Mini Review

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Intraoperative Anterior Segment Ocular Coherence Tomography in Ophthalmic Surgery

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ABSTRACT

Intraoperative OCT is becoming an established technology in ophthalmic surgeries. Its detailed cross-sectional images provide valuable morphological information during surgery, and several studies proved that it influences greatly the surgeon's intraoperative judgment and decisions. In this mini review, we are going to address anterior segment OCT in ophthalmic surgeries, mainly corneal surgeries.

Abbreviations: OCT: Optical Coherence Tomography; AS-OCT: Anterior Segment Optical Coherence Tomography; AC: Anterior Chamber; PKP: Penetrating Keratoplasty; iOCT: Intra-Operative Optical Coherence Tomography; DSAEK: Descemet Stripping Automated Endothelial Keratoplasty; DALK: Deep Anterior Lamellar Keratoplasty; DMEK: Descemet Endothelial Keratoplasty; DM: Descemet Membrane

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Introduction

Optical Coherence Tomography (OCT) is a non-contact imaging technology that produces detailed cross-sectional images, using low-coherence interferometry in biological tissues. [1] Anterior Segment OCT (AS-OCT) is an innovative tool for evaluation of the cornea, conjunctiva, sclera, anterior chamber (AC), anterior chamber angle, intraocular lens, and adjacent anterior segment structures. It has been helpful for the diagnosis and management of conjunctival diseases, anterior segment tumors, Corneal diseases, and AC inflammation. [2] Standard clinical OCT systems are large and stationary. In the past few years, the OCT became an important tool for selected ophthalmic surgeries, and adaptations had to be made to convert the OCT to a tabletop system. Today there are several commercial systems of microscope-integrated intraoperative OCT (*i*OCT), which focuses on OCT video visualization in high-resolution, maximum integration with the microscope, and some of them integrate a three-dimensional heads-up display system for maximum convenience of the surgeon while visualizing the surgical field. [3]

Intra-Operative Oct

The *i*OCT is a rather new technology and it is currently applied in a wide variety of ophthalmic surgeries. The AS-OCT is used in lamellar keratoplasty, Penetrating keratoplasty (PKP), cataract surgeries, glaucoma surgeries, and other corneal procedures (post-trauma, epithelial/fibrous growth). The posterior segment OCT aids in cases of optic pit-related maculopathy, retinopathy of premature, macular hole, retinal detachment, proliferative diabetic retinopathy, epiretinal membrane, and posterior uveitis. [3] Over the years, two major studies were conducted to test the benefits of the intra-operative OCT (*i*OCT)- the PIONEER study and the DISCOVER study. Both studies collected Clinical characteristics and *i*OCT imaging was obtained during surgical milestones as directed by the operating surgeon. A surgeon questionnaire was issued to each surgeon and completed after each case. The PIONEER study was published in 2014 and enrolled 531 eyes- 275 anterior segment cases and 256 posterior segment cases. In the anterior segment surgeries, the most common procedure was Descemet stripping automated endothelial keratoplasty (DSAEK, n=135), and the second most common was cataract extraction with an intraocular lens implant.

Immediately after the surgery, the surgeon was required to fill a feedback form. Overall following *i*OCT, 48% of the eyes revealed persistent interface fluid requiring additional manipulations. In deep anterior lamellar keratoplasty (DALK), 1 of 3 cases where the surgeon did not believe the trephination was deep enough, *i*OCT revealed the depth was optimal and did not require further deepening. In 56% of the cases of DALK, *i*OCT prompted further manual dissection to deepen the initial trephination. [4] The DISCOVER study was published in 2015, enrolled 227 eyes, 91 of them were anterior segment cases. The most common procedure was DSAEK (43%), following DALK (9%). In this study, 8% of the cases were Descemet endothelial keratoplasty (DMEK) cases (in the PIONEER study there were no DMEK cases at all). According to surgeons in the study, 44% of the total anterior segment cases were changed or modified due to the *i*OCT findings. [5] Regarding the influence of *i*OCT on surgical time, the DISCOVER study concluded that in 47% of the cases, the *i*OCT minimized the surgical time by eliminating unnecessary manipulations but did not measure the minutes that were spared. Recent studies of iOCT use in anterior segment procedures (Figure 1).

