Intraoperative Optical Coherence Tomography (OCT): A New Frontier in Vitreo-Retinal Surgery

Vinod Kumar, Amit Gadkar, Parijat Chandra, Atul Kumar
Dr R P Centre for Ophthalmic Sciences, All India Institute of Medical Sciences, New Delhi, India

Abstract

Optical coherence tomography, a non-invasive imaging technique is an indispensable tool in the armamentarium of modern day ophthalmologists. With evolution in technology, modern day OCT machines (swept source OCT) are able to provide high resolution images of vitreous, retina, choroid and sclera simultaneously. As a better understanding of various retinal disorders was obtained with the use of OCT, the need for refinement of vitreo-retinal surgery utilizing intra-operative OCT was felt. While earlier versions of intra-operative OCT were hand held, the newer versions are fully integrated with microscope (MIOCT). MIOCT provides spectral-domain OCT (SD-OCT) images while performing the surgery on heads up display. MIOCT has been found to be useful in the management of various disorders such as macular hole, epiretinal membrane, vitreomacular traction syndrome, vitreous hemorrhage and retinal detachment. However the present day intraoperative OCT machines have several limitations, which need to be sorted out before they can be incorporated in the daily practice.

Keywords: optical coherence tomography, intra-operative, microscope, pars plana vitrectomy

Introduction

Optical coherence tomography (OCT) is a noninvasive imaging technique that provides high-resolution, cross-sectional images of the retina, retinal nerve fiber layer and the optic nerve head. It has revolutionized the clinical practice of ophthalmology and is an indispensable tool in the day to day practise of both anterior and posterior segment surgeons as well as physicians. Over the years OCT has evolved from time-domain OCT (TD-OCT) which had axial resolution of 15 microns to spectral-domain OCT (SD-OCT) having axial resolution of 5 to 7 microns. Swept-source OCT (SS-OCT), with a resolution of up to 3 microns, also gives an overview of choroidal pathologies. With its growing use in out patient clinics, the need for OCT was felt in operation theatres as well. This has become particularly relevant in recent years with the evolution of sophisticated micro incision vitrectomy surgery, stress on intraoperative safety measures and better post operative outcomes.

The earlier versions were in the form of hand held portable machines, attached or mounted on to the microscopes. Although these systems provided good visualization, they were limited by the pause required to bring the system into alignment. Hence real-time visualization of surgical manoeuvres was not feasible. In addition, since these devices did not have co-axiality, it was difficult to focus on specific regions of interest. To overcome these limitations, OCT technology capable of intrasurgical imaging of live manoeuvres with integration of OCT scanner into microscope tube was tested in model eyes. However, fiber probe based instruments have traditionally been limited by inherent trade-offs in imaging field-of-view (FOV), sampling density, and resolution. Manual positioning and aiming of probes results in poor imaging stability, all of which need to be addressed prior to their clinical translation.

Microscope integrated OCT (MIOCT) devices designed to enable simultaneous surgical viewing and high-resolution SD-OCT imaging are based on folding of the optical OCT path into the full beam path of the operating microscope to enable high resolution imaging. This system is confocal with surgical microscope allowing multimodal imaging in supine patients. MIOCT has demonstrated high resolution SD-OCT images and videos during cadaveric porcine vitreoretinal surgical manoeuvres, providing the first OCT characterization of vitreoretinal surgical instruments interacting with the retina. The shared optical path of the MIOCT and surgical microscope enabled OCT imaging simultaneous with surgical manipulations.

The RESCAN 700 (Carl Zeiss Meditec, Germany) is a MIOCT system that has been used clinically to visualize steps of surgeries “real time” that could not be documented before. It is an SD-OCT that provides in vivo imaging which can help the surgeon in decision making at the time of surgery and modify his surgical plan. This system is based on the Lumera 700 (Carl Zeiss Meditec, Germany) platform and the RESIGHT lens system is used for posterior segment imaging. Its features include Z tracking and focus control for image stabilization with quality control. The OCT images are projected into the surgeon’s operating field as a “heads up display” without interfering with the surgical procedure. This system provides the surgeon with options to select the scan length, angle, and location either using the foot pedal control or through the video monitor display system.

