

CASE IN POINT

Using Optical Coherence Tomography in the Management of Postoperative Wound Leaks After Cataract Surgery

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Health care providers who participate in postoperative care of patients who have had cataract surgery should carefully evaluate for the presence of wound leak or wound gape as a potential complication.

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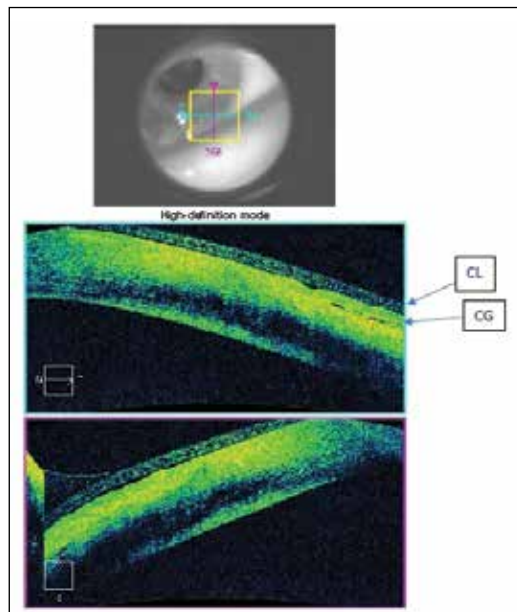
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The term *cataract* is derived from the Latin word “catarractes,” which means “waterfall,” as the foamy white opacity of an advanced cataract can be likened to a tempestuous cascade. Cataract is the leading cause of preventable blindness worldwide.^{1,2} It is no surprise, therefore, that cataract surgery is the most frequently performed ophthalmic surgical procedure worldwide. Cataract surgeries may reach 30 million annual cases by 2020.³ Given the large number of surgeries being performed, postsurgical complications are not uncommon.

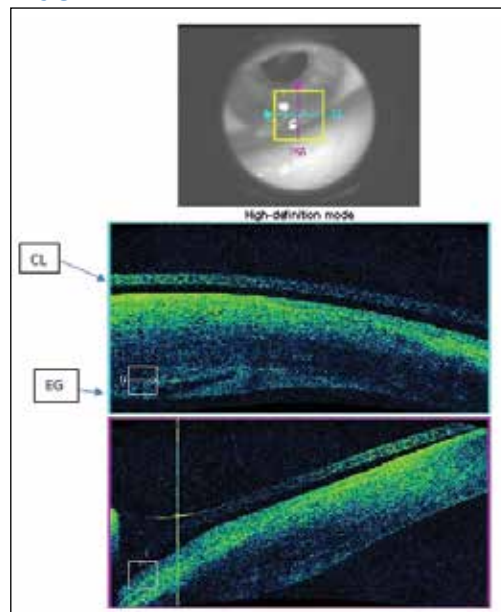
Early postoperative complications from lens exchange (cataract) surgery include increased intraocular pressure (IOP), corneal edema, and corneal wound leakage.⁴ Corneal wound leakage is not uncommon; one study showed that, in 100 cases, almost one-third of incisions leaked.⁵ A 2014 prospective study of 500 postcataract surgery eyes revealed that 48.8% had fluid egress.⁶ Early detection is important so that efforts to restore corneal integrity can immediately be implemented. If not caught early, patients are at risk for

FIGURE 1

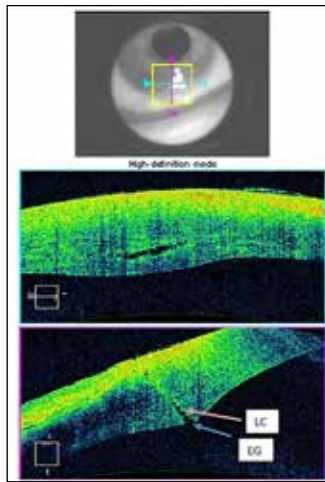


High-resolution optical coherence tomography image showing bandage contact lens (CL) providing a protective barrier and corneal gaping (CG) at the epithelial side of the clear corneal incision.

