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Intraoperative Changes in Idiopathic Macular Holes by Spectral-Domain Optical Coherence Tomography

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Key Words

Spectral-domain OCT · Macular hole · Base diameter · Intraoperative OCT

Abstract

Purpose: To examine anatomical changes in idiopathic macular holes during surgery using handheld spectral-domain optical coherence tomography (SD-OCT).

Methods: Five eyes of 5 patients who underwent surgery for the repair of idiopathic macular holes were examined. The surgery included standard 25-gauge, 3-port pars plana vitrectomy, removal of the internal limiting membrane (ILM), fluid-air exchange, and 20% sulfur hexafluoride tamponade. Intraoperative SD-OCT images of the macular holes were obtained after ILM removal and under fluid-air exchange using a handheld SD-OCT. From SD-OCT images, the macular hole base diameter (MHBD) was measured and compared.

Results: All macular holes were successfully closed after the primary surgery. The mean MHBD under fluid-air exchange was significantly smaller than the mean MHBD after ILM removal and the preoperative mean MHBD. In 1 eye with a stage 3 macular hole, SD-OCT images revealed that the inner edges of the macular hole touched each other under fluid-air exchange.

Conclusion: Fluid-air exchange significantly reduced MHBD during surgery to repair macular holes. Fluid-air exchange may be an important step for macular hole closure as it reduces the base diameter of the macular hole.

Introduction

Spectral-domain optical coherence tomography (SD-OCT) enables physicians to noninvasively obtain detailed retinal images of various retinal diseases in a clinical environment. Intraoperative use of SD-OCT using an OCT-mounted surgical microscope or a handheld SD-OCT has been attractive because OCT images can be obtained immediately during vitreoretinal surgeries and used to detect retinal changes resulting from the surgical procedures, as well as to decide on the next procedures to be taken during surgery [1–4].

Macular hole surgery has been successfully developed to obtain more than 90% closure rates after the primary surgery. Recently, several studies reported that macular holes could be closed with shorter periods of prone positioning or no prone positioning [5–8]. Wykoff et al. [3] reported that, in their patient, the traumatic macular hole appeared to be closed in the OCT images after removal of the internal limiting membrane (ILM) during the surgery. Because the anatomical changes in macular holes during macular hole surgery are not clearly understood, intraoperative anatomical changes in macular holes using a handheld SD-OCT were examined in this study.

Patients and Methods

Patients

This interventional case study included 5 eyes of 5 consecutive patients with idiopathic full-thickness macular holes who visited Toyama University Hospital between November 2010 and February 2011. All patients were naïve to treatment for idiopathic macular holes and underwent the primary surgery at Toyama University Hospital. The patients were followed up for more than 1 month after the surgery with eye examinations of visual acuity and using SD-OCT.

Surgical Procedures

All patients underwent the standard surgery for idiopathic macular holes by a single surgeon (A.H.). Briefly, after local anesthesia with subtenon injection of 2% lidocaine, cataract surgery was performed before vitrectomy. Then, a standard 3-port pars plana vitrectomy was performed using a 25-gauge system. After the core vitrectomy, triamcinolone particles were used to visualize the vitreous and posterior vitreous detachment created in all eyes. Vitrectomy was performed using contact lenses, after which 0.05% indocyanine green solution was injected onto the posterior retinal surface and washed out immediately. Under a flat concave contact lens, the ILM was removed in the circular region around the macula up to about 2.5- to 3-disc diameters. The vitreous cavity was washed out again and the fluid was exchanged with air. Then, the air in the vitreous cavity was replaced with 20% sulfur hexafluoride (SF₆) and the 3 ports were sutured with 10-0 vicryl. Finally, about 0.4 ml dexamethasone was injected into the subconjunctival space and antibiotic ointment was applied to the cul-de-sac. All patients were asked to lie in a prone position for several hours immediately after the surgery, after which they were allowed to take any position other than the supine position for 1 week.

OCT Examinations

A handheld SD-OCT (iVue-100®; Optovue Inc., Fremont, Calif., USA) was attached to a specially made OCT holder and used intraoperatively. The OCT images of all eyes were obtained with the retinal map program or the cross section program on 2 occasions during the macular hole surgery, with both these procedures taking place after ILM removal and under fluid-air exchange. The OCT images were taken several times in order to examine changes in the macular hole at every occasion. All patients

underwent OCT examinations with an SD-OCT (RTVue-100®; Optovue Inc.) in the clinics before the macular hole surgery. From the OCT images, the macular hole base diameter (MHBD) was measured as the widest point of the inner/outer segment junction defect in each macular hole using SD-OCT caliper software [9]. The postoperative shapes of the macular holes were classified as bridge formation or simple closure, according to previous studies [5, 10]. SD-OCT examinations were performed at 7 to 10 days and at 1 month after surgery using an RTVue-100 SD-OCT at the clinics after more than half of the intraocular gas was absorbed and the fovea was observed through the intraocular fluid.

