

# Intraoperative optical coherence tomography in the full-thickness macular hole surgery with internal limiting membrane inverted flap placement

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## Abstract

**Purpose** To describe the helpfulness of using intraoperative optical coherence tomography (OCT) during surgery for full-thickness macular hole (FTMH).

**Observations** This observational case series identifies three patients with FTMH who were treated with vitrectomy, internal limiting membrane (ILM) peel with inverted ILM flap, which was tucked into the MH, and air with 18% Sulfur Hexafluoride (SF<sub>6</sub>) gas tamponade. Intraoperative OCT was used to confirm positioning of the ILM flap, even after complete air-fluid exchange. The patients were followed for three months after surgery and all reached a good morphological and functional outcome.

**Conclusions** If confirmed by a prospective longitudinal study, the intraoperative OCT might become an important tool in assisting FTMH surgery.

**Keywords** Intraoperative OCT · Full-thickness macular hole · Vitrectomy · ILM peeling · ILM flap

## Introduction

Full-thickness macular hole (FTMH) is a defect of the foveal retina, which extends from the inner limiting membrane (ILM) to the outer segment of the photoreceptor layer. This disorder most commonly occurs in elderly patients without an apparent underlying cause, and in these cases we may refer to this disease as idiopathic FTMH. However, FTMH may also be secondary to different conditions such as trauma, high myopia, and retinal surgery [1, 2].

Although the pars plana vitrectomy (PPV) followed by retinal tamponade is recognized as the gold standard in the treatment of FTMH, the additional use of ILM peeling is still a matter of debate [3]. Recently, the inverted ILM flap technique has been introduced as an alternative [4].

Spectral domain-optical coherence tomography (SD-OCT) has evolved into a resourceful imaging technology and has provided the capability to identify bands that seem to correspond to the anatomic layers of the human retina. For this reason, SD-OCT has allowed a more detailed description of the FTMH stages, followed by a deeper understanding of its pathogenesis. Indeed, several OCT studies confirmed that FTMH is usually associated with either vitreofoveal traction (VFT) or epiretinal membrane (ERM) [5–7]. In addition, the most recent application of OCT is its use in the operating theater to guide intraoperative decision [8].

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Here, we report three cases of patients who underwent PPV with ILM inverted flap technique for FTMH. Furthermore, the generated ILM flap was tucked into the MH. During the procedure, the macula was imaged by intraoperative OCT (iOCT), in order to assess both the complete ERM and ILM peeling, as well as the correct ILM flap placement.

## Case series

### Case 1

A 64-year-old man was referred to our department for a progressive decreased visual acuity (VA) with central relative scotoma in his right eye (RE). The patient was successfully treated few months before with a PPV for retinal detachment. His Snellen VA was 20/200 in the RE, and 20/25 in the left eye (LE). Fundus biomicroscopy and OCT showed the presence of a stage IV FTMH in the RE (Fig. 1). The patient underwent PPV with 27-gauge trans-conjunctival system (Constellation<sup>®</sup>, Alcon Inc, Fort Worth, Texas, USA), ERM and ILM peeling after staining with MembraneBlue-Dual<sup>®</sup> (Dutch Ophthalmics Research Centre, Zuidland, The Netherlands), and creation of the ILM flap, which was tucked into the MH. A mixture of air and 18% sulfur hexafluoride (SF<sub>6</sub>) gas tamponade was finally used. The iOCT system (CALLISTO eye<sup>®</sup>, Carl Zeiss Meditec Inc., Dublin, CA, USA) was used during the surgery to assess the ILM and ERM peeling, as well as the correct ILM flap placement, even after the air–fluid exchange (Fig. 1). Postoperatively, the patient adopted a face down posture for 3 days and his progresses were monitored with serial visual acuity, intraocular pressure, and SD-OCT examinations.

Two weeks after surgery, the gas bubble was almost completely absorbed.

The patient's VA was improved to 20/80 and 20/40, at the 2-week and 1-month follow-up visits, respectively. The OCT showed a complete resolution of the FTMH and a continuity of the external limiting membrane at the 2-week visit. Moreover, a complete resolution of the edema and a continuity of the ellipsoid band were achieved at the 1-month follow-up visit (Fig. 1). No further improvements/changes were noted at the 3-month follow-up visit.