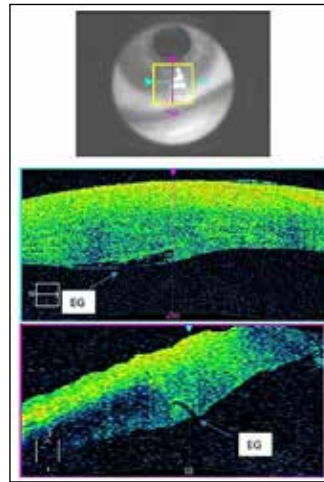
FIGURE 2



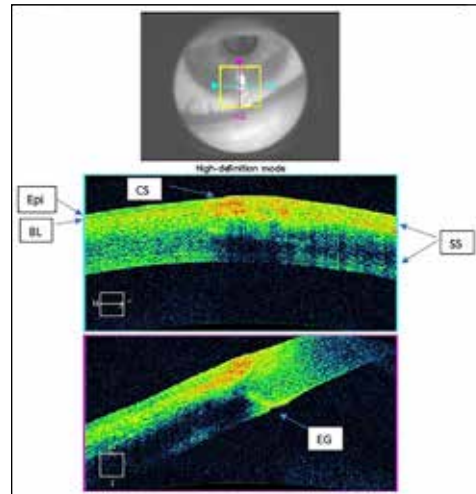
High-resolution optical coherence tomography image showing bandage contact lens (CL) in place with corneal gaping at the endothelial side (EG) of the clear corneal incision.

FIGURE 3

High-resolution optical coherence tomography image showing misalignment at the endothelial side (EG) of the clear corneal incision and loss of coaptation (LC) along the clear corneal incision tunnel and stripping of Descemet membrane.

FIGURE 4

High-resolution optical coherence tomography image showing gapping at the endothelial side (EG) of the clear corneal incision.

FIGURE 5

High-resolution optical coherence tomography image at the 4-month follow-up visit showing corneal scarring (CS) of the epithelial layer (Epi), Bowman's layer (BL), and stromal scarring (SS) with mild persistent endothelial gapping (EG).

developing a cascade of sequelae, including endophthalmitis.

The majority of corneal wound leaks post-phacoemulsification are self-limiting and self-sealing. Moderate wound leaks require treatment, as in the following case. Strategies to detect, image, and treat wound leaks are covered in this discussion.

CASE PRESENTATION

A 69-year-old male veteran presented with no complaints for a 1-day postoperative visit following right eye phacoemulsification cataract extraction. His best corrected visual acuity in the right eye was 20/40, and his pinhole visual acuity was 20/25+2. On slit-lamp examination, the temporally located main incision appeared well-adhered and was found to be Seidel negative; however, the inferior paracentesis wound was found to be Seidel positive, demonstrating a slow leak. Intraocular pressure (IOP) measured with tonopen was 9 mm Hg.

A bandage soft contact lens was placed on the eye. The patient was instructed not to rub or place any pressure on the eye and to avoid bending and heavy lifting. He was also instructed to continue his postoperative medications (prednisolone 1% every 2 hours

and polymyxin B sulfate 4 times daily) in his right eye. A follow-up appointment was scheduled for the next day.

The patient presented for his postoperative day-2 visit with a best corrected visual acuity in the right eye of 20/20. He reported no visual problems, no eye pain, and mentioned that he had had a comfortable night sleep. A slit-lamp examination revealed trace diffuse injection in the operative eye, predominantly central Descemet membrane folds, 1+ stromal edema, and a Seidel negative main incision wound. However, the inferior paracentesis wound showed a moderate leak (Seidel positive), and the anterior chamber showed a 1+ cell and flare. Goldmann tonometry revealed an IOP of 5 mm Hg, indicating hypotony.