Figure 1: Corneal staff in Hadassah Hospital during DMEK procedure, using iOCT, ARTEVO 800 of produced by ZIESS.

DALK

The DALK procedure gained popularity as an alternative to PKP. The "big-bubble" technique uses a forceful injection of air into the deep stroma, to create cleavage and to separate the Descemet membrane (DM) from the overlying stroma. The reported rate of successfully achieving a big bubble is 66% to 90%. For novice surgeons, the step of big-bubble generation is the most common surgical step at which perforation of DM occurs. [6] According to Myerscough et al, there are two main advantages of *i*OCT in DALK procedure - the first is assessing the depth of the cannula tip before performing pneumatic dissection, and the second is confirming that pneumatic dissection has indeed occurred. [7] Liu et al presented a new approach for DALK surgery in which a low-energy FSL created an anterior stromal dissection and a pre-Descemet intrastromal tunnel for the air injection in one step, to a preprogrammed depth, with the guidance of the *i*OCT and to facilitate big-bubble creation. 14 eyes were included: 11 eyes with keratoconus and no evidence of a history of acute hydrops and 3 eyes with corneal scars. In all cases, a big bubble was successfully achieved without intraoperative complications related to lasers (Figure 2).

DSAEK

Most of the data about the DSAEK procedure still relies on the data drawn from the PIONEER study, due to its relatively large cohort. The two main surgical techniques of DSAEK differ in the air infused to the anterior chamber- one uses an active air infusion system while the other manually introduce air into the anterior chamber for graft positioning. Hallahan, et al analysed the fluid dynamics and clinical outcomes for iOCT-assisted DSAEK from the PIONEER study. They used a few features measured with the iOCT and discovered that high amounts of interface fluid significantly correlated with graft non-adherence rates within the first postoperative week, following placement and optimization of intraoperative lenticule adherence. Also, the iOCT revealed a significant difference between the area, volume, and thickness of maximum fluid pockets between the two surgical techniques- the manual technique had higher values, but in both techniques, there was a significant reduction of interface fluid during the procedure [8].

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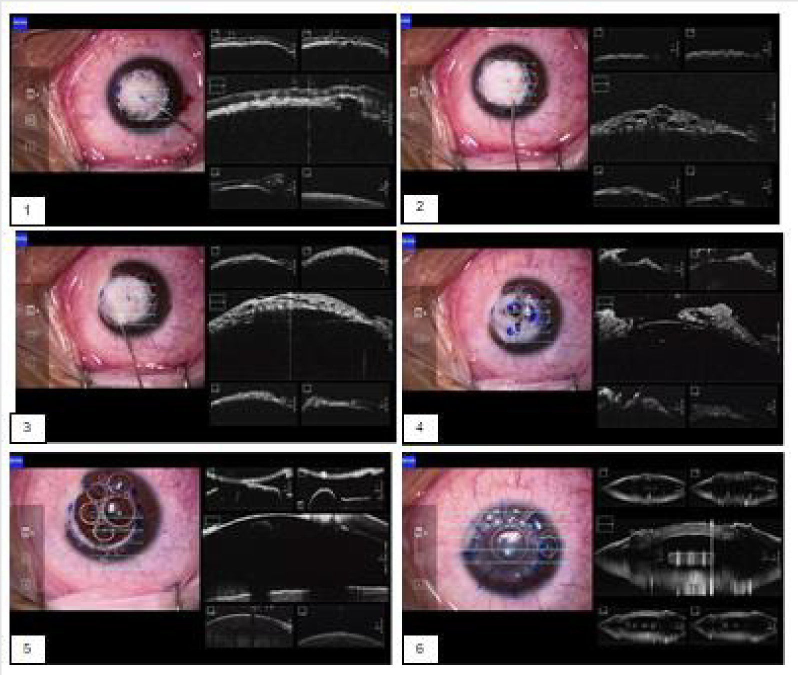

Figure 2: A 30-year-old woman with advanced keratoconus, in DALK procedure using iOCT.