### Case 2

A 67-year-old woman was diagnosed with a stage IV FTMH in her RE. The patient's ocular history was unremarkable and her Snellen VA was 20/200 in the RE and 20/100 in the LE. She underwent 27-gauge PPV with ERM and ILM peeling, creation of the ILM flap, which was tucked into the MH, and air with 18% SF<sub>6</sub> gas tamponade. All the stages of the surgery were assessed using iOCT (Fig. 2). Postoperatively, the patient adopted a face down posture for 3 days.

The patient's RE VA was improved to 20/50 and 20/32, at the 2-week and 1-month follow-up visits, respectively. The OCT showed a complete resolution of the FTMH and a continuity of the external limiting membrane as soon as 2 weeks after the surgery. A complete resolution of the edema and a continuity of the ellipsoid band were found at the 1-month follow-up visit (Fig. 2). Neither further improvement nor changes were noted at the 3-month follow-up visit.

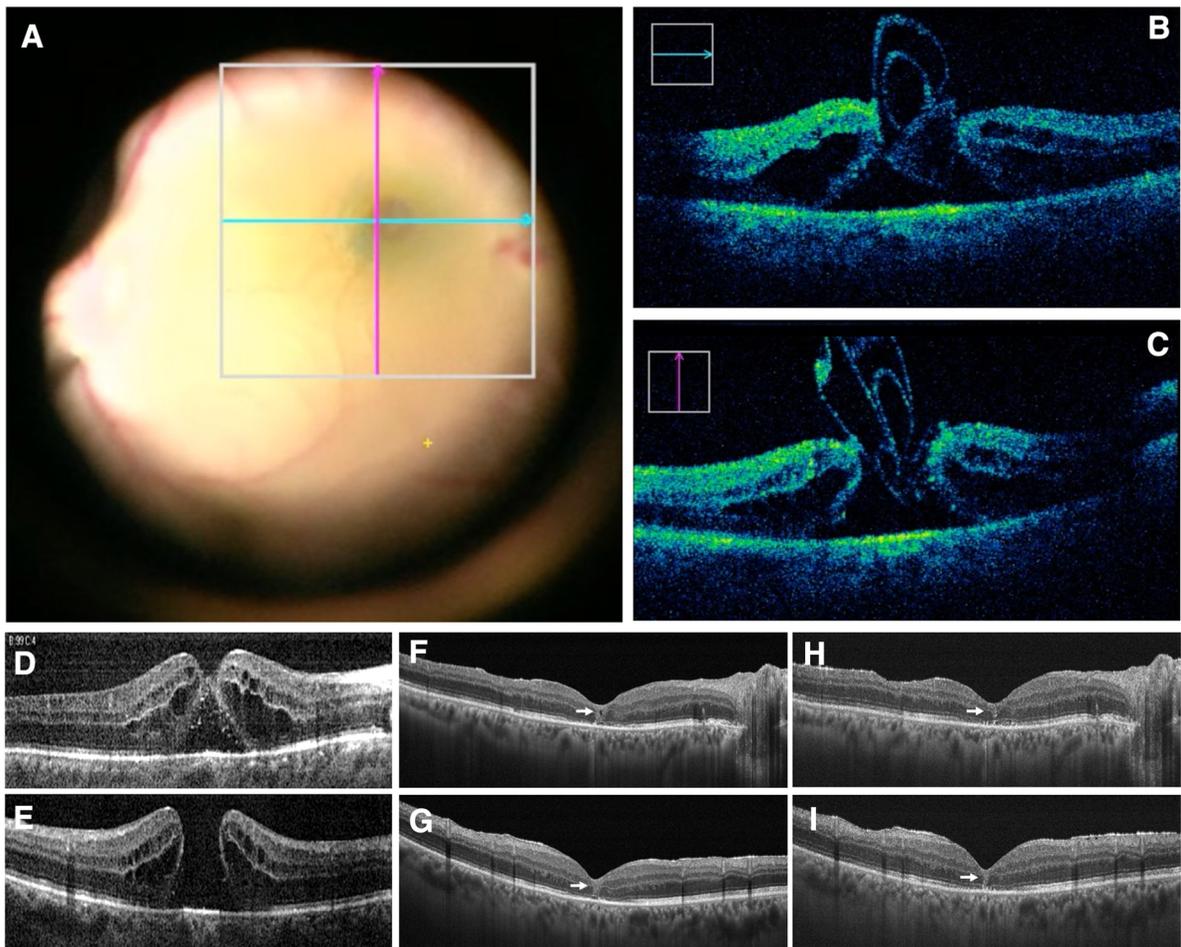
### Case 3

A 67-year-old man complaining of decreased visual acuity in his RE was found to be affected by stage IV FTMH and was scheduled for 25-gauge PPV in his RE. His Snellen VA at baseline was 20/200 in the RE and 20/100 in the LE. The iOCT was used to appreciate the completion of the ILM peeling obtained after staining with MembraneBlue-Dual<sup>®</sup>, as well as the correct location of the ILM flap, which was tucked into the MH, even after the air–fluid exchange (Fig. 3). Air with 18% SF<sub>6</sub> gas tamponade was injected. The patient adopted a face down posture for 3 days.