Anterior segment cube 512 x 128 optical coherence tomography (OCT) was obtained with the bandage contact lens (Figures 1 and 2), and then repeated with the bandage contact lens removed (Figures 3 and 4). OCT imaging confirmed epithelial and endothelial gapping, loss of coaptation, and a localized detachment of the Descemet membrane. The veteran was referred to his surgeon that same day, and 2 limbal vicryl sutures were placed. The patient was instructed to continue

TABLE 1 Cataract Surgery Complication Rates for All Cataract Surgery Subtypes

Complications	Complication Rates, %
Endophthalmitis ^{13-17,48}	.001 to .327
Pseudophakic bullous keratopathy ⁴⁹	.3
Pseudophakic cystoid macular edema/Irvine-Gass syndrome ⁵⁰⁻⁵³	Optical coherence tomography: 41; angiography: 24 with capsulotomy; optical coherence tomography measured and reduced acuity: 14 (vary greatly depending on surgical technique and method used to diagnose)
Retinal detachment ⁵⁴⁻⁵⁹	.62 to 4
Posterior capsule opacification ^{60,61}	4.2 to 50 (rates vary greatly depending on study, lens material, design, surgical technique, patient characteristics)
Wound leak ^{14,62,63}	.17 to 48.8
Elevated intraocular pressure (> 28 mm Hg) ⁴	18 to 45

prednisolone 1% 4 times daily and polymyxin B sulfate every 2 hours; erythromycin ointment 3 times daily was added to his regimen.

He was scheduled for a follow-up examination 1 week later. At that visit, the wound was no longer leaking and IOP had risen to a preoperative value of 17 mm Hg. The corneal sutures were removed at the 1-month postoperative examination and a follow-up was scheduled for 4 months later. An anterior segment OCT was obtained (Figure 5).

DISCUSSION

In July 1967, Charles Kelman, MD, suggested using a dental ultrasonic tool, normally employed to clean teeth, to fragment the nucleus of the crystalline lens. Dr. Kelman’s first operation using phacoemulsification on a human eye took 3 hours.⁷ As the procedure for cataract removal has been refined, complication rates and surgical times have vastly improved.

Phacoemulsification is the most commonly performed outpatient surgery in the US; about 3 million cases are performed annually. Due to the high volume of cases, adverse events (AEs) are not uncommon. The incidence of complications following phacoemulsification is < 5%; the frequency of severe complications has been estimated at < 0.7%.⁸ Severe complications include endophthalmitis, suprachoroidal hemorrhage, and/or retinal detachment.⁹ Studies have shown a decline in rates of sight-threatening AEs from 1994 to 2006.⁹ A retrospective study of 45,082 vet-

erans from 2005 to 2007 identified that a preoperative disease burden such as diabetes mellitus, chronic pulmonary disease, age-related macular degeneration, and diabetes with ophthalmic manifestations, was positively associated with a greater risk of cataract surgical complications.¹⁰

Complications

The level of a surgeon’s proficiency with phacoemulsification is directly correlated to the number of operations performed; there is a lower complication rate among more experienced surgeons, including those who work in high-volume settings.^{11,12} One study identified that the AE rate within 14 days of surgery was 0.8% for surgeons performing 50 to 250 cataract surgeries per year, but only 0.1% for those performing > 1000 cataract surgeries annually.¹²

Potential postoperative lens exchange complications include increased IOP, corneal wound leakage, corneal edema, bullous keratopathy, cystoid macular edema, retinal detachment, and endophthalmitis (Table 1). A corneal wound leak can provide a potential ingress for bacteria, putting the patient at risk for endophthalmitis, perhaps the most devastating complication following cataract surgery.