Statistical analyses were performed with Wilcoxon signed-rank test and a p value <0.05 was recognized as statistically significant.

Results

Baseline Results

All patients were female and their mean age was 62.2 ± 9.9 years (mean \pm SD). All patients underwent simultaneous cataract surgery with the macular hole surgery, and all showed successful closure of macular holes at 7 to 10 days after the surgery. The mean visual acuity improved from 0.70 ± 0.30 to 0.58 ± 0.31 logMAR units at 7 to 10 days and to 0.32 ± 0.16 logMAR units at 1 month after the surgery ($p = 0.07$), as shown in [table 1](#).

OCT Findings

The 5 treated eyes of the 5 patients consisted of 2 eyes with a stage 2 macular hole and 3 eyes with a stage 3 macular hole by Gass classification with preoperative SD-OCT. The size of the macular hole was expressed as MHBD [9]. The preoperative and intraoperative MHBD of each eye are shown in [table 1](#). The preoperative MHBD was nearly the same as the intraoperative MHBD after ILM peeling in each eye, but the intraoperative MHBD under fluid-air exchange was smaller than that after ILM peeling in all eyes. The mean preoperative MHBD and intraoperative MHBD after ILM peeling were 678 ± 173 μm (range, 452–815 μm) and 690 ± 155 μm (range, 479–801 μm), respectively. However, the mean MHBD under fluid-air exchange was 484 ± 122 μm (range, 333–608 μm) and significantly smaller than that after ILM peeling ($p < 0.05$) or before the surgery ($p < 0.05$). One of the 3 eyes with a stage 3 macular hole (case 1) showed contact of the inner edges of the macular hole under the fluid-air exchange with SD-OCT ([fig. 1](#)). The remaining 2 eyes (cases 2 and 3) showed open macular holes under the fluid-air exchange ([fig. 2](#)).

At 7 to 10 postoperative days in case 1, SD-OCT images showed that both edges of the macular hole were bridged and the retinal layers of the macular hole seemed continuous ([fig. 1](#)). According to previous reports on macular hole closure types [5, 10], 3 of the 5 eyes showed the bridge formation and 2 eyes showed the simple closure at 7 to 10 days postoperatively. At 1 month after the surgery, 4 of the 5 eyes showed the simple closure configuration. The remaining 1 eye still showed the bridge formation at 1 month postoperatively.

Discussion

In previous studies, the early changes in macular holes after vitrectomy surgery were characterized as follows: at 1 day after surgery, 77–93% of the eyes showed closure of the macular hole in subjects lying in a prone position based on OCT imaging [5, 8] and even as early as 3 hours after surgery, 3 of 5 eyes with macular holes showed hole closure based on OCT imaging [5].

In the present study, we have shown that the mean MHBD under fluid-air exchange became significantly smaller than that after ILM peeling or before the surgery, and that when using a handheld SD-OCT, the inner edges of the macular hole were observed to come into contact with each other under the fluid-air exchange in 1 of the 3 eyes with a stage 3 macular hole. In a case involving a 14-year-old boy with a traumatic full-thickness macular hole, there was nearly a complete closure of the macular hole immediately after vitrectomy and ILM peeling [3], whereas idiopathic macular holes in this study did not close before fluid-air exchange. We speculate that both anterior-posterior traction and tangential traction might be more involved in traumatic macular holes than in idiopathic macular holes.

Masuyama et al. [5] reported that the OCT patterns of macular hole closure showed the bridge formation in 9 of 12 eyes (75%) and the simple closure in 3 of 12 eyes (25%) within 7 days after macular hole surgery, whereas 12 of 16 eyes (75%) showed the simple closure and 4 of 16 eyes (25%) still showed the bridge formation at 1 month after the surgery. Takahashi and Kishi [10] showed that the bridge tissue needed an average of 2 months to attach to the retinal pigment epithelium after macular hole surgery. These results suggest that the reduction of MHBD caused by fluid-air exchange may be an important step in macular hole closure, and that the contact of both the inner edges of the macular hole after fluid-air exchange may result in the bridge formation of macular holes.