At the follow-up visits, the VA in the patient's RE was 20/100 and 20/80, at the 2-week and 1-month visits, respectively (Fig. 3). Two weeks postoperatively, the OCT showed both the closure of the FTMH and the integrity of the ellipsoid band. No further improvements or changes were noted at the 3-month follow-up visit.

## Discussion

Although anatomic closure of FTMH may be achieved in almost all patients undergoing surgical treatment, nowadays a significant improvement in visual acuity



**Fig. 1** A 64-year-old man with a full-thickness macular hole (FTMH) in his right eye underwent vitrectomy, internal limiting membrane (ILM) peel with inverted ILM flap, which was tucked into the MH, and air with 18% sulfur hexafluoride ( $\text{SF}_6$ ) gas tamponade. Intraoperative optical coherence tomography (OCT) (a–e) was used to confirm positioning of the inverted

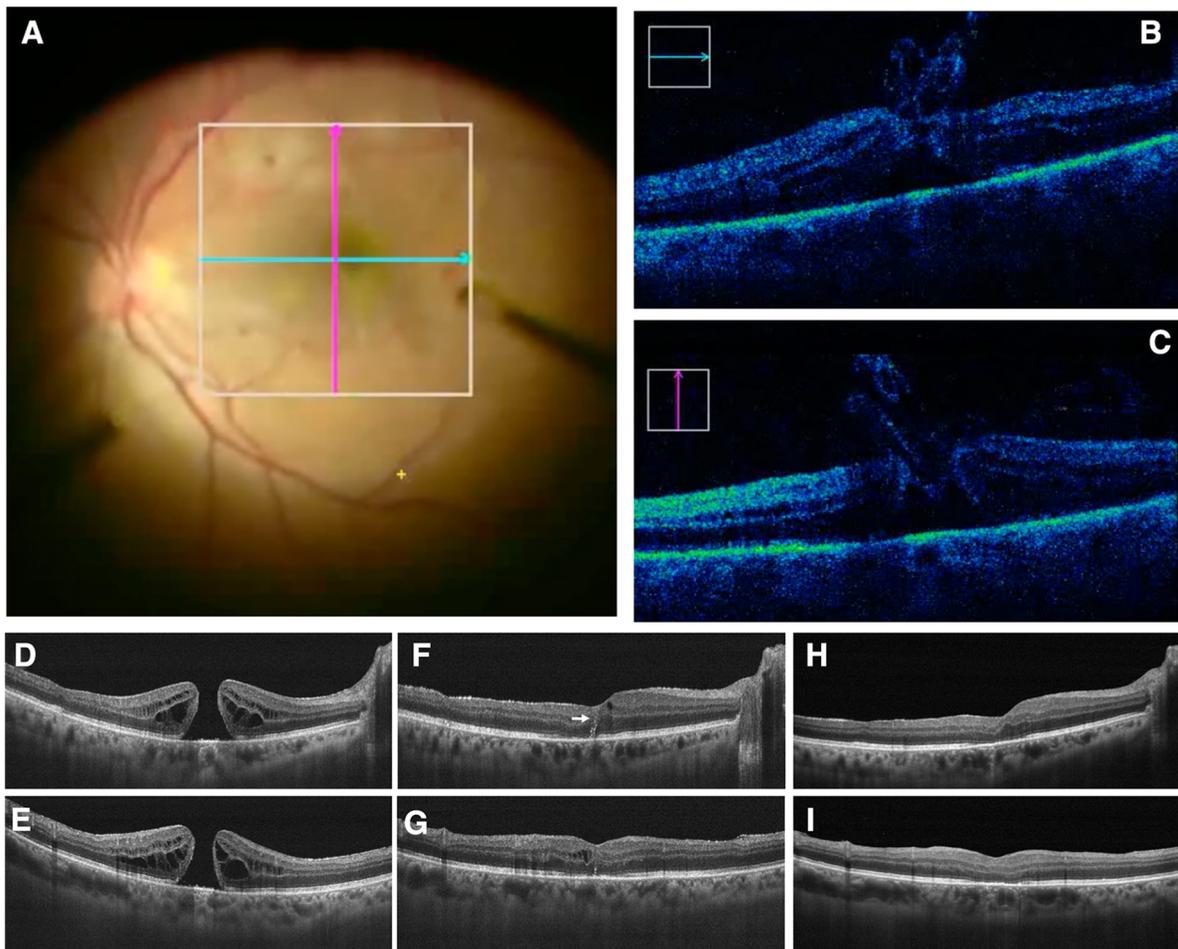
ILM flap following complete air–fluid exchange. In comparison with baseline OCT (d, e), 2-week (f, g) and 1-month (h, i) follow-up visits showed FTMH closure and an hyperreflective structure at the level of the fovea (white arrow), which presumably corresponds to the ILM flap tucked into the MH