Endophthalmitis

Endophthalmitis has been reported to occur in .001% to .327% of patients during postoperative care.^{5,13-17} Early detection is important to maintain corneal integrity and prevent

a cascade of detrimental ocular sequelae including the potential for endophthalmitis. According to Zaida and colleagues, endophthalmitis occurred in fewer than 1 of 1000 consecutive cases.¹⁴ A leaking clear corneal incision wound on the first day postoperatively has been associated with a 44-fold increased risk of endophthalmitis.¹³

Causes of endophthalmitis

In a retrospective case-controlled series of 57 patients with postcataract endophthalmitis, implantation of an intraocular lens with a resultant wound abnormality was thought to be the causative factor in 5%.¹⁷ Another source of endophthalmitis can be the intraocular lens (IOL), which may act as a vector for bacteria. By placing the IOL against the conjunctiva or exposing it to the theater air during surgery, bacteria can be introduced prior to implantation.¹⁷ Immunosuppressive treatment is the only patient antecedent factor that can be considered a predictor for endophthalmitis.¹⁷

The internal corneal seal is IOP dependent, and postoperative ocular hypotony may cause a seemingly watertight wound to leak. Taban and colleagues used anterior segment OCT to image numerous self-sealing incisions. They found that the corneal incision wound more tightly seals at higher IOPs. Additionally, more perpendicular (larger angle) incisions seal better at a lower IOP while less perpendicular (smaller angle) incisions seal better at a higher IOP (Figure 6).¹⁸

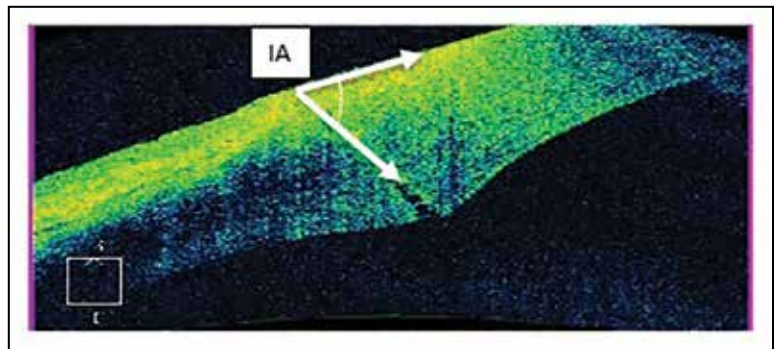
Incision Placement

Studies have shown that the main incision site is more clinically competent than is the side port incision site, as in our case study.¹⁹ Side-port incisions have a 1- or 2-plane architectural profile in contrast to the 3-plane profile typical of a main incision.¹⁹ Recent advances including the conversion to clear-corneal incisions of diminishing size, techniques used for wound construction, phacoemulsification machine design, and small-incision IOLs, should further reduce the prevalence and complications of wound compromise.²⁰

Seidel Testing

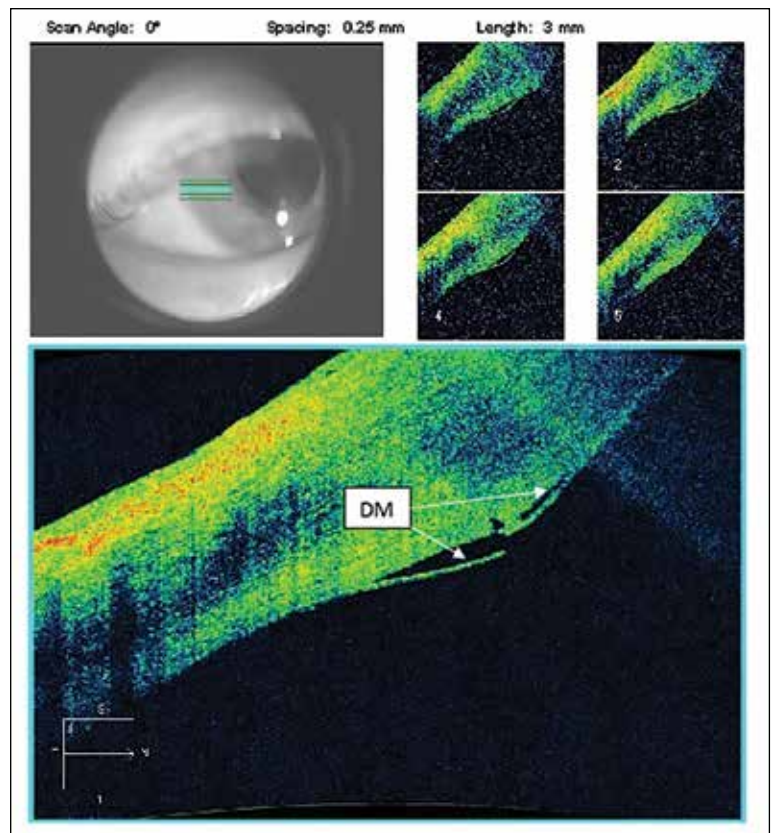
Seidel testing is the most common method to evaluate corneal wound integrity and iden-

