Introduction

Optical coherence tomography (OCT) is a non-invasive imaging technique that provides high resolution, cross-sectional images of the retina, the retinal nerve fiber layer (RNFL) and the optic nerve head. With axial resolution in the 5–7 μm range, it provides close to an in-vivo 'optical biopsy' of the retina ***(Sull et al., 2010).***

It works similar to ultrasound, simply using light waves instead of sound waves. The time-delay information contained in the light waves reflected from different depths inside a sample the OCT system can reconstruct a depth-profile of the sample structure.

By scanning the light beam laterally across the sample surface three-dimensional images can then be created. The lateral resolution is determined by the spot size of the light beam, the depth (or axial) resolution depends primarily on the optical bandwidth of the light source. ***(lalwani et al ., 2007)***

OCT systems may combine high axial resolutions with large depths of field. Therefore, their primary applications include in vivo imaging through thick sections of biological systems, particularly in the human body.

The technique has already become established as a standard imaging modality for imaging of the eye, with numerous commercial instruments on the market ***(Sampson, 2004).***

At present, OCT imaging is used extensively for imaging the macula, optic nerve and RNFL, and aids in analyzing the morphology and quantifying changes in various disease states. For example, the automated retinal thickness measurements generated by the SD-OCT systems are used clinically for the monitoring progression of diseases such as wet age-related macular degeneration (AMD) and macular edema from various causes including diabetes and retinal vein occlusion. The ability to detect fluid within the retina and the thickness alterations induced by this fluid helps direct clinical decisions regarding treatment ***(Brown, 2007).***

The diagnosis of macular hole and its differentiation between lamellar holes and pseudomacular holes have become straightforward using OCT. In addition, the size and configuration of macular holes, determined by OCT, correlates well with the functional and anatomic outcomes following surgical intervention ***(Negretto et al., 2007).***

Evaluation of the vitreoretinal interface using OCT is important in the evaluation and treatment of diseases of the vitreomacular interface such as epiretinal membranes and vitreomacular traction ***(Hillenkamp et al., 2007).***

In addition, OCT is used to asses optic disc morphology and RNFL thickness to monitor the progression and quantitatively assess the treatment response in patients with glaucoma ***(Ojima et al., 2007).***

Pediatric ophthalmology is a challenging niche of the ophthalmic clinical practice and pathologies, such as cataract, glaucoma or corneal diseases, are far to have the same pathophysiology and management than in adults. The major advantages of the newer, spectral domain devices are their non-contact nature, high acquisition speeds, the range of quantitative and qualitative information they provide, the ability to obtain a 3D in vivo examination of human eyes, and their safety, even in a pediatric population. With the introduction of new generation, high-speed OCT, pediatrics ophthalmology is likely to become an interesting new field for OCT application. The shape and the dimension of the cataract, the IOL position, the posterior capsular bag and the incision healing are potential new targets for OCT. On the

basis of our results, it seems that, in children with aniridia and congenital cataracts, OCT can provide clinically relevant information ***(Matteo et al., 2012).***

Currently, interest in the use of OCT in pediatric patients is mainly focused on retinal disease, with recently published papers reporting the macular changes in patients with ocular albinism and the OCT macular appearance of preterm children with and without retinopathy of prematurity ***(Ecsedy et al., 2007).***

Aim of the Work

The aim of the work is to discuss the role OCT in pediatric ophthalmology.

Chapter (I)
Categories of OCT instrumentation

There are two main categories of OCT instrumentation: Time-Domain OCT (TDOCT) and Spectral-Domain OCT (SDOCT). Time-Domain OCT technology is easier to understand, and most early research and commercial instrumentation was based on this technology. Spectral-Domain OCT is rapidly replacing the Time-Domain technology in most applications because it offers significant advantages in sensitivity and imaging speed ***(Sampson; 2004).***

1. Time-Domain OCT (TDOCT):

Time-domain OCT (TD-OCT) systems featured scan rates of 400 A-scans per second with an axial resolution of 8-10 μm in tissue, the technique employed by commercially available OCT systems such as the Stratus OCT ***(Sull et al., 2010).***

It consists of the Michelson interferometer which splits the light from the broadband source into two paths, the reference and sample arms.

The reference arm is terminated by a mirror allowing scanning in the axial direction, while in the sample arm the light is weakly focused into a sample.

