Int J Ophthalmol, Vol. 19, No. 4, Apr. 18, 2026 www.ijo.cn
Tel: 8629-82245172 8629-82210956 Email: ijopress@163.com

· Review Article ·

# Identification and management of Descemet's membrane detachment during glaucoma and cataract surgery

*Ahmed Al Habash[1], Enas Alkhoutani[2], Halah Bin Helayel[3]*

[1]Department of Ophthalmology, College of Medicine, Imam Abdulrahman Bin Faisal University, King Fahd Hospital of the University, Dammam 31952, Saudi Arabia
[2]Department of Ophthalmology, Alnoor Specialist Hospital, Makkah 24241, Saudi Arabia
[3]Anterior Segment Division, King Khaled Eye Specialist Hospital, Riyadh 11462, Saudi Arabia
**Correspondence to:** Halah Bin Helayel. King Khaled Eye Specialist Hospital, Uruba Road, Riyadh 11462, Saudi Arabia. hbinhelayel@kkesh.med.sa
Received: 2025-03-07 Accepted: 2026-01-15

## Abstract
● Descemet's membrane detachment (DMD) is defined as the detachment of Descemet's membrane that occurs spontaneously or secondary to intraocular surgery. This review focuses on the characteristics and incidence of DMD following phacoemulsification and glaucoma surgery, and aims to compare DMD cases after phacoemulsification (PCE) and different types of glaucoma surgery in terms of incidence, risk factors, clinical manifestations, diagnosis and management strategies. The reported incidence of DMD after PCE ranges from 0 to 5%, and the complication is less frequently observed following glaucoma surgery. Patients with DMD may be asymptomatic or present with severe visual impairment caused by corneal edema, which is associated with the size and location of the detachment. The management of DMD varies according to the primary surgical procedure (PCE or glaucoma surgery), as well as case-specific factors including visual acuity, corneal clarity, and the size and location of the detachment. Longitudinal observational studies are warranted to investigate the underlying cellular mechanisms of DMD. Retrospective studies can be conducted to clarify the incidence and identify all potential risk factors for DMD following glaucoma surgery. In addition, it is crucial to explore all possible risk factors to reduce and prevent this complication.
● **KEYWORDS:** surgery complications; corneal decompensation; Descemet's membrane detachment; cataract; glaucoma; treatment
**DOI:10.18240/ijo.2026.04.20**

**Citation:** Al Habash A, Alkhoutani E, Bin Helayel H. Identification and management of Descemet's membrane detachment during glaucoma and cataract surgery. *Int J Ophthalmol* 2026;19(4):799-807

## INTRODUCTION

Descemet's membrane detachment (DMD) or rupture was initially identified by Bernard Samuels in 1928[1]. DMD is a condition that affects the posterior cornea; it is characterized by the separation of the endothelium–Descemet's membrane complex from the posterior corneal stroma[1]. DMD can occur during certain eye operations, such as cataract surgery, glaucoma surgery, and keratoplasty[1]. It can also occur spontaneously in cases of acute hydrops associated with ectatic corneal diseases, especially keratoconus; it has also been observed in patients with healed keratitis who have not undergone prior intraocular surgery and following ocular surface chemical injuries[1-3]. Patients with DMD may present with visual impairment caused by corneal edema and Descemet's membrane folds; however, they may also be asymptomatic[1]. DMD is a common occurrence during cataract surgery, with incidence rates of approximately 2%-6% during extracapsular cataract surgery and 0-5% during phacoemulsification cataract surgery[1]. Most cases are identified intraoperatively or immediately after surgery[4]. There are multiple risk factors for DMD, including genetic influences, surgical equipment, and surgical technique[1,4]. DMD has numerous therapeutic options that differ depending on contextual factors, including visual acuity and the location and size of the detachment. It can be either monitored or managed with medical or surgical interventions[1,4]. Vision loss and corneal decompensation may occur in certain instances if the condition is left untreated[1,4]. DMD can occur following various types of glaucoma surgery, but it is more commonly associated with cataract surgery. However, it is more challenging to diagnose and manage in the latter case[5].

The aim of this review is to discuss and compare DMD following phacoemulsification and different types of glaucoma surgery in terms of incidence, risk factors, clinical presentation, diagnosis, and management options.

## METHODOLOGY

**Classification Systems** Persisting edema of the epithelium and corneal stroma is the defining clinical characteristic of DMD[6]. Multiple classifications of this condition have been proposed that vary by pathology, clinical characteristics, and imaging techniques[6-8]. Based on the pathology, the initial classification; Samuel Classification (1928) outlined three specific types of DMD: active (the affected area is pushed backward), passive (the area is pulled back and torn away), and a third type resulting from differences in elasticity between the anterior parenchyma and Descemet's membrane[6-8]. According to Mackool and Holtz (1977)[9], DMDs can be classified as planar or non-planar[6-8]. Planar DMDs refer to cases in which the distance between the DMD and the posterior stroma is equal to or less than 1 mm, while non-planar DMDs indicate a separation larger than 1 mm[6-8]. Based on the extent, Jain classification (2013) described three types: mild DMD (involving <25% of the peripheral cornea), moderate DMD (involving 25%-50% of the peripheral cornea), severe DMD (involving >50% of the cornea and central cornea)[8]. Jacob *et al*[10] proposed a novel classification of Descemet's membrane detachment using anterior segment optical coherence tomography (AS-OCT)[6]. They divided the condition into four types–rhegmatogenous, tractional, bullous, and complex–and proposed treatment protocols to match this classification[6-8].

Rhegmatogenous Descemet's detachment occurs as a result of a hole, tear, or dialysis of Descemet's membrane at Schwalbe's line.