FIGURE 6



High-resolution optical coherence tomography image of side port clear corneal incision showing incision angle (IA) and 1-plane architectural profile.

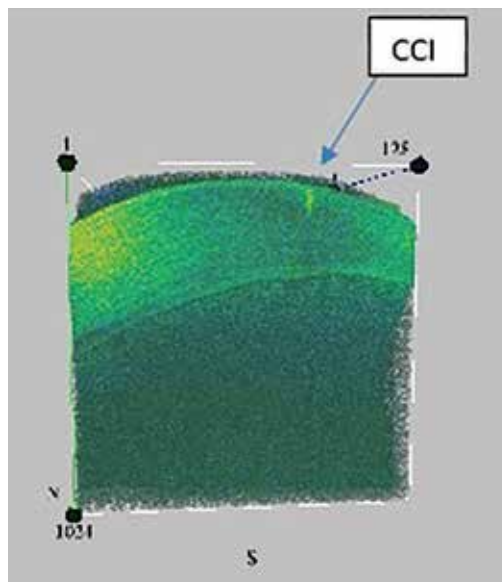
FIGURE 7



High-resolution optical coherence tomography image of a 1-day postoperative phacoemulsification patient with a Descemet membrane (DM) detachment.

tify leaks. A drop of topical anesthetic is instilled in the eye and then a fluorescein strip (not fluorescein sodium and benoxinate hydrochloride ophthalmic solution, which may become less sterile since it has a multiuse container) is applied to the superior conjunctiva. The clinician then looks for evidence of fluid egress using the cobalt blue

FIGURE 8



High-resolution optical coherence tomography image showing 3-dimensional visualization of the clear corneal incision (CCI).

filter. The patient is instructed to blink once. Fluid egress appears as a black stream as the fluorescein dye becomes diluted by aqueous humor escaping the nonintact wound and the appearance of bright green dye surrounds the leak site. The term *Seidel positive* indicates a leak. An estimate should be made of the rate and volume of fluid exiting the wound.

Gonioscopy

Gonioscopy can be used to evaluate the postsurgical incision, more specifically for identification and management of internal incision wound gape. On gonioscopy, internal wound gape appears as an elongated oval opening resembling a fish mouth. If internal incision wound gape is identified gonioscopically before surgery is complete, the leak can be managed intraoperatively. The surgeon can irrigate along the length of the incision to remove cortical fragments or viscoelastic that may cause internal wound gaping. If unsuccessful, rapidly deepening the anterior chamber with balanced salt solution through the paracentesis incision may be employed. These methods may improve wound stability, reduce risk of postoperative hyphema, lower the incidence of endophthalmitis, and lessen the likelihood of late against-the-rule drift.²¹

ANTERIOR SEGMENT OPTICAL COHERENCE TOMOGRAPHY

Instances when Seidel testing was negative despite actual wound gaping have been described.^{22,23} Anterior segment OCT is useful to evaluate incision architecture. A 2007 United Kingdom study investigated the corneal architecture in the immediate postoperative period following phacoemulsification using anterior segment OCT. This study showed the benefits of identifying architectural features such as epithelial gaping, endothelial gaping, stripping of Descemet membrane, and loss of coaptation. These features were found to be more common at low IOP and could represent a significant risk factor for endophthalmitis.²⁴ Another study published by Behrens and colleagues indicated that a localized detachment of Descemet membrane may be more common than observed with slit-lamp (Figure 7). Corneal gaping, especially if along the entire length of the surgical wound, may lead to inadvertent bacterial access into the anterior chamber.²⁵

