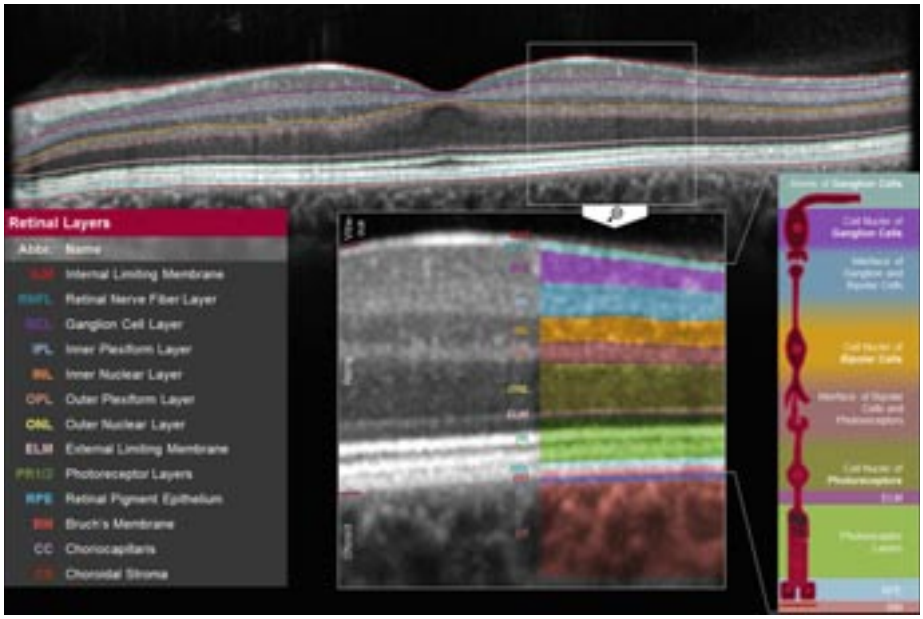

Figure 2. A high resolution macula B-scan showing the 13 retinal layers and the various cells which make up the retina (image courtesy of Heidelberg Engineering)

reducing scanning time. SD-OCT also has better resolution of images (3µm to 6µm) and improved visualisation of the retinal layers.

The latest technology in OCT is swept source (SS-OCT) (**Figure 1**, upper right image). Here a sweeping, tuneable laser light source with a wavelength of 1050nm is used and interference output is measured as a function of time. The scanning speeds are considerably quicker – at approximately 100,000 A-scans per second – and larger areas can also be scanned in a single turn.

The high imaging speed allows high-resolution images (approximately 5µm) to be obtained while reducing the negative effect of the patient's eye movements on scan quality. Signal-to-noise ratio is vastly improved13,14. The longer wavelength enhances the ability to image deeper ocular structures such as the choroid.

SS-OCT can provide clearer images in patients with media opacities compared to conventional SD-OCT due to less light scattering13,14. Despite these advantages, SS-OCT is not commonly found in widespread optometric practice due to the high purchase cost of the machine.

LIMITATIONS OF OCT

The following factors must be taken into consideration when analysing OCT images as they can affect the quality of the scan:

- High prescription and axial length can affect accuracy
- Poor signal strength: due to media opacities, ocular surface disease, miotic pupils, reduced tear film quality and motion artefacts
- It is important to consider whether boundaries defined by the software have been placed correctly, otherwise thickness measurements may not be accurate and poorly centred scans may also make the statistical analysis inaccurate
- Frequent blinking, tremors, nystagmus

RETINAL ANATOMY AND IMAGE INTERPRETATION

OCT images represent an *in vivo* histology of the retina. Before they can be interpreted and analysed, it is important to understand the normal chorioretinal anatomy and what a normal OCT scan looks like. Only then can abnormal scans be detected.

Figure 2 shows a high resolution OCT macula B-scan highlighting 13 layers of the retina including the choroid. Retinal anatomy can be complicated to understand. It is simpler to divide it into two zones: the inner retina and the outer retina.

The top part of a B-scan is the inner retina, which lies closest to the vitreous humour. The inner retina consists of the internal limiting membrane through to the external limiting membrane (ILM, RNFL, GCL, IPL, INL, OPL, ONL, ELM). The vascular supply of the inner retina is from the central retinal artery; its largest capillaries are innermost and its smallest capillaries outermost at the level of the INL and IPL[15,16]. These are usually the first to leak in diabetic eye disease.

The outer retina is closest to the choroid (bottom of B-scan) and consists of the photoreceptor layers through to the choroid (PR, RPE, Bruch's membrane, choriocapillaris and choroidal stroma). The outer retina is avascular and gets its oxygen and nutrient supply from the choroid[17].

Another way to understand retinal anatomy is to divide it into the neurosensory retina and the RPE/Bruch's membrane complex.

The neurosensory retina is classified from the ILM to the photoreceptor level. This layer is responsible for converting light into electrical signals, which are then sent to the occipital lobe in the brain for analysis and image construction. The neurosensory retina has high metabolic activity[18].