The tear is the most typical form that usually occurs after the installation of an intraocular lens or a blunt instrument[10]. A hole may develop after microperforation of the Descemet's membrane during deep anterior lamellar keratoplasty, leading to DMD with a double anterior chamber[10].

Descemet's membrane dialysis from its attachment at Schwalbe's line can take place as a complication of viscocanalostomy, trabeculotomy, and punch insertion in trabeculectomy, or with a peripheral extension of descemetorhexis during Descemet's membrane endothelial keratoplasty. Clinically, rhegmatogenous DMD is observed as an undulating membrane in the anterior chamber, on irrigation, undulating movements of the Descemet's membrane are seen[10].

AS-OCT is highly effective for identifying and distinguishing various types of DMD, particularly when corneal edema is present. Rhegmatogenous DMD appears as an undulating linear hyperreflective signal in the anterior chamber[10]. Tractional DMD is infrequent and results from traction and shortening of the Descemet's membrane due to inflammation, peripheral anterior synechiae, fibrosis, or incarceration at the wound-graft host junction, or sutures, leading to subsequent contraction. Descemet's membrane is taut, shortened, and stretched out between the points of attachment[10]. The arc length of the overlying cornea exceeds the length of the detached Descemet's membrane. In irrigation, the Descemet's membrane is either sharp or immobile and exhibits fluttering movements[10]. On AS-OCT, Tractional DMD appears as a linear taut signal connecting the points of attachment. AS-OCT reveals that the arc length of the overlaying cornea exceeds the chord length of the detached Descemet's membrane in cases of tractional DMD, whereas in rhegmatogenous DMD, these two lengths are equivalent[10]. Bullous DMD manifests as a smooth bulge of Descemet's membrane into the anterior chamber, either in the absence of any membrane rupture or with a needle puncture that is too small to let the escape of contents (balanced salt solution, viscoelastic device, blood, *etc*.). This is frequently caused by the insertion of a viscous fluid (blood, air, or viscoelastic) in the supra-Descemet's space during cataract surgery or viscocanalostomy[10]. Additional causes involve localized islands of DMD in an otherwise attached graft post Descemet's membrane endothelial keratoplasty, loculated blood, and a purposeful separation of the Descemet's membrane facilitated by Anwar's huge bubble approach in deep anterior lamellar keratoplasty. AS-OCT reveals a convex hyper-reflective signal indicative of bullous DMD[10]. Complex DMD show Descemet's membrane macrofolds, rolls, scrolled edges, and many combinations of other DMD varieties. These are frequently observed following Descemet's membrane endothelial keratoplasty, particularly during the phase of learning, as well as in cases with significant postoperative DMD or inadequately repositioned rhegmatogenous DMD. AS-OCT in complex DMD reveals the complex folds, scrolls, and adhesions[10].

The HELP Algorithm (2015) which utilizes height, extant, chord length, and relation to the pupil, proposed management options based on these criteria[8]. Samarawickrama *et al*[7] classification categorizes DMD based on their involvement of the visual axis into peripheral and central DMD, and proposes management guidelines accordingly[7-8]. Dua further classified DMD (2020) into three distinct categories: the first type, which corresponds to big bubble 1 in lamellar keratoplasty, involves the Descemet's membrane being attached to the posterior surface of the predescematic layer as it separates from the deep stroma; AS-OCT with this type reveals a straight, hyper-reflective line that resembles the chord of a circle and is relatively thick and taut[6]; the second type refers to the separation of Descemet's membrane from the predescematic layer, as in big bubble 2; AS-OCT reveals a relatively thin, hyper-reflective undulating line in these cases[6]; the third type, which corresponds to a mixed big bubble, is characterized by the separation of the predescematic layer and Descemet's membrane from the deep stroma and from one another. In this case, AS-OCT reveals two hyperreflective lines that resemble the chord of a circle and an undulating pattern[6].

**DMD Following Cataract Surgery**

**Pathogenesis and risk factors** Risk factors for DMD are classified as preoperative, intraoperative, or postoperative[4,11-12]. Preoperative risk factors include congenital and genetic predisposition (caused by a mutation in the *TGFBI* gene), Fuchs' endothelial dystrophy, posterior polymorphous corneal dystrophy, and birth trauma causing a weakened adhesion between the Descemet's membrane and the posterior stroma. Intraocular surgery frequently results in DMD in these individuals due to weak adhesion. The location of the DMD usually depends on the site of the incision; another factor is an inadvertent injection of viscoelastic and basic salt solution between Descemet's membrane and the posterior stroma. The aqueous flow between the Descemet's membrane and the posterior stroma further worsens the DMD[8]. Advanced age constitutes an additional preoperative risk factor for DMD, attributable to age-related thickening of the Descemet's membrane, arcus (lipid degeneration), and peripheral degenerations that compromise the connections between the Descemet's membrane and the posterior stroma[8]. Other ocular disorders: the prevalence of DMD is known to be higher in eyes affected by pseudoexfoliation syndrome, primary angle closure glaucoma due to a shallow anterior chamber, and in eyes subjected to intraocular surgery[8].

Elevated preoperative intraocular pressure resulting in persistent edema may have compromised the adhesion between the stroma and Descemet's membrane, leading to DMD[13]. An abrupt release of the intraocular pressure may also contribute to this phenomenon[8]. Idiopathic DMD has been reported in patients with healed keratitis who have not undergone prior intraocular surgery[2].

Intraoperative risk factors include uncooperative behavior in patients, including those under light anesthesia; patients may cause harm to the Descemet's membrane by abruptly moving their eyes[14]. Iatrogenic factors: hard cataracts along with complicated surgeries increase the risk[8]. DMD may also result from the use of blunt keratome, excessive anterior clear corneal incision, oblique entry, or an incision that is too long or tight[1,4,8,15]. The probability of DMD is influenced by the size of the incision; the smaller the incision, the greater the incidence of DMD[16]. DMD can occur during irrigation or aspiration; the injection of viscoelastic substances, air, or antibiotics between the stroma and Descemet's membrane; intraocular lens implantation; and hooking intraocular lens haptics[1,4,8,11,15,17]. Postoperative DMD can occur immediately or after a delay due to trauma and eye rubbing[14].