Anterior segment OCT imaging was first described by Izatt and colleagues in 1994.²⁶ Unlike posterior segment OCT, anterior segment OCT requires a greater depth of field and higher energy levels as images are commonly distorted by refraction at boundaries where the refractive index changes. Longer infrared wavelengths improve the penetration through tissues that scatter light, such as the sclera and limbus, which allows visualization, for example, of the iridocorneal angle.^{27,28}

Two main scan patterns are used for anterior segment OCT: 512 x 128 cube scan (4-mm width x 4-mm length) and 5-line raster (3-mm length) with adjustable rotation and spacing. A recent software update allows measurement of corneal thickness, visualization of anterior chamber angle structures along with topographic analysis, anterior and posterior elevation maps of the cornea, and reliable pachymetric maps.^{29,30} The anterior segment cube acquires a series of 128 horizontal scan lines each composed of 512 A-scans. These high-definition scans acquire vertical and horizontal directions composed of 1024 A-scans each. This cube may be used to measure corneal thickness and visualize corneal architecture,

TABLE 2 Corneal Wound Leak Management Options

Wound Closure Products	Advantage	Disadvantage
Bandage contact lens ³²	Enhanced convenience; improved healing; least invasive option; temporary; low cost	May lead to infectious keratitis; ineffective for more severe corneal leaks; may be rubbed out
Sutures ^{36,38,64-66}	Standard of care; readily available; low cost	Leak 23.8%-34%; may weaken wound site; loose or broken sutures are susceptible to leaks and infections; tight sutures may distort wound; increased astigmatism; reduced visual acuity; application time consuming; may change wound architecture; increased risk of infection
Cyanoacrylate ^{35,39,40-42}	Similar to super glue; extremely strong; good bacteriostatic activity; able to withstand the highest IOP	Inflexible; inflammatory; cannot be reabsorbed; has been shown to be toxic
Fibrin laser-activated thin film adhesive ^{15,35,39,67}	Flexible; noninflammatory; biodegradable; promotes wound healing; withstands modest IOP	Weaker adhesive than cyanoacrylate; not bacteriostatic; theoretical risk of viral transmission; expensive
Corneal welding ⁴⁵⁻⁴⁷	Quick procedure (25-45 sec); good astigmatism control	Application of light-absorbing dyes toxic to anterior chamber; denatured collagen may result in tissue shrinkage reducing visual acuity
Polyethylene glycol-based products ^{6,35}	Bio-compatible and frequently used in contact lenses and artificial tears Examples: OcuSeal liquid adhesive ocular bandage; ReSure Sealant (FDA approved)	Expensive

Abbreviations: FDA, US Food and Drug Administration; IOP, intraocular pressure.

creating a 3-D image of the data (Figure 8). The anterior segment 5-line raster scans through 5 parallel lines of equal length to view high-resolution images of the anterior chamber angle and cornea. Each line, fixed at 3-mm in length, is composed of 4096 A-scans.³¹ Anterior segment cube OCT allows identification of subtle variations in incision architecture at different locations across the width of the OCT image.

Bandage Soft Contact Lens

Upon reviewing the anterior segment OCT images of our patient with the bandage contact lens in place, it was evident that the adherent ocular bandage was protecting the incision. A tighter fitting bandage contact lens is ideal and adheres firmly to any area of epithelial damage and epithelial gapping to help seal the incision, protecting the wound and improving structural integrity. The bandage contact lens is gradually replaced by new cells via re-epithelialization; thus, it behaves as an adjunct to natural wound healing. A bandage contact lens also improves patient comfort.