Intraoperative use of SD-OCT has been attractive because the OCT images provide valuable information which can assist in the choice of procedures during vitreoretinal surgery [1, 2]. In this study, OCT images were obtained both under fluid and under air during the macular hole surgery. With the air of the vitreous cavity, refractive errors were changed, but measurements of retinal thickness with OCT images were not affected until –10 diopters, except for inferior segments [11]. As only MHBD was measured and the SD-OCT software automatically focused the retina in each eye at each measurement, the effects of refractive errors on the measurements of MHBD seemed negligible.

Early detection of macular hole closure with SD-OCT after the surgery contributed to a reduction in the duration of prone positioning [5, 8]. Previous studies have reported closure rates of 88.6–90.5% following macular hole surgery without prone positioning [6, 7]. Further studies using intraoperative SD-OCT will be needed to clarify the detailed changes in macular holes in order to achieve higher closure rates of macular hole surgery without prone positioning.

Disclosure Statement

The authors have no financial or conflicting interests to disclose.

Table 1. Visual acuity and macular hole parameters

Case	PreO VA logMAR	MH stage	PreO MHBD µm	MHBD after ILM removal µm	MHBD under fluid-air exchange, µm	7 to 10 days PO VA logMAR	1 month PO VA logMAR	1 month PO type of MH closure
1	1.00	3	815	801	574	0.70	0.30	simple closure
2	0.70	3	549	586	378	0.52	0.52	simple closure
3	0.40	3	722	716	528	0.52	0.40	simple closure
4	0.40	2	452	479	333	0.15	0.10	simple closure
5	1.00	2	853	855	608	1.00	0.30	bridge formation

ILM = Internal limiting membrane; MH = macular hole; MHBD = macular hole base diameter; PO = postoperative; PreO = preoperative; VA = visual acuity.

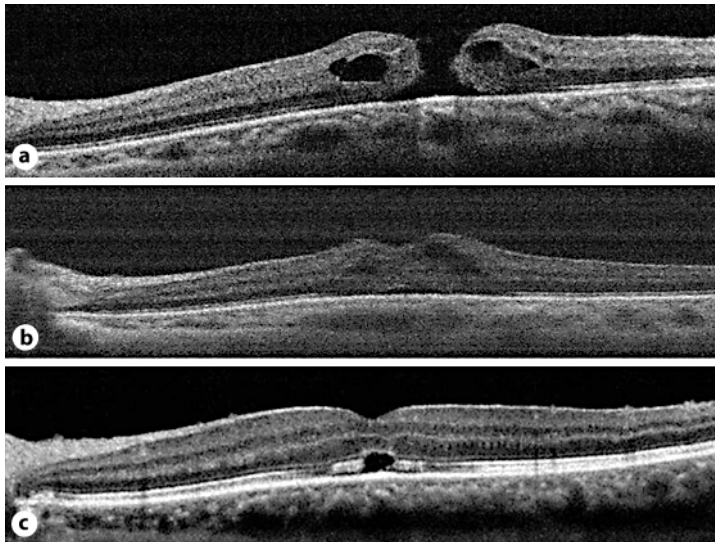


Fig. 1. SD-OCT images of a macular hole from case 1. **a** Macular hole after ILM removal. **b** Macular hole under fluid-air exchange. The inner edges of the macular hole touched each other. **c** Macular hole at 7 postoperative days, showing a bridge formation.

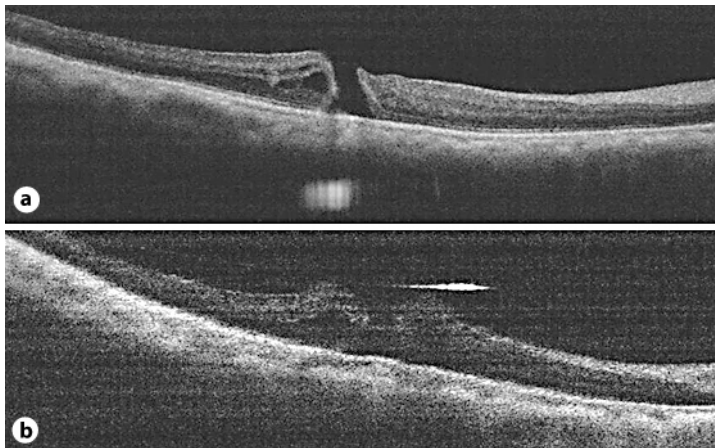


Fig. 2. SD-OCT images of macular holes from cases 2 and 3. **a** Macular hole from case 2 under fluid-air exchange. **b** Macular hole from case 3 under fluid-air exchange. The macular holes were open under fluid-air exchange.

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