1. **Picture number 1:** separating the stroma layer from the DM, with the cannula corneal plane clearly visible.
2. **Picture number 2:** During air injection (Big bubble), the air reached the stroma, and caused an emphysema.
3. **Picture number 3:** The emphysema in the stroma is seen, and there is an additional air bubble underneath the stroma, separating it from the pre-Descemet. This separation succeeded after six attempted injections of air. The iOCT was a crucial factor is the success of this procedure.
4. **Picture number 4:** Removing the stroma. The pre-Descemet is exposed.
5. **Picture number 5:** after full removal of the stroma.
6. **Picture number 6:** After suturing the graft- it is visible in the OCT that it is attached properly to the DM

DMEK

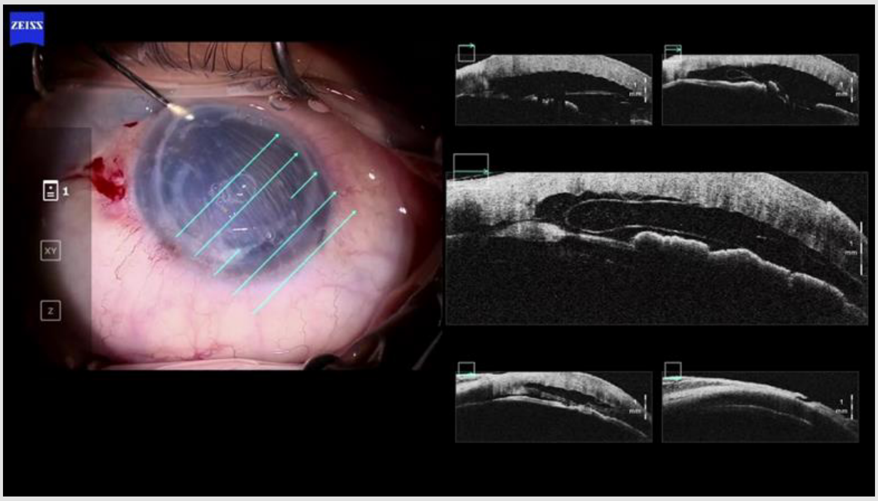

Figure 3: A 61-year-old woman who suffered from a graft failure after PKP, during DMEK using iOCT. In the cross section of the imaging the cornea appears thick and edematous. In the en face surgical microscope view the graft is barely visible. The iOCT enables to identify the location and orientation of the graft, and it is possible that the outcomes of the surgery would be less satisfying without the use of the OCT.

DMEK is currently the preferred procedure to replace diseased endothelium and is superior to DSAEK and PKP for visual recovery and a lower graft rejection rate. On the other hand, the surgeon must be skilled to perform this procedure. The difficult steps are preparation of the donor lamella, transfer of the graft into the AC, unfolding and orientation of the graft, and successful attachment after air filling. Another major challenge is operating through a hazy and/or scarred cornea, which makes the visibility obscure. [9-10] Muijzer, et al. examined 38 eyes which underwent DMEK procedure. iOCT was used during the surgery and its main steps. In 42% of the cases, the iOCT altered the surgical decision-making process. In 21% of the surgeries, OCT revealed interface fluid or a minor detachment of the graft, findings that were not noted using the en face surgical microscope view; In 32% of surgeries, the iOCT image provided crucial information regarding the graft orientation [10] (Figure 3).