To decrease the incidence of DMD, careful preoperative examination, investigation with AS-OCT, and specular microscopy in both eyes should be performed to look for all possible risk factors. Good surgical technique, use of sharp blades, minimization of traumatic instrumentation, and awareness of the risk of high-flow irrigation are critical in preventing DMD[12].

**Clinical presentation and workup** Patients with phacoemulsification-related DMD present in variable clinical states; they may be asymptomatic, or they may suffer a significant loss of vision, with minimal to severe corneal edema[18]. Early postoperative diagnosis of DMD is critical for appropriate management and prevention of further complications. Slit-lamp biomicroscopy can be used to diagnose DMD in cases in which corneal edema is mild; however, severe corneal edema may make detection challenging[18]. In such circumstances, AS-OCT emerges as a highly efficacious modality of diagnostic confirmation[14-15,17]. It is unaffected by corneal edema and produces high-resolution images that are accurate to the micron level and distinguish the tissue structure of the corneal layers. AS-OCT helps identify the etiology of postoperative corneal edema, specifically DMD, based on its size and location[18]. It also helps in determining the appropriate treatment option and monitoring for DMD recurrence after treatment[19].

**Management** There is currently no gold standard in terms of treatment options for DMD. It can be observed; medically treated with topical steroids or hyperosmotic agents; or managed surgically with intracameral air or expandable gas injection of octa-fluoropropane ($C_3F_8$) or sulfur hexafluoride ($SF_6$), injection of viscoelastic material, transcorneal suturing, or corneal transplant, whether endothelial keratoplasty or penetrating keratoplasty[20]. Reports indicate that intracameral gas injection following cataract surgery for DMD can achieve success rates ranging from 90% to 95%[21].

The severity of corneal edema, visual acuity, and the location, size, and extent of the separation (planner or non-planner), that is, whether it is smaller or larger than 1 mm, all influence DMD management[7,17-18]. In the case of peripheral and small detachments, close observation and conservative management may result in spontaneous reattachment over a period of weeks to months[7,17-18]. Conversely, a large, central detachment that obscures the visual axis requires surgical intervention[7,17]. Early intervention is recommended to enhance visual function, obviate stromal scars, and minimize the risk of secondary complications, including infectious keratitis[12].

In a case study conducted in China, 60% of the cornea was affected by severe DMD following phacoemulsification; air descemetopexy was used to treat the condition, but it was unsuccessful in attaching the Descemet's membrane[22]. The patient was subsequently managed with aspiration of predescematic fluid combined with an intracameral air tamponade while they remained in a strict supine position for one day[22]. This strategy led to the effective reattachment of the Descemet's membrane[22]. In addition, a prospective, interventional, comparative randomized clinical trial was carried out at a private eye clinic in Egypt between March 2019 and March 2020; the purpose of the trial was to compare the effects of an air bubble tamponade alone and with internal fluid aspiration guided by AS-OCT on nonplanar DMD with corneal edema following phacoemulsification[20]. Air descemetopexy in conjunction with internal fluid aspiration was discovered to be more effective in treating post-phacoemulsification DMD than air descemetopexy alone, as evidenced by the rapid reattachment of the Descemet's membrane, fast visual recovery, and decreased need for secondary interventions[20]. The authors recommend that this approach be tried first in cases of severe DMD before arranging major corneal surgery, such as corneal transplants[20].

A successful repositioning of the Descemet's membrane with a favorable visual prognosis was reported by Wang and Tseng[18] fourteen months after cataract extraction. Thus, corneal endothelial cells over the detached Descemet's membrane appear capable of surviving for an extended duration within the anterior chamber. Therefore, prior to attempting corneal transplantation, ophthalmologists should make every effort to reattach the Descemet's membrane, even if it been separated for years[18].

Double bubble pneumo-descemetopexy is an innovative technique described by Sharma *et al*[23], to treat a rolled DMD following cataract extraction when the detached Descemet's membrane is only folded upon itself, a singular big air bubble can be created by positioning the cannula between the attached Descemet's membrane and the folded Descemet's membrane, so elevating and securing the Descemet's membrane. However, if the detached Descemet's membrane is rolled up, the surgeon has to unroll it and then attach it with the double bubble pneumo-descemetopexy, utilizing a smaller bubble for unrolling and a larger bubble for attaching the Descemet's membrane. Double-bubble pneumo-descemetopexy, a more controllable approach, yields excellent anatomical and visual results in DMD, eliminating the need for endothelial keratoplasty or penetrating keratoplasty[23].

Hirabayashi *et al*[24] reported a case of postsurgical corneal decompensation in a female patient with Fuchs endothelial dystrophy after cataract surgery characterized by a persistent sectoral DMD and overlying corneal edema for 6mo, as confirmed by an AS-OCT. Specular microscopy revealed cell dropout, with a cell density of 929 cells/mm$^2$ in a region of clear cornea in the affected eye. The case was effectively treated with a targeted Descemet's stripping only procedure with post-operative netarsudil and prednisolone drops. By the tenth week postoperatively, the corneal edema had completely disappeared. The central corneal thickness was 583 μm preoperatively and subsequently improved to 548 μm. Preoperative visual acuity was 20/70, which improved to 20/30$^{+3}$. A slit-lamp examination revealed the presence of guttae in the Descemetorhexis region. Nevertheless, no cells were observed on specular microscopy. By the fourth month postoperatively, central corneal thickness had improved to 492 μm, and specular microscopy was capable of detecting a cell density of 318 cells/mm$^2$. By the eighth month postoperatively, the cell density increased to 675 cells/mm$^2$[24]. The current case has been classified as postsurgical corneal edema, which is more similar to a bullous keratopathy phenotype despite having an underlying diagnosis of Fuchs dystrophy. This is because the postoperative course following the initial cataract surgery is typical of non-Fuchs patients with DMD complication. This case report furthers the indications for the Descemet's stripping only procedure to involve postsurgical corneal edema. Thus far, the Descemet's stripping only procedure has been identified as an alternative option to endothelial keratoplasty for Fuchs endothelial dystrophy[24].