The interference signal is recorded between the reflected reference wave and the backscattered sample wave.

The technique has an axial optical sectioning ability because the light is emitted from a broadband source (large range of optical wavelengths) therefore a strong interference signal is only detected when the light from the reference and sample arms has travelled the same optical distance. **(*Chang et al., 2007)***

When the optical path lengths differ by less than the coherence length of the light source the coherent interference is observed, a quantity that is inversely proportional to its optical bandwidth.

The act of translating (axially scanning) the reference arm reflector is equivalent to performing optical sectioning of the sample, allowing for the generation of map of optical reflectivity versus depth ***(Sampson, 2004).***

Transverse scanning of the sample (to build up a two- or three-dimensional tomographic image) is achieved via rotation of a sample arm galvonometer mirror (fig. 1).

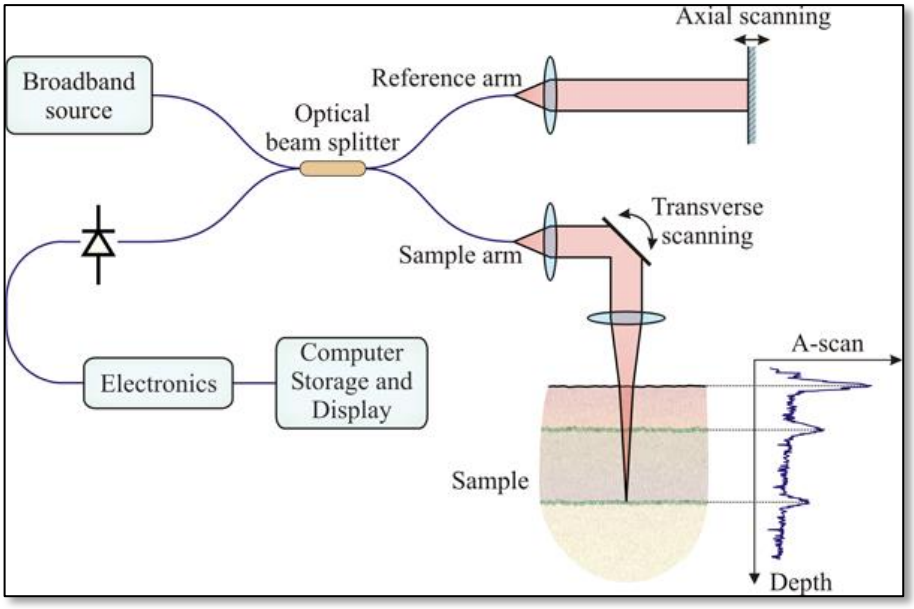

Figure (1): A schematic diagram of the basic fiber-based TDOCT setup ***(Sampson; 2004)***

2. Spectral-Domain OCT (SDOCT):

The key difference from Time-Domain is that the reference arm length is fixed in an SDOCT system.

The output light of the interferometer is analyzed with a spectrometer (hence the term Spectral-Domain).

The measured spectrum of the interferometer output contains the same information as an axial scan of the reference arm.

The interferometer output spectrum by a Fourier Transform provide the map of optical reflectivity versus depth.

This technique achieves scan rates of 20000–52 000 A-scans per second and a resolution of 5–7 μm in tissue (fig. 2) ***(Leitgeb et al., 2003) .***

Recently, spectral-domain (SD) OCT has provided higher-resolution images (less than 5 μm axial resolution) with rapid image acquisition useful for both 2-dimensional (2D) and 3-dimensional (3D) imaging. Because data acquisition is more than 40 times faster with SD OCT than with TD OCT, one can image across larger areas of the retina or scan smaller areas at much greater density ***(Ramos et al., 2009).***

SD OCT has been used to document spontaneous closure of idiopathic macular holes in adult patients and also has been used to document an optic nerve pit with a macular schisis-like cavity in an adult patient ***(Punjabi et al., 2007).***

The particular implementation of SDOCT is referred to as Frequency-Domain OCT (FDOCT) (fig. 2).