It is hypothesized that a bandage contact lens improves the structural integrity of the incision site and helps prevent leaking, hypotony, and minor wound leaks. One study revealed a statistically significant lower IOP in nonbandage contact lens patients by an average of 6 mm Hg (mean [SD] 13.4 mm Hg [5.3]; range, 5 - 23 mm Hg) vs patients with a bandage contact lens (mean [SD] 19.4 mm Hg [5.9]; range, 11 - 29 mm Hg) in the immediate postoperative period.³² The authors suggested that the bandage contact lens may prevent microleaks, resulting in a higher IOP.

Aqueous Suppressants

Aqueous suppressants are a great option when IOP is abnormally elevated by decreasing the IOP and allowing the cornea to heal and self-seal. Effective aqueous suppressants are β blockers and carbonic anhydrase inhibitors.

After phacoemulsification ocular hypotony (< 6 mm Hg) occurs most commonly due to wound leakage or excessive intraocular inflammation. However, with the presence of corneal wound leakage and ocular

hypotony, aqueous suppressants are *not* the best option.

FURTHER MANAGEMENT OF WOUND LEAKS

Management of a postoperative wound leak will vary based on severity. The majority of mild leaks are self-sealing. Anterior segment OCT helps the clinician to identify microleaks in an otherwise Seidel negative eye. If wound leakage is moderate with a formed anterior chamber, the use of a bandage contact lens is a good option, as can be the prescription of aqueous suppressants, depending on IOP.³³

If the anterior chamber is flat, iris prolapse is apparent, or extremely low IOP exists, the patient needs to be referred to the surgeon. Current standard of care directs the surgeon to use sutures to further manage corneal wound leak. However, several studies have recognized the increased risk of suture-related complications, such as induced astigmatism, corneal opacities, incomplete wound closure, and corneal neovascularization.^{6,34-38} Other wound closure options include polyethylene glycol-based products, corneal welding, cyanoacrylate, or fibrin (Table 2).³⁹ Traditionally nylon sutures have been used for clear corneal incision wound closure. However, tissue adhesives are gaining popularity as a substitute for sutures in wound closure.⁴⁰

Cyanoacrylate

Numerous studies have been published on the efficacy of cyanoacrylate as a substitute for sutures, specifically in clear corneal incisions. AEs of cyanoacrylate include a transient foreign-body sensation and diffuse or focal bulbar conjunctival hyperemia.^{41,42} Shigemitsu and Majima found that fibrin and cyanoacrylate glue had tensile strength similar to sutures when used in cataract surgery.³⁹ Polyethylene glycol-based products, also used in artificial tears and contact lens materials, may also help seal wound leaks. Another agent is ReSure (Ocular Therapeutics, Bedford, MA), an FDA-approved synthetic, polyethylene glycol hydrogel sealant that is 90% water after polymerization. ReSure has been shown to be safe and effective in sealing cataract surgical clear corneal incisions.^{6,43} ReSure takes about 20 seconds

to prepare, and placement is aided by the use of a blue dye that dissipates within hours. This hydrogel will gradually slough off in the tears once the tissue has fully regenerated; there is no need to remove the sealant.⁴⁴

Rossi and colleagues evaluated the efficacy of corneal welding to close wounds after cataract surgery. The technique involves laser-assisted closure of the corneal wound(s) by a diode laser that welds the stroma.⁴⁵ Corneal welding takes seconds to achieve good closure without significant astigmatism or inflammation; however very careful application of the light absorbing dyes is required as they are toxic if allowed to enter the anterior chamber.⁴⁵⁻⁴⁷

CONCLUSION

Optometrists may be called to manage patients during both the preoperative and postoperative phases of cataract surgical care. Those who participate in postoperative care should carefully evaluate for the presence of wound leak or wound gape as a potential complication. The OCT may be employed to evaluate patients suspected of having these leaks or gapes. Proficiency in the interpretation of OCT results and more traditional evaluation methods allows for successful detection of wound leaks or gapes. The timely diagnosis and treatment of postoperative wound leaks allow for the best possible outcomes for cataract surgery patients.

Author disclosures

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