**DMD Following Penetrating Glaucoma Surgery**

**Trabeculectomy** Compared to post-cataract surgery, DMD is less commonly associated with glaucoma surgery. The risk factors are not well described in the literature. However, management is more challenging and differs depending on the type of glaucoma surgery[5]. The eye no longer functions as a closed system in penetrating glaucoma surgeries, such as trabeculectomy and tube surgeries; therefore, the use of tamponading agents to secure Descemet's membrane is less effective because they may escape through the fistula or the tube[5,21]. Case reports that address the management of DMD subsequent to trabeculectomy are limited[25]. Li *et al*[25] described a case of DMD managed by several intracameral injections of ophthalmic viscosurgical device, air, and gas subsequent to trabeculectomy. The patient's endothelial cell count decreased from 2427 cells/mm$^2$ before surgery to 1506 cells/mm$^2$ after 70d; 1079 cells/mm$^2$ after 10mo, with increased size and shapes of the endothelial cells; and 763 cells/mm$^2$ at the 3-year follow-up[22]. However, repeated injections might result in elevated intraocular pressure, intraocular inflammation, infection, and decreased endothelial cell count[25]. Endothelial pleomorphism and polymegathism can improve over time after the reattachment of Descemet's membrane[25].

A case of DMD following anterior chamber reformation for hypotony following trabeculectomy and flat anterior chamber was described by Wigginton *et al*[26]. The case involved a large DMD that completely resolved within six months through conservative treatment, resulting in a clear cornea. In Rasouli *et al*'s[27] case study, following several attempts to reform the anterior chamber and address hypotony by injecting ophthalmic viscosurgical device after trabeculectomy, the condition was managed using a viscoelastic tamponade; full-thickness 10–0 nylon sutures secured the Descemet's membrane to the stroma, and the fluid between the stroma and the Descemet's membrane was allowed to drain.

Sharifipour *et al*[5] documented a post-trabeculectomy case of DMD accompanied by choroidal effusion with a shallow anterior chamber. The condition was successfully treated after three surgical attempts. The initial attempt, based on intracameral air injection, failed. A subsequent effort using a choroidal tap with intracameral air injection yielded temporary success, followed by a recurrence of DMD. Finally, through a transconjunctival suture of the scleral flap to close the functioning bleb, a choroidal tap, and an injection of intracameral 20% $SF_6$, the Descemet's membrane was successfully attached, yielding a clear cornea. The suture was removed, and bleb needling was later performed to preserve bleb function[5].

Yang *et al*[13] reported a case of a spontaneous resolution of recurrent DMD after trabeculectomy in a 66-year-old woman had an attack of angle closure in the right eye; the intraocular pressure was 40 and 15 mm Hg of the right and left eye, respectively. A slit lamp examination showed corneal edema with Descemet's folds, shallow anterior chamber, atrophic iris, and mid-dilated pupil in the right eye[13]. The anterior chamber was shallow for the left eye, but the rest of the anterior segment was generally normal[13]. Topical and systemic medical management to reduce the intraocular pressure was given. Two days later, trabeculectomy was performed under local anesthesia; the surgery was successful. However, the corneal edema was still present, and a significant Descemet's membrane detachment was identified *via* anterior segment AS-OCT, prompting surgical intervention[13]. Viscoelastic and sterile air were subsequently injected into the anterior chamber to facilitate the reattachment of Descemet's membrane. AS-OCT showed that the DMD was adequately resolved. Seven days later, AS-OCT revealed a recurrence of the DMD, but smaller than previously observed[13]. The patient was urged to undergo surgical repair but refused and failed to return for follow-up. Eight months later, the patient was re-hospitalized due to an acute episode of angle-closure glaucoma in her left eye. The slit lamp examination indicated that the cornea of the right eye was clear. AS-OCT was conducted and demonstrated that the DMD recovered spontaneously[13].

The potential causes and risk factors of DMD following trabeculectomy in this instance may include the patient being advanced in age and elevated intraocular pressure continued for an extended duration prior to the surgical intervention[13]. Prolonged corneal edema may result in a significantly weakened adhesion between Descemet's membrane and the stroma; the significant reduction in intraocular pressure post trabeculectomy may weaken the adhesion between Descemet's membrane and the corneal stroma, leading to DMD. The patient's compromised physical condition precluded the use of general anesthesia, and the involuntary head movements due to Parkinson's disease exacerbated the surgical challenges; the shallow anterior chamber of the operative eye complicated the corneal incision[13]. These elevated the risk of DMD. Moreover, unintentional injection of balanced salt solution between the stroma and Descemet's membrane may occur during the procedure and might potentially contribute to DMD[13].

The detached Descemet's membrane/endothelial complex in the anterior chamber may also receive nourishment from aqueous humor. Consequently, the functionality of endothelial cells may remain intact throughout time, and corneal transparency could be regained following the spontaneous resolution of DMD[13]. DMD with significant separation and scrolling is unlikely to recover spontaneously without surgical intervention[13]. The recurrent DMD in this patient, characterized by a wide detachment range, resolved spontaneously. Nonetheless, we observed that the corneal endothelial cell density in the right eye was markedly inferior to that of the other eye. It was discovered that the extended duration of DMD could result in ocular endothelial cell damage, though it resolved spontaneously. Furthermore, the mechanism and necessary duration for the spontaneous resolution of DMD remain unclear[13]. Despite prior reports of spontaneous remission of DMD, the majority of researchers continue to advocate for early surgical intervention to preserve the patient's visual function upon occurrence[13].