Another variant of SDOCT uses a wavelength-tunable laser to rapidly sweep through a range of wavelengths, allowing the spectrum of the interferometer output to be recorded sequentially using a single detector. This technique is called Swept-Source OCT (SSOCT)

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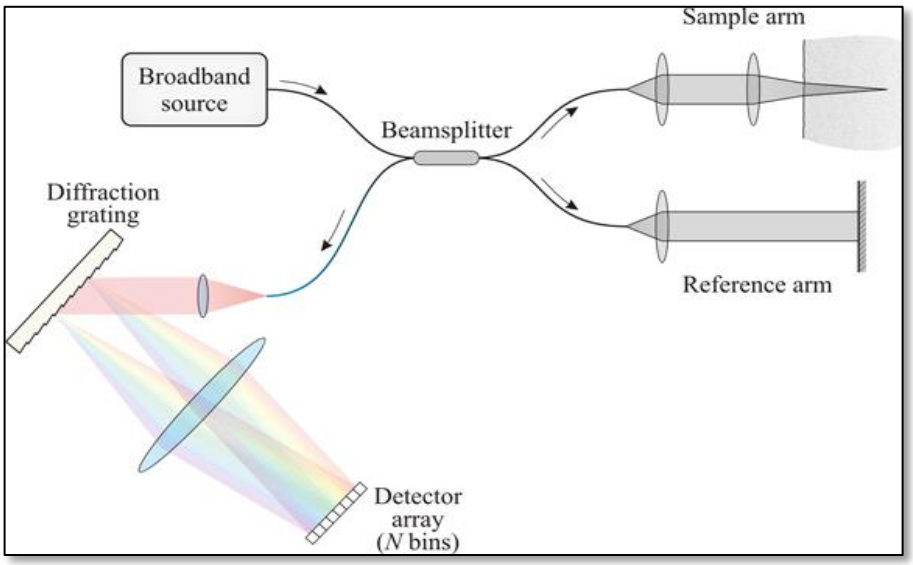

Figure (2): A schematic diagram of a SDOCT system ***(Sampson; 2004)***

Choroidal imaging is an emerging area of research so new innovations in SDOCT hardware and software now allow accurate choroidal thickness measurements ***(De Boer et al., 2003).***

Basic applications of OCT in eye disorders:

Different models of OCT machines are in use ranging from Stratus (resolution 10 microns) to Cirrus-HD (resolution 5 microns) to ultrahigh-resolution models (resolution 2-3 microns) ***(Leitgeb et al., 2003).***

The normal values which help to interpret OCT scans in a better way:

- Distance between vitreoretinal interface and anterior surface of retinal pigment epithelium (RPE): 200 - 275 microns.
- Mean thickness in the foveal region: 170 – 190 microns.
- Mean thickness in peripheral retina: 220 – 280 microns.
- Mean thickness of retinal nerve fiber layer (RNFL): 270 microns (1000 microns from fovea where nerve fibers form a slight arcuate thickening).
- Normal retinal volume: 6-7 cubic mm***. (Nadia et al., 2013)***

Different color codes (white, red, orange, yellow, green, blue, and black in order) printouts by the OCT scan bear pseudo color imaging and retinal mapping, (Fig. 3)

1. White being the thickest scanned retina (>470 microns)

2. Black the thinnest scanned retina (<150 microns) ***(Hee et al., 2004.)***

Color maps may vary for different models of OCT equipment. The retinal pigment epithelium (RPE) is highly light scattering so the choroid cannot be well visualized using the Stratus OCT, resulting in attenuation of the relatively weak reflection signal from the choroid.

The signal and image information from the deeper layers of the choroid is not of high quality to see precise morphological details because of the relatively low signal-to-noise ratio of TD-OCT ***(Manjunath et al., 2010).***

The pixel density of TD-OCT is limited by the number of axial scans in the OCT image which makes visualization of the choroid difficult. On contrary to SD-OCT systems the choroid is visualized using techniques such as image averaging and enhanced depth imaging (EDI) **(*Imamura et al ., 2009).***

Multiple B-scans from the same retinal location are obtained in Image averaging technique to increase the signal-noise ratio, typically in proportion to the square root of the number of images averaged ***(Spaide et al.,2008).***

While EDI involves setting the choroid adjacent to the zero delay line, taking advantage of the sensitivity roll-

off characteristic of SD-OCT systems which allows enhanced visualization of choroid up to the sclera.