Clinical Applications

1. Macular hole: Peeling of the internal limiting membrane (ILM) after completing the vitrectomy is an important step in the macular hole surgery. The focus over the years has changed from “successful” to “atraumatic” ILM peeling. Trauma to the nerve fibre layer is not
uncommon, especially while initiating the ILM peeling. This can lead to visual field defects in the post-operative period and hence compromise the final outcomes of this commonly performed procedure. MIOCT can assist surgeon to visualise ILM (Figure 1a) and nerve fiber layer in real time and hence initiate and complete ILM peeling in an atraumatic manner. Structural changes are known to occur after completion of ILM peeling in macular hole (Figure 1b and c). MIOCT helps in peeling the membranes without using vital dyes thus avoiding their potential toxic effects. MIOCT documented closure of hole following fluid-air exchange, may avoid gas injection and its associated problems. MIOCT thus helps in assessment of structural changes in retina during ILM peeling and may lead to safer methods of ILM peeling in the future (Figure 2).

3. Vitreous hemorrhage: MIOCT is of great help in cases with vitreous hemorrhage as preoperative OCT assessment of the macula is not possible in these cases. The surgeon can be faced with various macular pathologies such as ERM, macular hole or cystoid macular edema after clearing of the vitreous haemorrhage, which may warrant further action (Figure 5a and b). The MIOCT can help in diagnosis, documentation and plan of action in such cases. Thus MIOCT can be a good clinical and medicolegal aid in such cases.

4. Proliferative retinopathy: MIOCT helps in removal of membranes in proliferative retinopathies with great precision. The important step in such cases is to

strength of vitreomacular adhesion in these patients (Figure 3). One of the important roles of MIOCT is to recognise any residual subclinical membranes, which if missed, may lead to later recurrence. It can help to reduce the risk of inadvertent deroofing of intraretinal cysts in retina leading to full/partial thickness macular holes. Optic disc pit maculopathy are another group of cases in which MIOCT can provide valuable information (Figure 4).

2. Epiretinal membrane (ERM), Vitreomacular traction and Optic disc pit maculopathy
MIOCT can assist surgeon to visualise extent and

Figure 1: MIOCT capture during surgery showing ILM peeling in process. The ILM is clearly visible as a hyperreflective membrane (a). MIOCT capture showing traction at one edge of hole before peeling which has been released after the ILM was peeled (b and c).

Figure 2: MIOCT capture during ILM peeling showing localised elevation of the inner retina at the site of ILM peeling.

Figure 3: MIOCT capture during ERM peeling showing a thick membrane with corrugations of the inner retina.

Figure 4: MIOCT capture showing optic disc pit communicating with the macular schisis.

Figure 5: MIOCT captures following vitrectomy for vitreous hemorrhage showing macular hole with detachment (a) and thick posterior hyaloid with attachment at the optic disc (b).
find a correct cleavage plane between the retina and proliferative membranes, which is aided perfectly by MIOCT (Figure 6 a and b). Further, MIOCT is an important aid in the detection and peeling of residual traction, also known as the “second membrane”.

5. **Myopic foveoschisis**: Myopic foveoschisis is characterized by retinoschisis at multiple levels. Progression can lead to outer retinal hole, localized serous detachment, macular hole formation and rhegmatogenous retinal detachment. Complete removal of hyaloid with ILM peeling is the key to the success of surgery. Vitreoschisis is frequently present in these eyes and it may be difficult to peel this layer of residual vitreous even after staining with triamcinolone crystals because of poor background contrast in myopes. In addition, the retina is thinner in myopic eyes predisposing to inadvertent break formation. MIOCT can assist in these patients to completely remove the posterior hyaloid and peel the ILMatraumatically, without the use of repeated stains. The surgical success rates are increased and repeat surgeries can be avoided.

6. **Retinal detachment**: The MIOCT system can assist in the induction of posterior vitreous detachment, removal of proliferative vitreoretinal membranes and detection of remnants of subretinal fluid.

**Drawbacks**: The MIOCT does not automatically image the seen area in the microscope. The surgeon has to centre the OCT image over the area of interest which may change continuously. This increases the total surgical time. Also, the surgeon has to get accustomed to viewing the microscope and OCT view simultaneously while using MIOCT. Currently used metallic instruments like vitrectomy cutter, light pipe and forceps block the view of underlying structures due to back shadowing (Figure 7).

To summarise, MIOCT is a very useful technological advancement which helps in the documentation and detection of various changes occurring in the retina and vitreous during vitreo-retinal surgery. This information translates into better post-operative outcomes in the clinical setting.

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**Corresponding author**: Vinod Kumar MS, DNB, MNAMS, FRCS (Glasg)
 Assistant Professor, Dr R P Centre for Ophthalmic Sciences, All India Institute of Medical Sciences, New Delhi, India
E mail: drvinod_agg@yahoo.com