Guided intracameral air injection based on 3D reconstructed anterior optical coherence tomography images in iatrogenic Descemet’s membrane detachment
Case report
Hye Yeon Yoon, MDa, Hyun Seung Kim, MD, PhDb, Hyung Bin Hwang, MD, PhDb,∗

Abstract
Rationale: We emphasize the importance of using anterior optical coherence tomography (OCT) to understand the details of iatrogenic Descemet’s membrane detachment (DMD) in 3 dimensions; this allows appropriate air injection into the anterior chamber in terms of both direction and method.

Patients concerns: A 74-year-old Korean female presented with progressive visual impairment. On slit-lamp examination, an iridocorneal adhesion was observed, associated with a full-thickness corneal opacity 3.0-mm in diameter. Adherence between the crystalline lens (with moderate cortical cataracts) and the iris was evident near the opacity. Therefore, we decided to perform cataract surgery.

Diagnosis: Intraoperatively, iatrogenic DMD occurred during removal of the iridocorneal adhesion, as clearly shown on postoperative OCT. However, slit-lamp examination did not reveal the details of the DMD because of the corneal edema.

Interventions and Outcomes: The DMD was evaluated via 3-dimensional (3D) reconstruction of multiple anterior OCT images. The reconstructed images were used to guide intracameral sterile air injection from an appropriate direction using an optimal method. The patient was asked to maintain an appropriate head position to allow the injected air to re-attach the DM.

Lessons: Three-dimensional (3D) reconstruction of an iatrogenic DMD developing during intraocular surgery is necessary to establish the details of the injury and allow accurate air injection into the anterior chamber; the air stream effectively re-attached the DM. It is important that the iatrogenic DMD can be treated properly only by confirming the accurate 3-dimensional shape as well as the position, height, and width of the DMD.

Abbreviations: 3D = three-dimensional, DMD = Descemet’s membrane detachment, OCT = optical coherence tomography.

Keywords: 3D reconstruction of OCT images, Descemet’s membrane detachment, intracameral sterile air injection

1. Introduction
Descemet’s membrane (DM) is a thick basement membrane lining the posterior surface of the cornea above the endothelium. As the membrane lies adjacent to the corneal endothelium, it is indirectly involved in maintenance of corneal transparency. Descemet’s membrane detachment (DMD) is a rare complication of cataract surgery (0.5% of phacoemulsification surgeries and 2.6% of extracapsular cataract extractions). To repair DMD, sterile air is typically injected into the anterior chamber. Alternatively, long-duration tamponade can be induced by injecting a gas such as C3F8. In general, small DMDs in the corneal periphery usually spontaneously reattach and do not significantly affect postoperative visual prognoses. However, DMDs involving the central cornea, or extensive DMDs, trigger corneal edema that in turn deteriorates visual acuity permanently; re-attachment is essential. Air or gas tamponade varying by the height, range, length, and position of detachment is very useful clinically. However, other factors must be considered when treating DMDs caused by mechanical trauma/surgical instruments, or DMDs developing when removing cornea/iris adhesions. As such, DMDs are not usually bullous and 1 side of the detachment can be open or curled. If air or gas is injected in the wrong...
direction, the DMD becomes more extensive. It is not easy to observe the DMD using a surgical microscope because corneal edema is inevitably present. Therefore, we created a 3-dimensional (3D) image of the DMD by superimposing 2-dimensional (2D) optical coherence tomography (OCT) images taken from various directions to determine whether the detached membrane was curled or folded, and in which direction the aqueous humor was passing. Based on this information, we

Figure 1. Anterior OCT images taken 1 (A) and 2 (B) days after cataract surgery. The DMD curls inward; membrane entry of aqueous humor is possible. DMD = Descemet’s membrane detachment, OCT = optical coherence tomography.
injected air into the anterior chamber as appropriate and successfully repaired the DMD by positioning the patient to maximize the effectiveness of air tamponade. Here, we report the first such case of DMD repair.