The RPE is a single layer of cells between the photoreceptors and choroid. Its three main functions are: to keep the neuroretina and sub retinal space dry by pumping out water; to prevent glare by using melanin to absorb excess light; and to remove waste products from photoreceptors to the choroid as well as moving oxygen and nutrients from the choroid to photoreceptors[19].

The photoreceptors and RPE have a very close relationship and any damage to or loss of these layers can result in poor vision[20,21]. Bruch's membrane is a multi-layered structure, which allows the exchange of metabolic waste products, oxygen, nutrients and fluids between the RPE and choroid.

Several factors such as age, gender and ethnicity can affect macular thickness[22-24]. The thinnest part of the macula is the fovea. The average central macular thickness is approximately 200 to 230 microns[22-24]. Being aware of this value enables the clinician to determine any abnormalities and potential concerns. Thickness values are usually shown on normative data plots/thickness map plots.

COLOUR SCAN VERSUS GREY SCALE SCAN

The various layers on a grey scale B-scan appear as either bright (hyper-reflective) or dark (hypo-reflective) bands depending on whether the layer is reflecting or absorbing light (**Figures 2**

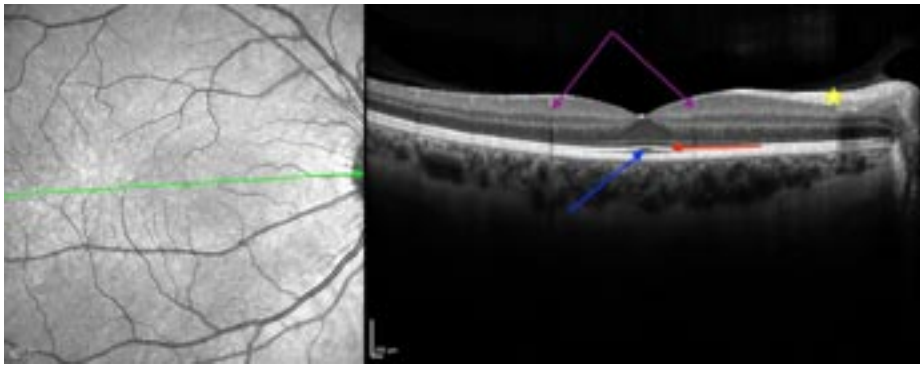

Figure 3. A high resolution macula grey scale B-scan on the right side of the image. Left image is the fundus and OCT was taken along the green line
Annotate: Ellipsoid zone (red arrow), area under fovea (blue arrow), retinal BV (purple arrow), RNFL (yellow star), macula (white circle) (image courtesy of Heidelberg Engineering)

and 3). In a colour OCT scan, the warm colours indicate high reflectivity (red, yellow, white) and the cooler colours (green and blue) indicate low reflectivity (**Figure 4**). Grey scale resolution tends to be better and is more widely used for image interpretation.

HYPER-REFLECTIVE LAYERS AND LESIONS

The RNFL, inner and outer plexiform layers, ELM, inner segment photoreceptor layer, RPE/Bruch's complex, blood, exudates and pigment clumps will all appear hyper-reflective on an OCT scan.

Blood and exudates, although appearing hyper-reflective, can themselves cast shadows on the scan below their location as they block the infrared light signal. Shadows are always cast downwards as the infrared light comes from the front of the eye down to the retina.

HYPO-REFLECTIVE LAYERS AND LESIONS

The ganglion cell layer, layers with cell nuclei such as the inner and outer nuclear layer, and the outer segment photoreceptor layer all appear hypo-reflective on an OCT scan. The vitreous humour and serous fluid also appear hypo-reflective.

A point worth noting is that serous fluid, unlike blood or exudates, does not cast a shadow on the retina below its location. This is because fluid is clear and therefore does not block the infrared light falling on the retina. Fluid can be: intra-retinal, when it is located above the photoreceptors; sub-retinal, which forms below the photoreceptors but above the RPE; or sub-RPE, when it forms below the RPE.

Key signs to be aware of when assessing the OCT B-scan images:

- The photoreceptor inner segment/outer segment junction (also known as the photoreceptor inner segment ellipsoid zone) is clearly visible on OCT (indicated by the red arrow in **Figure 3**). A well-defined, hyper-reflective ellipsoid zone indicates good visual acuity and good photoreceptor function. Disruption of this zone represents photoreceptor damage and a corresponding drop in a patient's visual acuity[25,26]
- The outer segments of cones under the foveal pit are longer and narrower than any other part of the retina. Due to a high concentration of cones in this region, the centre under the foveal pit appears slightly raised (indicated by the blue arrow in **Figure 3**). This is a normal physiological finding and is required for good visual acuity[27-29]
- The retinal nerve fibre layer is thickest nasally and thinner temporally. The thicker side represents the collection of nerve fibres from the macula to the optic nerve (indicated by the yellow star in **Figure 3**)
- The retinal blood vessels are highly reflective and cast a shadow through the whole OCT section because they block the infrared signal (indicated by the purple arrows in **Figure 3**)
- The vitreous humour is 98 per cent water and two per cent collagen. Since it is optically empty, it appears hypo-reflective on an OCT scan. Vitreous floaters, if present, will appear hyper-reflective in the vitreous cavity. However, if they are large enough they can cast a shadow through the whole retina
- If the choroid appears illuminated, it means less infrared light has been absorbed by the neurosensory retina and RPE. Effectively a reverse shadow is produced, for example, in advanced dry macula degeneration