Traumatic/Post-Operative Damage

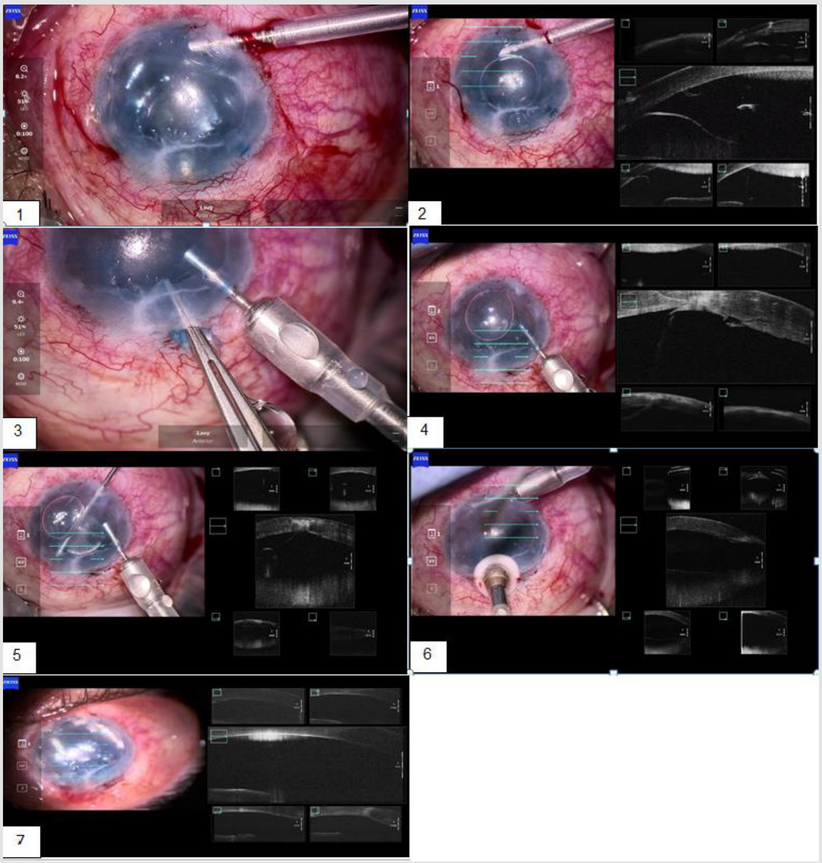

Figure 4: A 23-year-old patient who suffered an eye trauma 10 years ago. He underwent vitrectomy with intraocular lens implantation successfully. After 10 stable years, his intra-ocular pressure increased uncontrollably, and an Ahmed valve was eventually implanted with a suspicion of epithelial downgrowth. Later, the patient underwent an ingrowth membrane removal with 5-Fluorouracyl treatment and followed by eight Methotrexate injections to the AC twice a month. Then he was referred to remove the remained tissue, opening the Ahmed valve and go through a DMEK procedure.

1. **Picture number 1:** During the insertion of the maintainer the surgeon came across a tissue which cover the whole corneal endothelium and the Ahmed valve opening.
2. **Picture number 2:** The tissue is demonstrated in the iOCT
3. **Picture number 3:** Excision of the tissue by pulling it through a limbal incision.
4. **Picture number 4:** The epithelial downgrowth is demonstrated in the iOCT- a bright finding appears in the center of the cornea from the outer layer to the innermost layer and into the AC.
5. **Picture number 5:** Removing the hidden epithelial downgrowth tissue with a vitrectome.
6. **Picture number 6:** An additional cryotherapy was conducted in the area to prevent further growth of the epithelium.
7. **Picture number 7:** A DMEK procedure was conducted, the graft seals the limbal opening.

A year and a half after the surgery, there is no return of the epithelial growth, and the patient best corrected visual acuity is 0.5 (decimal).

Epithelial downgrowth is a rare complication of intraocular surgery or trauma characterized by the invasion of surface epithelial cells into the AC of the eye. Fibrous downgrowth is a similar but somewhat less aggressive condition characterized by fibrovascular connective tissue invading into the eye. Those pathologies may have a devastating sequela. There are a few case reports published that emphasized the utility of *i*OCT in those uneventful cases. Shazly, et al. discussed a case of a woman that underwent a DSAEK procedure in an eye with fibrous ingrowth and 2 glaucoma shunt devices. The *i*OCT provided a clear dissection plane of the fibrous membranes and a clear view of their relation to the iris and corneal endothelium. This proved to be valuable given poor visibility through the opacified cornea. In addition, it allowed determining the extent and location of the interface fluid gap between the DSAEK graft and the host cornea. [11] Ruland, et al. published a case of a woman with primary open angle glaucoma and corneal decompensation of the right eye secondary to tube shunt presented for a 3-month follow-up of PKP. The patient had a membrane connecting the iris to the host cornea and underwent a biopsy and excision of the membrane assisted by *i*OCT. The poor view of the peripheral anterior chamber secondary to recent corneal transplantation was aided using *i*OCT, especially in the manipulation and acquisition of material for biopsy [12] (Figure 4).

Conclusion

Anterior segment *I*OCtl in ophthalmic surgeries is proven to be an efficient and important tool, which can impact surgeon decision in many cases, and perhaps surgical outcomes. Cases of opaque corneas which were almost impossible to operate are given hope due to this technology. Further prospective studies should be conducted on this issue.

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