2. Case report

This study was conducted in accordance with the ethical standards stated in the Declaration of Helsinki and with the approval of the Institutional Review Board of Incheon St. Mary’s

Figure 2. Anterior OCT images taken 3 (A) and 5 (B) days after cataract surgery. The flap of the DMD is curled outward, rendering spontaneous re-attachment unlikely. OCT = optical coherence tomography.
Hospital, College of Medicine, The Catholic University of Korea, Seoul, Korea. Informed written consent was obtained from the patient for publication of this case report and accompanying images. A 74-year-old female visited our clinic with progressive visual loss. On slit-lamp examination, the left eye exhibited phthisis bulbi, but the cause of blindness remained unknown. The right eye evidenced moderate cortical cataracts and corneal opacities 2.0 and 3.5 mm in diameter on the right and lower sides of the pupil center, respectively. The lower opacity was accompanied by iris adhesion; the pupil was not round. Mydriasis was restricted by adhesion between the iris and the crystalline lens at the same site. OCT also revealed irregular astigmatism caused by the corneal opacity; it was difficult to measure the axial length or corneal curvature. The fovea contained thick drusen evident on macular OCT. It was difficult to guarantee a good visual prognosis after cataract surgery; we predicted that the operation would be complicated. However, as the visual acuity fell to about 0.2 Snellen units (caused by progressive cataract development) over a follow-up period about 3 years, cataract surgery was performed at the request of the patient.

After removing the adhesion of the crystalline lens and iris, capsulorhexis was performed, but it was difficult to create an adequate visual field. We tried to remove the iridocorneal adhesion, but this was more severe than expected and was thus we resected the tissue using retinal scissors. Phacoemulsification proceeded normally, and a 1-piece acrylic intraocular lens (Tecnis PCB00; Abbott Medical Optics, Santa Ana, CA) was inserted into the capsular bag and the operation completed. However, the edema around the lower corneal opacity (from which the iridocorneal adhesion had been removed) did not improve for 2 days postoperatively, affecting visual acuity by invading the visual axis. High-magnification slit-lamp microscopy revealed that the DM had peeled away. However, the DMD details were obscured by the corneal edema. The Snellen visual acuity score was only 0.1 unit and could not be corrected. The patient complained of persistently poor visual acuity.

We used OCT to explore the DMD site. On the first postoperative OCT scan, DMD was evident at the site of corneal opacity (from which the iridocorneal adhesion had been removed); an inwardly curled flap, possibly allowing aqueous humor entry, was observed (Fig. 1A). The next day, although the

Figure 3. Reconstructed 3-dimensional (3D) images on postoperative days 1 (A), 3 (B), and 5 (C) using multiple anterior OCT 2-dimensional (2D) images. The images reveal the details of DMD. Over time, the torn flap of DM gradually curled outward, indicating that detachment was continuing. To re-attach the DMD in the inferonasal area of the cornea, a 1-mm-diameter incision was made at 11 o’clock in the direction of the corneal limbus, and air was slowly injected (D). DM = Descemet’s membrane, DMD = Descemet’s membrane detachment, OCT = optical coherence tomography.
DMD had extended slightly, the form remained essentially bullous (Fig. 1B). The DMD was bullous in shape but part of the flat region was inwardly curved; thus, there was a risk that the aqueous might flow into the gap and extend the DMD, but the DMD width and height were not sufficiently large to permit re-attachment. However, over time, aqueous humor flowing into the gap of the flap increased the width and height, creating edema of the central cornea and decreasing visual acuity. Thus, the DMD flap became completely outwardly curled, rendering spontaneous re-attachment unlikely (Fig. 2A, B). Therefore, we decided to induce re-attachment by injecting sterile air into the anterior chamber. However, OCT revealed that the DMP was no longer

Figure 4. Anterior segment images (A, B) and an anterior OCT image (C) obtained immediately after intracameral sterile air injection. The patient was instructed to lift her chin up and tilt her head to the right, so that air compressed the DMD (D). DMD = Descemet’s membrane detachment, OCT = optical coherence tomography.
bullous; the membrane was torn and curled in a specific direction. Therefore, if sterile air were to be injected in the wrong direction, DMD would be exacerbated. We constructed 3D images by combining multiple 2D OCT images, to determine the exact shape of the DMD. Fig. 3A, B, and C show the 3D images obtained over time; the DMD flap gradually curled outwards, indicating that the extent of detachment was increasing.