can be achieved in approximately the 70% of cases [9–11].

Since the introduction of PPV as treatment for FTMH [12], several refinements have been made in the surgical technique aimed at improving both the anatomic and functional outcomes. One of these improvements consists in peeling the ILM during the surgery, whose rationale is in relieving the tangential tractional forces occurring around the fovea and ensuring the removal of the whole epiretinal tissue. Cornish et al. [3] showed that although no differences in VA were observed between patients with and without ILM peeling, ILM peeling allows a higher

anatomic rate success. Moreover, peeling the ILM has been demonstrated to considerably reduce the rate of reoperation due to the unsuccessful closure of idiopathic MH, resulting in a more cost-effective technique compared to vitrectomy without ILM removal [13].

In 2010, Michalewska et al. [4] introduced the inverted ILM flap technique, which was proved to improve both the rate of FTMH closure and the visual outcome. In the inverted ILM flap technique, instead of fully removing the ILM after staining, a remnant attached to the margins of the macular hole was left in place, and finally inverted upside-down to cover the



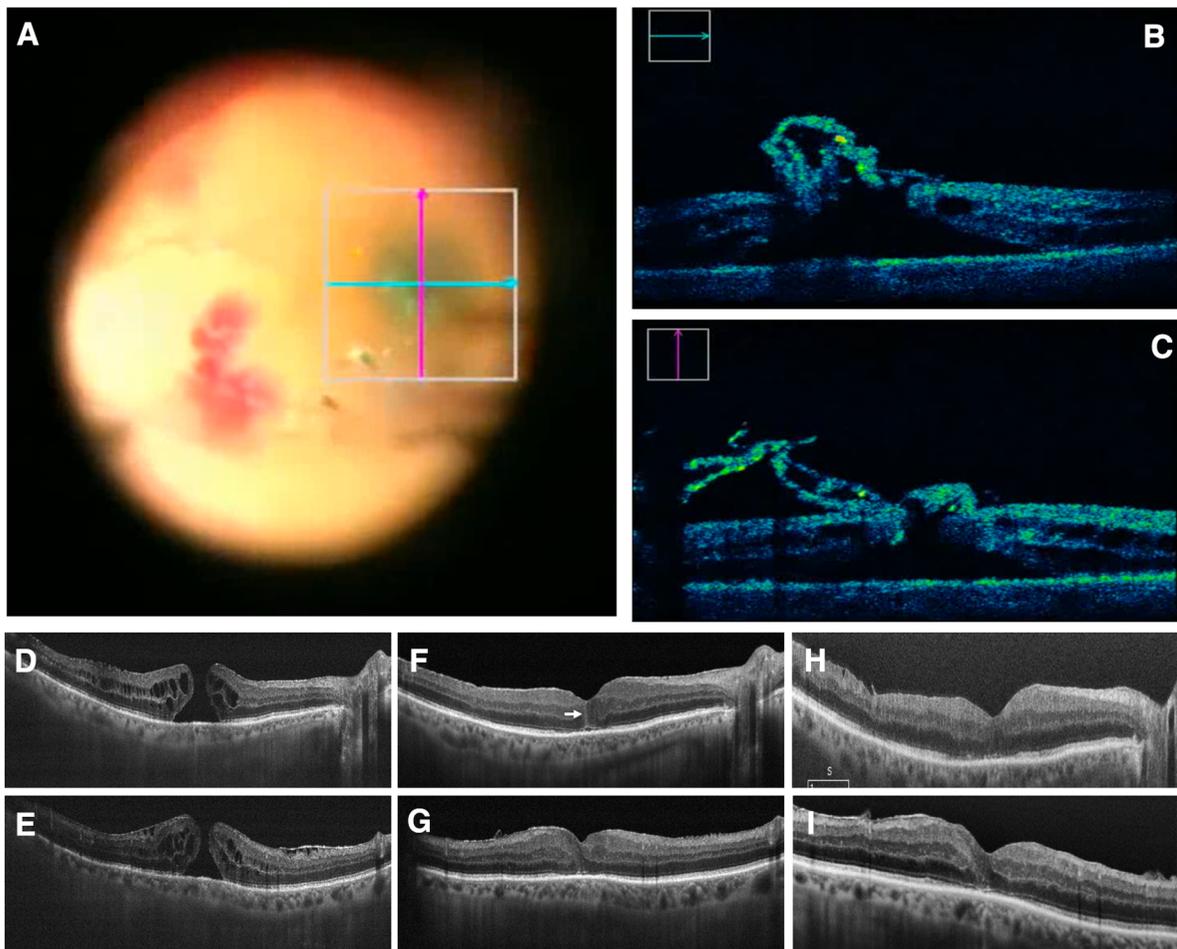
**Fig. 2** A 67-year-old woman with a full-thickness macular hole (FTMH) in her right eye underwent vitrectomy, internal limiting membrane (ILM) peel with inverted ILM flap, which was tucked into the MH, and a mixture of air and 18% sulfur hexafluoride ( $\text{SF}_6$ ) gas tamponade. Intraoperative optical coherence tomography (OCT) (a–c) was used to confirm positioning of the