Maheshwari *et al*[28], reported a case of iridocorneal endothelial syndrome with spontaneous resolution of DMD following bleb needling. A 43-year-old female complained of poor vision in the left eye. Her best corrected visual acuity was 20/80. The intraocular pressure was 36 mm Hg by Goldmann applanation tonometry[28]. Slit lamp examination showed corneal guttae and immature cataract. The cup disc ration was 0.9. Maximum medical therapy was initiated, followed by phacotrabeculectomy[28]. One year later she developed a failed bleb, and underwent bleb needling. In the first day post postoperative her intraocular pressure reduced to 8 mm Hg with a diffuse bleb. One week post operation she presented with poor vision, corneal edema and DMD which was confirmed by an AS-OCT[28]. The patient was planned for a descemetopexy in one week, upon follow up the vision and the corneal edema improved. AS-OCT showed complete spontaneous reattachment of the Descemet's membrane, avoiding the need for surgical intervention[28]. This case report highlights that iridocorneal endothelial syndrome, might have been at a high risk for DMD. A spontaneous resolution of DMD can occur over time and can be managed conservatively[28].

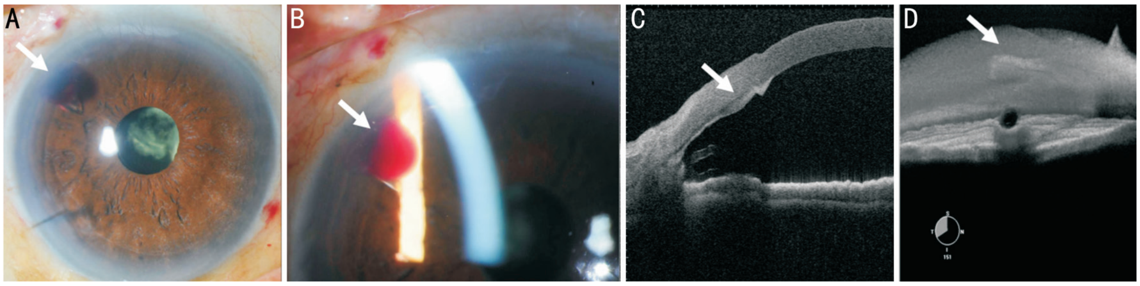


**Figure 1 Hemorrhagic Descemet's membrane detachment post glaucoma drainage device** A: Highlighted in a slit lamp photo using diffuse beam illumination; B: Magnified slit beam finding; C, D: Anterior segment optical coherence tomography.

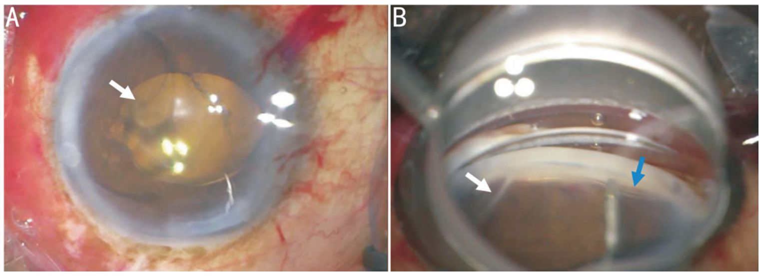


**Figure 2 Descemet's membrane detachment after AB Interno canaloplasty** A: Direct view from the operative microscope; B: Gonioscopic view. The white arrow indicates Descemet's membrane detachment, and the blue arrow indicates the catheter.

**Post-glaucoma drainage devices** A few cases of DMD have been associated with glaucoma tube drainage device use (Figure 1). Claudio *et al*[21] reported a case of DMD in a patient with corneal graft following anterior chamber reformation after the removal of a Baerveldt shunt intraluminal stent. The patient had low intraocular pressure, choroidal detachment, and DMD, was managed *via* reinsertion of the intraluminal stent and viscoelastic injection in the anterior chamber to reattach and tamponade the Descemet's membrane. However, the DMD persisted, requiring another treatment-namely, a 14% $C_3F_8$ gas injection into the anterior chamber as the patient maintained a supine position[21]. Despite the presence of a functioning Baerveldt aqueous shunt, the gas remained in the anterior chamber for sufficient time[21]. The cornea cleared, vision improved, and the Descemet's membrane was reattached, with no episodes of high intraocular pressure. This was unlike the case reported by Claudio *et al*[21] who injected intracameral gas into a patient with a Baerveldt aqueous shunt due to DMD; they successfully attached the Descemet's membrane but observed an increase in intraocular pressure, leading to aspiration of the retained gas from the anterior chamber.

Jainuddin[29] reported a case of DMD following a post-viscoelastic injection for ocular hypotony from an over-filtered Ahmed valve implant. The patient was treated with descemetopexy, and anterior chamber reformation was pursued with a Healon GV® (USA), leading to patrial attachment of the Descemet's membrane. However, repeated descemetopexy with venting incisions was necessary to completely resolve the DMD[29]. Most cases associated with penetrating glaucoma surgeries (trabeculectomy and glaucoma drainage) occur following hypotony or attempts at anterior chamber reformation, which indicates the role of hypotony in inducing DMD. Anterior chamber reformation using viscoelastic material can also be considered a risk factor for post-glaucoma surgery DMD[29]. Care must be taken when injecting viscoelastic material into the anterior chamber, especially into a shallow anterior chamber; this process should be performed through the use of microscopes to clearly visualize the tip of the cannula and ensure proper placement inside the anterior chamber before the injection[21,29].