Under topical anesthesia, we planned to re-attach the DM. The anterior chamber was pierced with a sharp 1-mm-diameter blade at the far peripheral corneal region (close to the limbus), distal to the DMD region in the 11 o’clock direction. A 30-gauge blunt cannula was introduced into the anterior chamber and slowly advanced toward the DMD (Fig. 3D). Sterile air was then steadily but slowly injected into the anterior chamber, creating a large bubble. The corneal dome around the DMD site was gently massaged using a muscle hook. The air bubble was further enlarged to fully fill the anterior chamber, but care was taken to prevent IOL displacement. The bubble was left in place for about 2 minutes to allow uniform re-attachment of the DM. Then, the 30-gauge blunt cannula was introduced once more and the size of the air bubble was reduced to about 60% of the anterior chamber volume. No peripheral iridectomy was required.

Immediately after this procedure, a slit-lamp microscopic examination and anterior OCT were performed (Fig. 4A, B, and C). These confirmed that air had been appropriately injected; the DM was completely re-attached. Thereafter, we asked the patient to assume a posture allowing air in the anterior chamber to press against the re-attached DM. As the DMD was on the inferonasal side of the right eye, the patient was instructed to lift her chin up and tilt her head to the right (Fig. 4D). This posture was maintained for about 3 days until the air in the anterior chamber was completely absorbed. Then, complete DM re-attachment was confirmed by slit lamp microscopy (Fig. 5A, B) and anterior OCT (Fig. 5C). The corneal edema steadily fell, and the Snellen visual acuity recovered to about 0.3 units. Posterior capsular opacity (clinically significant because of manipulation of the anterior chamber) developed 1 month after cataract surgery, and Nd-Yag-laser posterior capsulotomy was performed. Finally, the Snellen visual acuity recovered to about 0.4 units.

Figure 5. The final anterior segment image (A, B) and the OCT image (C) reveal complete re-attachment of DM. DM = Descemet’s membrane, OCT = optical coherence tomography.
3. Discussion

DMD is an uncommon complication of intraocular surgery; if the visual axis is involved, vision can be catastrophically affected in the absence of appropriate treatment. As DMD is associated with corneal edema at the lesion site, slit-lamp microscopy cannot always detect DMD; anterior OCT may be helpful. DMD should be suspected if uneventful corneal edema persists after intraocular surgery. The risk factors include a shallow anterior chamber, use of a blunt microkeratome, accidental DM contact with a surgical instrument, inadvertent injection of balanced salt solution or an ophthalmic viscosurgical device into the space between the stoma and DM, and genetically determined poor adhesion between the stoma and DM.[5,7,8] Iatrogenic DMD can be treated via medication or surgical intervention. One medical treatment is injection of a topical hyperosmotic agent such as 0.9% (w/v) sodium chloride solution. Surgical interventions include intraocular injection of sterile air or gas into the anterior chamber (14% [v/v] perfluoropropane [C3F8] or 20% [v/v] sulfur hexafluoride [SF6] gas have been used to this end).