inverted ILM flap following complete air–fluid exchange. In comparison with baseline OCT (d, e), 2-week (f, g) and 1-month (h, i) follow-up visits showed the closure of the FTMH closure with the presence of a hyperreflective structure at the level of the fovea (white arrow), likely corresponding to the ILM flap tucked into the MH

macular hole [4]. Recently, additional surgical manipulation steps of the ILM flap (e.g., ILM trimmed, ILM tuck inside the hole, and ILM massage) have been described. Nevertheless, these additional steps seem to not improve the post-surgical outcome [14]. However, the success of the ILM flap techniques, especially with regard to the “ILM tuck inside” variant, may be limited by the relocation of the flap after the air–fluid exchange. Therefore, the presence of a tool allowing the surgeon to observe ultrastructural changes of the retina occurring during the surgery would be extremely helpful.

In the same way that OCT has transformed the clinical management of vitreoretinal conditions, integration of OCT technology into the operating theater may redefine the approach to the FTMH surgery. The intraoperative OCT lets the surgeon to directly see the interaction between retinal structures and epiretinal membrane, as well as follow ultrastructural changes occurring during surgery [15–17].

We described three cases of FTMH treated with PPV followed by ILM peeling and “ILM tuck inside” technique. Following our experience, the use of iOCT during surgery may be important for the following reasons: (i) permits the identification of subclinical



**Fig. 3** A 67-year-old man with a full-thickness macular hole (FTMH) in his right eye underwent vitrectomy, internal limiting membrane (ILM) peel with inverted ILM flap, which was tucked into the MH, and air with 18% sulfur hexafluoride ( $\text{SF}_6$ ) gas tamponade. Intraoperative optical coherence tomography (OCT) (a–c) was used to assess the correct position of the

inverted ILM flap following complete air–fluid exchange. In comparison with baseline OCT (d, e), 2-week (f, g) and 1-month (h, i) follow-up visits showed that the FTMH was repaired. Moreover, an hyperreflective structure at the level of the fovea (white arrow) was noted, this presumably corresponding to the ILM flap tucked into the MH

residual membranes and ILM, whose presence requires additional peeling; (ii) facilitates surgeons to form the ILM flap and to invert the flap on and into the FTMH; (iii) enables to confirm the position of the inverted ILM flap following complete air–fluid exchange, which may generate turbulences in the vitreous chamber.

For the reasons explained above, iOCT may be considered as a useful tool to improve both the morphological and functional outcome in FTMH surgery. A prospective longitudinal evaluation of the ILM flap technique assisted by the iOCT will help in understanding its role in the post-surgical result.

#### Compliance with ethical standards

**Conflict of interest** All the authors declare that they have no conflict of interest.

**Ethical approval** All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

**Informed consent** Informed consent was obtained from all individual participants included in the study.

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