**DMD Following Non-Penetrating Glaucoma Surgeries**

**Canaloplasty** Canaloplasty glaucoma surgery enhances the aqueous flow from the anterior chamber through the trabecular meshwork and Descemet's window, into Schlemm's canal, and out *via* the collector channels, thereby restoring the natural aqueous outflow[30]. Hyphema, transient hypotony, and hemorrhagic and non-hemorrhagic DMD are all potential complications of canaloplasty (Figure 2)[30]. The reported incidence of DMD following canaloplasty ranges from 1.1% to 7.4%, whereas the incidence of hemorrhagic DMD is 6.7% following phacocanaloplasty[30].

Several intraoperative risk factors contribute to the occurrence of DMD; these factors primarily manifest during catheter withdrawal and viscodilation step[30-31]. To begin with, the use of viscocohesive agents during microcatheter withdrawal and viscodilation of Schlemm's canal may disrupt the canal's vulnerable wall, allowing for leakage and subsequent DMD, followed by episcleral blood reflux to the collector channels of Schlemm's canal; the space created by the DMD results in the formation of hemorrhagic DMD and hematoma[30]. Second, excessive pressure during sodium hyaluronate injection in the catheter withdrawal phase can result in DMD, which is predominantly inferior in such cases[30-31]. Third, suture knots at the tip of the microcatheter may cause damage to the canal within Schlemm's walls; excessive pressure in the Schlemm's canal may result from the combination of a slow withdrawal of the microcatheter and the injection of sodium hyaluronate[30-31]. Most hemorrhagic DMD cases manifest as inferior[30-31]. Sodium hyaluronate readily exits through the opened canal of Schlemm's ostia during the viscodilation and catheter withdrawal step when injected in the superior quadrant; however when injected with excessive pressure into the inferior quadrant, sodium hyaluronate can induce DMD[20,30]. Most of the collector channels that connect the episcleral veins to the canal are located inferiorly and nasally, which contributes to blood reflux in the Descemet's membrane region and ultimately results in hemorrhagic DMD[30-31]. The major intraoperative risk factor for hemorrhagic DMD in combined phacocanaloplasty is hypotony, which can occur in different stages of phacoemulsification due to the fragility of Schlemm's canal walls; this can lead to significant blood reflux from the collector channels[30-31]. Orejudo de Rivas *et al*[31] conducted a case series with three cases of DMD among 180 individuals who undergone canaloplasty or phacocanaloplasty. These cases demonstrate the low incidence of this complication (1.67%) and offer more proof that DMD is more common during phacocanaloplasty than during standard canaloplasty, especially in patients with open angle glaucoma and uncontrolled intraocular pressure[31]. This includes secondary glaucomas characterized by an open angle, such as pseudoexfoliative glaucoma[31].

The management of hemorrhagic DMD is a controversial topic. The options are determined by a number of variables, including the location, size, and degree of the anteroposterior separation and the duration of observation[31]. The time to spontaneous resolution may range from six months to two and a half years[31]. The absorption process may be hindered by several factors, including the high viscosity of the 1.4% sodium hyaluronate solution that envelops the hemorrhage, which increases the likelihood of complications, including corneal staining, particularly when intraocular pressure is high; the possibility of developing a corneal scar, persistent epithelial defect, or ulceration; and the need for extensive visual rehabilitation. This makes watchful observation a suboptimal approach. It is not recommended to inject intracameral gas without evacuating the hematoma in an effort to move it away from the visual axis, as this may result in corneal staining and secondary intraocular pressure changes[31]. Early drainage is essential when the visual axis is affected, as early interventions are more likely to result in a restoration of corneal transparency and prompt visual rehabilitation[30]. One of the numerous drainage options reported is Descemet's membranotomy using an Nd:YAG laser in conjunction with 1.4% sodium hyaluronate in the anterior chamber[20]. The surgical interventions include endothelial micropuncture, transepithelial partial thickness incision, and partial stromal incision, followed by washing of the viscoelastic material and the hemorrhage, with intracameral tamponades (air, sulfur fluoride gas, balanced salt solution, and viscoelastic material) used to elevate intraocular pressure and facilitate blood drainage; this is followed by air or gas injection to reattach the Descemet's membrane[31].

**Deep Sclerectomy** DMD following deep sclerectomy (DS) is extremely uncommon, and its etiology remains unknown[32]. If DMD were to occur after non-penetrating DS, it would likely be attributed to the passage of aqueous humor from elevated pressure in the subconjunctival and decompression space reservoir of aqueous humor; additionally, vigorous eye rubbing, and postoperative trauma are potential risk factors[32]. The trabeculo-Descemet's membrane is a potential route for the aqueous humor to emerge behind the corneal stroma and separate the Descemet's membrane. A few cases of post-DS DMD have been reported in the literature, and most of these cases involved the use of an implant[32].

AlZaid *et al*[33] reported the only case of DMD following DS that was treated with air injection and did not involve the use of an implant. Al Obeidan[32] observed one case of total DMD accompanied by severe corneal edema, with no view of the anterior chamber three days after DS; it was managed with intracameral $SF_6$ and resolved completely in a few weeks. A case of post-DS hemorrhagic DMD was managed conservatively, as reported by Alzaid *et al*[33]. Within the first two weeks, rapid absorption was observed, followed by a subsequent decline in the absorption rate. Six months after the operation, the Descemet's membrane reattached completely, without any further intervention. The bleb continued to function, and the intraocular pressure remained within the target range; a paracentral corneal scar was left behind. Even in the absence of implant use or penetration, DMD may develop following non-penetrating glaucoma surgery[33]. Treatment options in persistent cases include observation; descemetopexy *via* injection of intracameral air, $SF_6$-$C_3F_8$ gas, or viscoelastic material; trans-corneal suturing; and endothelial or penetrating keratoplasty[33].