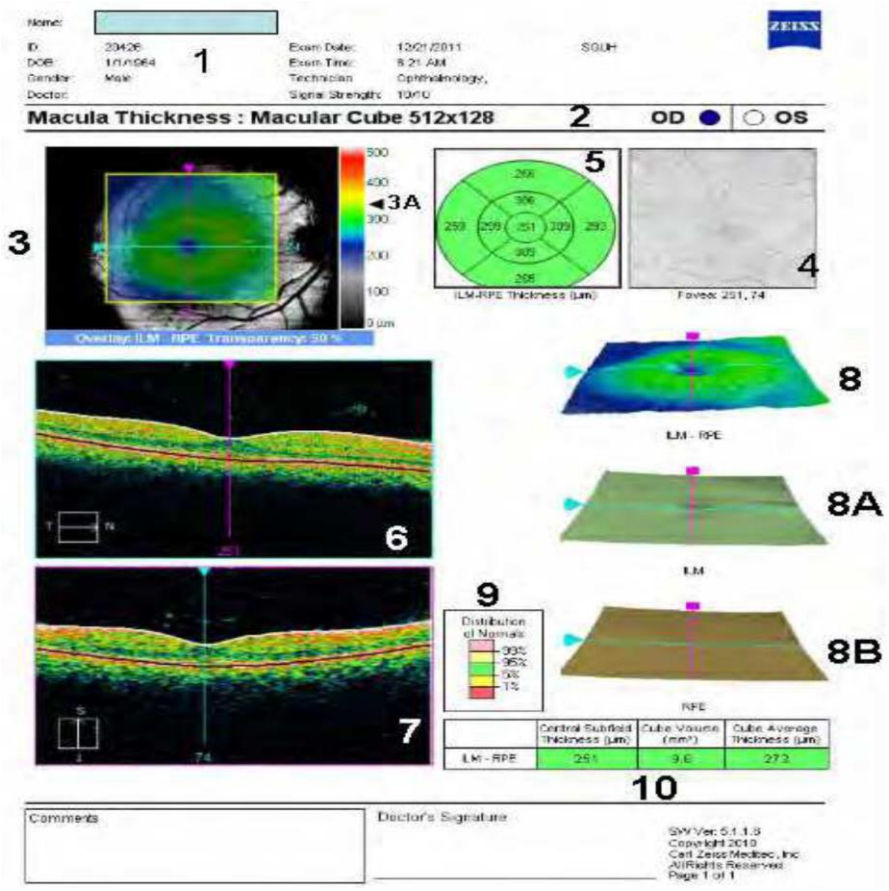

Figure (3): OCT macular thickness stock printout (The macular thickness stock and color code distribution depicted here is for Cirrus 3D HD-OCT) ***(Nadia et al., 2013)***

Figure (3) shows the following:

Section1:

Patient related data, examination date, list and signal strength. It is ideal to have minimum signal strength of 5. If it is less, look for media opacities, dry cornea or a very small pupil.

Section 2:

Indicates whether the scan is related to macula with its pixel strength (as in this picture) or optic disc cube, (It also displays the laterality of the eye: OD (right eye), OS (left eye).

Section 3:

Fundus image with scan cube overlay. 3A: Color code for thickness overlays.

Section 4:

OCT fundus image in grey shade. It shows the surface of the area over which the measurements were made.

Section 5:

The circular map shows overall average thickness in nine sectors. It has three concentric circles representing diameters of 1 mm, 3 mm and 6 mm, and except for the central circle, is divided into superior, nasal, inferior and temporal quadrants. The central circle has a radius of 500 micrometers.

Section 6:

Slice through cube front. Temporal-nasal (left to right).

Section 7:

Slice through cube side. Inferior-superior (left to right).

Section 8:

Thickness between Internal limiting membrane (ILM) to retinal pigment epithelium (RPE) thickness map. 8A: Anterior layer (ILM). 8B: Posterior layer (RPE). All these are 3-D surface maps.

Section 9:

Normative database uses color code to indicate normal distribution percentiles.

Section 10:

Numerical average thickness and volume measurements. The central subfield thickness refers to the central circle of the circular map (section 5) ***(Nadia et al., 2013).***

The total volume and average thickness refer to the ILM-RPE tissue layer over the entire 6 x 6 mm square scanned area. Red and white - High reflectivity (long white arrow); black and blue – low reflectivity (yellow arrow); green - intermediate reflectivity (small white arrow).

Normal retinal structures are labeled as: red for RNFL and junction of inner and outer segments of photoreceptors (PR); green for plexiform layers, and blue/black for nuclear