Intraoperative OCT in macular hole surgery

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ABSTRACT

Intraoperative SD-OCT (iOCT) offers **dynamic cross-sectional** real time imaging of the retina during vitreoretinal surgery. The system is integrated into the operating microscope and the OCT images of the structures in the surgical field. It can be switched on and off by the surgeon as required without external aid. The use of this technology during macular hole surgery has numerous **advantages**: facilitating and optimising the surgery, obtaining knowledge on real-time macula behaviour in response to surgical manoeuvres,[1] reducing the risk or intra and post-operative complications and facilitating training. This technology offers an insight into the pathophysiology of surgical vitreoretinal disease which can help improve the understanding and management of these conditions in the future.

Key words: Intraoperative OCT, macular hole, vitrectomy.

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ILM peel for macular hole surgery

Internal limiting membrane (ILM) peeling has been performed as adjuvant therapy during macular hole (MH) surgery, in addition to pars plana vitrectomy (PPV) and gas tamponade it has been shown to significantly improve MH closure rates.[2, 3]

Its effect on functional outcomes remains controversial with contradictory reports of improved visual outcome,[4,5,6] loss of visual potential[7,8] and no difference in visual outcomes compared with non-peeled eyes.[9] This may be partially due to the shortcomings of the surgical technique,[10] which can be optimised using intraoperative OCT.

FACILITATING SURGERY

Intraoperative OCT can be instrumental in finding **correct planes for dissection,** particularly in complex cases such as diabetic eyes with preretinal fibrosis[11] or **in eyes with hazy ocular media**.[1] It enables to assess the **depth of surgical instruments**, e.g. the depth of forceps while peeling the ILM and it provides information **on size of the area of the peel**, which should be 2.5-3 disc diameters.[12] iOCT can help **determine the completeness of ILM membrane removal**, reducing the need for repeated dying of the ILM intraoperatively, which can have potential side effects.[10,11,13,14,15]

ERM vs ILM

Currently, brilliant blue G dye is used to selectively stain the ILM. However, its use is limited **in the presence of epiretinal tissue** as it prevents the dye from accessing the ILM. Poor **ILM staining** may result in its **incomplete removal**, which contributes to reopening of a macular hole due to residual ILM fragments serving as a platform for cellular proliferation.[10]

This difficulty can be overcome by using intraoperative OCT which **enables differentiation between ERM and ILM without a dye**.

ILM inverted flap technique

iOCT can help to optimise the ILM inverted flap technique successfully used for repair of large macular holes[16,17,18] by enabling to determine the **position of flap** post fluid-air exchange when the direct visualisation is limited.

Knowledge of the macular behaviour during surgery and refining surgical technique.

Anatomical changes in the inner-segment/outer-segment (IO/OS) junction of photoreceptor layer after macular hole surgery have been correlated with visual outcomes.[19-24] Biomicroscopic visualisation of the surgery site with intraoperative OCT provides knowledge about the real time behaviour of the macula in response to surgical manipulation, which can help refine the surgical technique and improve patients' outcomes.[1]

Notable differences have been shown in the procedures necessary for closure of the macular holes, ranging from complete closure after vitrectomy and ILM peeling[25] to requiring **fluid-air exchange**,[12] which promotes **bridge formation** in the macular hole area.[26,27,12]

Intraoperative OCT can be used to reliably **determine the macular hole base diameter** during the surgery and whether the **inner edges of the macular hole are in contact**, including after fluid-air exchange.[12] It also helps to **assess the contour of the foveal depression** and to ascertain whether a **macular cyst** was not **deroofed** during the surgery.[13] Such knowledge allows to decide on the next procedures during the surgery and increases the probability of a successful macular hole repair during the first surgery,[12] thereby improving patients' outcome.

Reducing intra-operative complications

Intra-surgical SD-OCT imaging system can **enable easy identification of intraoperative complications**, including **creation of retinal breaks and holes or iatrogenic haemorrhage**. In cases of the latter, iOCT can be used to determine its depth thereby enabling immediate management such as injection of tissue plasminogen activator (tPA) with gas at the end of surgery in cases of subfoveal haemorrhage.

Improving the understanding of the pathophysiology of surgical vitreoretinal disease.

Intraoperative cross-sectional retinal imaging can also improve the **understanding of the pathophysiology of vitreoretinal changes** that can lead to post-operative complications or worsen the visual outcomes. An alteration of the retina appearance has been reported in the first few months post-operatively after ILM peeling, termed **dissociated optic nerve fibre layer (DONFL)**, which may be associated with retinal sensitivity loss and paracentral scotomas.[28,29,30]

It has been attributed to **intraoperative trauma during the ILM peeling**, however, its mechanism remains unclear.[31,32,28,33] Runkle and colleagues (2018) showed a significant association between the increase in intraoperative inner retinal thickness and the development of DONFL using intraoperative OCT consistent with broad-based peeling tractional forces as opposed to direct tissue manipulation with surgical instruments.[3] It has also been demonstrated that membrane peeling with either forceps or a diamond-dusted membrane scraper induced retinal alterations on iOCT including inner retinal and full thickness retinal elevations associated with tissue manipulation.[34,14] This suggests that iOCT may be a valuable tool aiding to elucidate the pathophysiology of DONFL and other iatrogenic changes to retinal anatomy and help to prevent them.[3]

Post-rhegmatogenous retinal detachment (RRD) macular hole formation

Ehlers et al (2013) found a possible novel mechanism for post-rhegmatogenous retinal detachment (RRD) macular hole formation using iOCT. They identified iOCT alterations consistent with subclinical macular hole formation, but dissimilar to idiopathic macular hole features, which were absent prior to the surgery. This suggests that subclinical MH formation in RRD may occur sooner than previously anticipated. Similarly, identification of newly formed **full-thickness macular holes after vitreomacular traction release** has been reported.[35]

Although the aetiology of post-RRD MH formation remains unclear, this study supports the role of iOCT for identifying novel retinal appearances which could alter surgical management.[36] Furthermore, these findings may suggest that consideration should be given to the possibility of a **macular hole-related retinal detachment in cases of macula-off retinal detachment in a myopic when no retinal breaks can be found**.

Evaluation of novel surgical instruments and training in VR surgery

Intra-surgical OCT is also a valuable tool for evaluation of new surgical equipment and its effect on retinal tissues. It has been employed to show an acceptable safety profile of a newly introduced membrane loop (Finesse Flex loop; Alcon) for ILM peeling.[34] It also enabled identification of subretinal fluid accumulation and expansion of the ellipsoid zone to retinal pigment epithelium (RPE) distance, whose significance remains to be determined.[34]

Finally, due to its ability to assess in real time the **depth of instruments** in relation to the structures in the surgical field as well as the effect of surgical tissue manipulation on the retina, iOCT is a valuable tool for **training of new vitreoretinal surgeons**.

Conclusion and way forward

In conclusion, iOCT provides a new dimension that makes the visualisation of the surgical details more detailed than ever before. It can improve the judgement of vitreoretinal structures thereby facilitating the surgery, support intra-surgical decisions and improve anatomical and functional outcomes. Integration of the iOCT into the operating microscopes makes it easy to use for the operating surgeon and aids training.

This technology offers an insight into the pathophysiology of surgical vitroretinal disease which can help improve the understanding and management of these conditions in the future.

Furthermore, next developments may include an integration of the iOCT into heads-up 3D surgery[37] offering new scope for intraoperative visualisation and training.

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