DMD after glaucoma surgery is rare compared to after phacoemulsification. The risk factors are less understood and the management is more challenging, especially in penetrating glaucoma surgery, where the eye is no longer a closed system[32-33]. It might take multiple attempts to re-attach the Descemet's membrane, and viscoelastic material might be necessary to reform the anterior chamber and tamponade the

Descemet's membrane. This can impact endothelial cell count, but it is still worth trying to reattach the Descemet's membrane, even with a long duration of DMD, before proceeding to corneal transplantation[32-33].

**DMD Following Minimally Invasive Glaucoma Surgeries** Khan and Lin[34] reported a case of DMD following Hydrus implant. A 75-year-old woman had visually significant corneal edema after a complicated Hydrus minimally invasive glaucoma surgery in her right eye. The operation encountered difficulties with the insertion of the Hydrus stent, resulting in the final explantation of the Hydrus implant. The visual acuity was 20/100, improved to 20/60 with pinhole, and the intraocular pressure was normal. The slit lamp examination demonstrated notable diffuse corneal edema, particularly prominent in the inferonasal region, with a localized DMD from 3:00 to 6:00. No guttae were evident in either eye[34]. Central corneal thickness measured by ultrasonic pachymetry was 628 μm in the right eye and 563 μm in the left eye. Ocular coherence tomography revealed an inferonasal Descemet's separation accompanied by overlaying edema. Specular microscopy indicated an absence of cells centrally, with a cell density of 1446 cells/mm$^2$ in the superior mid-peripheral region[34]. After the DMD failed to respond to an intracameral air injection, a Descemet's stripping-only surgery was carried out. Descemet's stripping-only forceps were utilized in performing a 4 mm×5 mm decentered inferior descemetorrhexis that included the DMD[34]. Histopathological examination showed endothelial cell atrophy and dispersed guttata indicative of Fuchs dystrophy. The ocular edema subsided by the sixth week postoperatively. Best corrected visual acuity was 20/40 at the second postoperative month, no corneal edema was detected, the central corneal thickness measured by ultrasound pachymetry was 530 μm, and specular microscopy suggested a central cell density of 975 cells/mm$^2$[34]. This case was categorized as post-surgical corneal decompensation; however, the patient was subsequently diagnosed with underlying Fuchs dystrophy, evidenced by the presence of guttae on histology[34]. The severity of Fuchs dystrophy was mild, as no visible guttae were observed in either eye[34]. In this instance, Descemet's stripping-only indications are broadened to encompass some situations of post-surgical corneal edema, for which penetrating keratoplasty and endothelial keratoplasty had been the only available treatments for visual rehabilitation[34]. The most favorable cases would involve sectoral corneal edema along with a healthy peripheral endothelium[34]. Patients with surgically induced corneal edema frequently possess or will acquire additional ocular co-morbidities; thus, the advantages of Descemet's stripping-only procedure-specifically, the eradication of graft rejection risk and the necessity for prolonged topical corticosteroids-are of particular interest. For glaucoma sufferers, mitigating the risk of optic nerve damage from steroid-induced glaucoma is a significant advantage[34].

**Complications of DMD** DMD can lead to folds, wrinkles, fibrosis, and shrinkage of the Descemet's membrane over time, which might hinder successful reattachment afterward and result in poor visual outcomes[18,20]. Severe or complete DMD carries the risk of delayed visual rehabilitation secondary to refractory corneal stromal edema, bullous keratopathy with pain, microbial keratitis, and corneal endothelial dysfunction, leading to corneal decompensation. Treating this severe condition requires corneal transplantation, and early diagnosis and treatment are essential to prevent complication and achieve good visual rehabilitation[7,14].

Due to the rarity of DMD after glaucoma surgery compared to cataract surgery, the pathophysiology and risk factors are not well understood, highlighting the need for longitudinal and observational studies to be conducted on the basic cellular mechanisms that lead to DMD. Retrospective studies can report incidence rates and address all possible risk factors for DMD post-glaucoma surgery. Because of the difficulty in managing DMD following glaucoma surgery, it is important to investigate all possible risk factors to decrease and prevent this complication. AS-OCT is a very effective technique for diagnosing, following up on, and managing this condition, as it is not affected by corneal edema and provides high-resolution images.

## ACKNOWLEDGEMENTS

**Authors' Contributions:** All authors contributed to the study conception and design. The first draft of the manuscript was written by Alkhoutani E, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript

**Conflicts of Interest: Al Habash A,** None; **Alkhoutani E,** None; **Bin Helayel H,** None.

## REFERENCES

1 Orucoglu F, Aksu A. Complex Descemet's membrane tears and detachment during phacoemulsification. *J Ophthalmic Vis Res* 2015;10(1):81.

2 Beniwal A, Bafna RK, Sharma N. Descemet detachment in a phakic patient. *Indian J Ophthalmol* 2020;68(5):906-907.

3 Li YT, Wu WY, Li JY, *et al*. Types of descemet membrane detachment after ocular surface burns: the factor long been ignored. *Cornea* 2023;42(11):1426-1431.

4 Bhatia HK, Gupta R. Delayed-onset descemet membrane detachment after uneventful cataract surgery treated by corneal venting incision with air tamponade: a case report. *BMC Ophthalmol* 2016;16:35.

5 Sharifipour F, Nassiri S, Idan A. Descemet's membrane detachment management following trabeculectomy. *J Ophthalmic Vis Res* 2016;11(3):323-325.

6 Dua HS, Sinha R, D'Souza S, *et al*. "Descemet membrane detachment": a novel concept in diagnosis and classification. *Am J Ophthalmol* 2020;218:84-98.