Although DMD affects vision, treatment is not required in all cases. Small DMDs at clear corneal incision sites after phacoemulsification do not affect visual acuity. However, DMDs that invade the visual axis may cause visual impairment (via corneal scarring) if left untreated. Therefore, standards and principles for treatment of iatrogenic DMD are required. One of the most reliable standards (based on anterior OCT) is the height-, extent-, length-, and pupil-based (HELP) algorithm of Kumar et al.[6,8] If a DMD requires treatment, rapid surgical intervention reduces scarring-induced vision impairment.[6,8]

The cited treatment protocol is generally valuable, but this was not true in the present case. The DMD was in zone 2 (paracentral, 5.0–8.0 mm); the height was <100 μm and the length 1 to 2 mm. Thus, the HELP algorithm indicated that the DMD did not require surgical intervention. However, the DMD invaded zone 1 of the cornea at 2 days after onset, and the corneal edema then gradually invaded the visual axis. Thus, we performed intraocular air injection. The exact shape and configuration of a post-surgical iatrogenic DMD must be considered in addition to location, width, and height. A DMD that is not bullous, such as a DMD with a tear or hole through which aqueous humor can enter the membrane, or a DMD with a flap curled to 1 side (even a DMD at the periphery of the cornea), can become exacerbated and invade the visual axis. Such DMDs require early surgical intervention.

However, again, it is difficult to diagnose such DMDs via single OCT examinations; slit-lamp microscopic examination is unreliable because of accompanying corneal edema. Therefore, we obtained multiple 2D OCT images from various directions and reconstructed 3D images showing that immediate surgical intervention (i.e., intracameral, sterile air injection) was required. In addition, if a detached flap is curled, or bears a hole or tear through which aqueous humor can enter the membrane; it is possible to determine the direction in which the cornea should be incised before air injection. It is very important to view a DMD in 3 dimensions; DMD can deteriorate if air is injected in the wrong direction.

In conclusion, we are the first to show that anterior OCT can be used to determine the 3D DMD pattern and the most appropriate treatment. We can confirm that the iatrogenic DMD can be treated properly only by confirming the accurate 3-dimensional shape as well as the position, height, and width of the DMD. Finally, the HELP algorithm has certain limitations; the algorithm requires modification.

Author contributions

Conceptualization: Hyung Bin Hwang.
Data curation: Hye Yeon Yoon, Hyun Seung Kim, Hyung Bin Hwang.
Formal analysis: Hyung Bin Hwang.
Investigation: Hyun Seung Kim, Hyung Bin Hwang.
Methodology: Hyun Seung Kim, Hyung Bin Hwang.
Supervision: Hyung Bin Hwang.
Writing – original draft: Hye Yeon Yoon, Hyung Bin Hwang.
Writing – review & editing: Hyung Bin Hwang.

References

[1] Khng CY, Voon LW, Yeo KT. Causes and management of Descemet’s membrane detachment associated with cataract surgery—not always a benign problem. Ann Acad Med Singapore 2001;30:532–5.
[2] Ti SE, Chee SP, Tan DT, et al. Descemet membrane detachment after phacoemulsification surgery: risk factors and success of air bubble tamponade. Cornea 2013;32:4549–9.
[3] Shah M, Bathia J, Kohli K. Repair of late Descemet’s membrane detachment with perfluoropropane gas. J Cataract Refract Surg 2003;29:1242–4.
[4] Gatzionas Z, Schirra F, Lou U, et al. Spontaneous bilateral late-onset Descemet membrane detachment after successful cataract surgery. J Cataract Refract Surg 2009;35:778–81.
[5] Couch SM, Baratz KH. Delayed, bilateral descemet’s membrane detachments with spontaneous resolution: Implications for nonsurgical treatment. Cornea 2009;28:1160–3.
[6] Kumar DA, Agarwal A, Swang nanam S, et al. Height, extent, length-, and pupil-based (HELP) algorithm to manage post-phacoemulsification Descemet membrane detachment. J Cataract Refract Surg 2015;41:1945–53.
[7] Zhang B, Pan F, Yao YF. Spontaneous resolution of extensive descemet membrane detachment caused by sodium cyanide injury to the eye. Cornea 2012;31:1344–7.
[8] Jain R, Murthy SI, Basu S, et al. Anatomic and visual outcomes of descemetopexy in post-cataract surgery descemet’s membrane detachment. Ophthalmology 2013;120:1366–72.