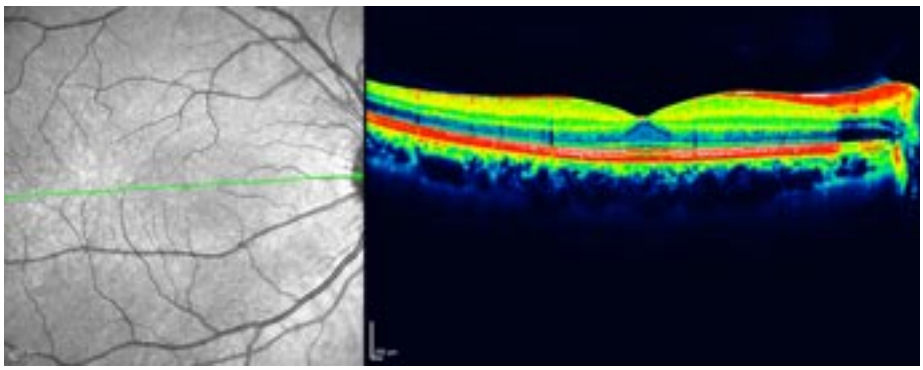

Figure 4. A high resolution macula colour B-scan of the same eye as Figure 3. Warm colours indicate hyper-reflectivity and cooler colours hypo-reflectivity. Grey scale OCT scans show layer detail better (image courtesy of Heidelberg Engineering)

OCT is extremely useful in differentiating features that have similar retinal appearances: for example, drusen and exudates, both of which are yellow retinal lesions. On an OCT scan, however, they are easily differentiated by their location. Drusen are photoreceptor waste products, which accumulate at the level of the Bruch's membrane/RPE. They appear as focal, hyper-reflective RPE elevations. Exudates are lipid residues which have leaked from damaged inner retinal blood capillaries and are located in or adjacent to the OPL.

All OCT instruments are able to image and assess the optic nerve head, RNFL thickness and ganglion cell layer at

the macula, which can be useful as part of glaucoma detection and monitoring. Algorithms compare RNFL thickness and ganglion cell values to stored, age-matched, normative databases. This allows areas of increased or decreased thickness to be identified and monitored for any changes over time.

EVALUATING OCT IMAGES

Normal variations in OCT images and data are crucial to understand in order to help differentiate normal from abnormal scans. OCT scans should always be interpreted in conjunction with other examination results: history and symptoms, visual acuity, intraocular pressures, visual fields and fundus exam. Using a systematic and structured approach when assessing the OCT image will help to ensure the scan is of good quality and that potential pathology is flagged.

Assess the scan quality

There is usually a colour coded scale from 0 to 10 displayed. Seven and above indicates a good quality scan and this can be indicated by a green colour.

Points to note: Is there a good laminar structure? Can the inner and outer retina be identified? Is there a good signal to noise-ratio?

Assess the overall scan profile and appearance

The overall normal retina profile at the macula has a slightly concave appearance (**Figures 2 and 3**). If the concavity or adjacent convexity is exaggerated then the profile would be abnormal. The scan profile will change depending on where it is placed in the eye. Points to note: Does it look like a reasonably good image? Does it look normal or not?

Assess the structure and layers of the retina for any abnormalities or changes

It is important to assess the pre-retinal/epi-retinal layers, intra-retinal layers, and sub- neurosensory retina and sub-RPE for any abnormal changes.

OCT has become an essential part of an optometrist's toolkit assisting in better detection, diagnosis and management of various ocular conditions. Dispensing opticians are well placed in the optical setting to take good quality OCT scans and to recognise common ocular conditions. A good understanding of the retinal anatomy is vital for this.

In the second article next month, we will look at case studies where OCT scans were used in the diagnosis and management of various ocular conditions. Specific signs and features of each condition will be discussed.

PRASHANT SHAH is an optometrist with more than 15 years of clinical experience. He holds postgraduate diplomas in ophthalmology and clinical optometry. Prashant is a regular contributor of CET articles and has had work published in the journals of both the College of Optometrists and Association of Optometrists.

YASHITA SHAH is an experienced optometrist working in independent practice where OCT is routinely used. She holds a postgraduate diploma in ophthalmology and has a keen interest in orthokeratology and dry eye.

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