7 Samarawickrama C, Beltz J, Chan E. Descemet's membrane detachments post cataract surgery: a management paradigm. *Int J Ophthalmol* 2016;9(12):1839-1842.

8 Beniwal A, Vanathi M, Venugopal A, *et al*. Descemet's membrane detachment: an updated comprehensive review of etiopathogenesis, diagnosis, and management. *Indian J Ophthalmol* 2024;72(11):1560-1568.

9 Mackool RJ, Holtz SJ. Descemet membrane detachment. *Arch Ophthalmol* 1977;95(3):459-463.

10 Jacob S, Agarwal A, Chaudhry P, *et al*. A new clinico-tomographic classification and management algorithm for Descemet's membrane detachment. *Cont Lens Anterior Eye* 2015;38(5):327-333.

11 Morkin MI, Hussain RM, Young RC, *et al*. Unusually delayed presentation of persistent Descemet's membrane tear and detachment after cataract surgery. *Clin Ophthalmol* 2014;8:1629-1632.

12 Samarawickrama C, Beltz J, Chan E. Spontaneously resolving Descemet's membrane detachment caused by an ophthalmic viscosurgical device during cataract surgery. *Saudi J Ophthalmol* 2015;29(4):301-302.

13 Yang X, Chen YZ, Yu GW, *et al*. Spontaneous resolution of recurrent Descemet's membrane detachment after trabeculectomy: a case report. *Am J Ophthalmol Case Rep* 2022;25:101276.

14 Guo P, Pan YJ, Zhang Y, *et al*. Study on the classification of Descemet membrane detachment after cataract surgery with AS-OCT. *Int J Med Sci* 2018;15(11):1092-1097.

15 Kocak Altintas AG, Ilhan C. Successful treatment of late onset post-phacoemulsification Descemet's membrane detachment. *Ther Adv Ophthalmol* 2019;11:2515841419853691.

16 Dai Y, Liu ZZ, Wang W, *et al*. Real-time imaging of incision-related Descemet membrane detachment during cataract surgery. *JAMA Ophthalmol* 2021;139(2):150-155.

17 Khalid M, Malik HA, Asrar A, *et al*. A case of Descemet membrane detachment postcataract surgery. *J Ayub Med Coll Abbottabad* 2020;32(4):575-576.

18 Wang SW, Tseng SH. Occult Descemet's membrane detachment after phacoemulsification surgery mimicking pseudophakic bullous keratopathy. *Taiwan J Ophthalmol* 2015;5(3):136-139.

19 Doi A, Akagi T, Tsujikawa A. Successful treatment of post-phacoemulsification descemet's membrane detachment assessed by anterior segment optical coherence tomography: a case report. *Case Rep Ophthalmol* 2021;12(2):611-615.

20 Gab-Alla AA. A comparative study between air bubble tamponade alone versus air bubble tamponade with internal fluid aspiration for nonplanar Descemet's membrane detachment after phacoemulsification. *J Ophthalmol* 2021;2021:9953418.

21 Claudio KMD, Covar RVA, Siong RLB, *et al*. Descemet's membrane detachment in a corneal graft after removal of a Baerveldt shunt intraluminal stent. *Philippine Journal of Ophthalmology* 2022;47(2):101-105.

22 Weng Y, Ren YP, Zhang L, *et al*. An alternative technique for Descemet's membrane detachment following phacoemulsification: case report and review of literature. *BMC Ophthalmol* 2017; 17(1):109.

23 Sharma A, Sharma R, Kulshreshta A, *et al*. Double bubble pneumo-descemetopexy for the management of Descemet membrane detachment: an innovative technique. *Indian J Ophthalmol* 2023;71(5): 2234-2236.

24 Hirabayashi KE, Mark D, Lau J, *et al*. Descemet stripping only for a chronic descemet detachment after cataract surgery. *Cornea* 2020;39(3):379-381.

25 Li YH, Shi JM, Fan F, *et al*. Descemet membrane detachment after trabeculectomy. *Int J Ophthalmol* 2012;5(4):527-529.

26 Wigginton SA, Jungschaffer DA, Lee DA. Postoperative Descemet membrane detachment with maintenance of corneal clarity after trabeculectomy. *J Glaucoma* 2000;9(2):200-202.

27 Rasouli M, Mather R, Tingey D. Descemet membrane detachment following viscoelastic injection for posttrabeculectomy hypotony. *Can J Ophthalmol* 2008;43(2):254-255.

28 Maheshwari D, Pillai MR, Segi A, *et al*. Spontaneous resolution of Descemet's membrane detachment following bleb needling in a patient with iridocorneal endothelial syndrome: a case report. *Indian J Ophthalmol* 2022;70(7):2639-2641.

29 Jainuddin NF. Descemet membrane detachment post-viscoelastic injection for ocular hypotony. *Eye South East Asia* 2019.

30 Alobeidan SA, Almobarak FA. Incidence and management of haemorrhagic Descemet membrane detachment in canaloplasty and phacocanaloplasty. *Acta Ophthalmol* 2016;94(5):e298-e304.

31 Orejudo de Rivas M, Martínez Morales J, Pardina Claver E, *et al*. Descemet's membrane detachment during phacocanaloplasty: case series and in-depth literature review. *J Clin Med* 2023;12(17):5461.

32 Al Obeidan SA. Nonpenetrating deep sclerectomy. *Expert Rev Ophthalmol* 2009;4(3):299-315.

33 AlZaid A, AlDarrab A, Malik R, *et al*. Ocular coherence tomography for the diagnosis of Descemet's detachment after deep sclerectomy and resolution after intracameral air injection. *Am J Ophthalmol Case Rep* 2019;15:100509.

34 Khan NC, Lin CC. Descemet stripping only for Descemet's membrane detachment and sectoral corneal edema. *Am J Ophthalmol Case Rep* 2023;29:101784.