The ocular surface: The first refractive interface of the eye

Refractive patient satisfaction: Expectations for postoperative vision

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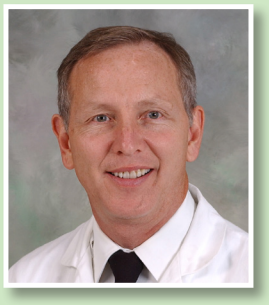
by Steven Schallhorn, MD



Practice pearl: Untreated ocular surface disease (OSD) associated with refractive surgery can lead to worse refractive outcomes, impaired vision, and reduced patient satisfaction. Properly diagnosing and managing OSD, before surgery or if it develops after surgery, is critical to providing the best care and meeting patient expectations.

–Steven Schallhorn, MD

Ocular surface disease may be an overlooked barrier

Patients have high visual expectations of laser vision correction and refractive cataract surgery. Although surgical and technologic refinements continue to advance our capabilities, surgeons need to address ocular surface disease (OSD) to deliver the results patients expect.

Postoperative satisfaction

Residual refractive error is a major driver of patient dissatisfaction because of its impact on visual acuity and quality of vision.

In a study of more than 4,970 eyes (2,585 patients) undergoing refractive lens exchange with multifocal IOLs at Optical Express centers in the U.K., patients completed questionnaires one month after surgery (Schallhorn SC, data presented at 2014 AAO annual meeting). A manifest refraction close to plano was closely associated with 20/20 uncorrected visual acuity. As expected, the greater the refractive error, the less likely the patient's uncorrected distance vision would be 20/20. Likewise, increasing postoperative cylinder reduced the likelihood of 20/20 vision.

Consequently, patients with increased residual refractive error after surgery were less likely to be satisfied with their outcomes. Nearly 71% of patients with no residual error were very satisfied with their results compared with 66.3% with 1.00 D MSE and 51.9% with 1.50 D MSE. Furthermore, 73.2% of those with no residual cylinder and 66.9% with 1.0 D cylinder were very satisfied, but this percentage declined with increasing cylinder.

The condition of the ocular surface critically impacts visual outcomes from refractive and cataract surgery. To achieve results that meet patients' high expectations, surgeons need to evaluate the ocular surface and treat OSD before performing preoperative measurements.

In the PHACO study, Trattler et al. found that nearly 77% of patients evaluated for cataract surgery demonstrated fluorescein corneal staining, with 50% having central corneal staining.[1] However, dry eye had been diagnosed in only 22.1%.

In a multicenter clinical trial, Epitropoulos et al. found that average K readings and anterior corneal astigmatism varied more in patients with increased tear osmolarity, resulting in significant

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This monograph is part of a year-long curriculum focused on treatment of ocular surface disease and management.

Accreditation Statement
This activity has been planned and implemented in accordance with the accreditation requirements and policies of the Accreditation Council for Continuing Medical Education through the joint providership of the American Society of Cataract and Refractive Surgery (ASCRS) and EyeWorld. ASCRS is accredited by the ACCME to provide continuing medical education for physicians.

Educational Objectives
Ophthalmologists who participate in this activity will:
• Identify the true impact of a dysfunctional ocular surface on cataract and refractive outcomes, identify the consequences that accompany an unstable tear film, and discuss the presentation of symptomatic vs. asymptomatic OSD

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Symptom questionnaires:
Necessary but not sufficient for preoperative patients

by Elizabeth Yeu, MD

Adequate screening necessitates additional targeted steps

Because many cataract patients with ocular surface disease (OSD) are asymptomatic, a preoperative symptom questionnaire may not be adequate to detect this condition.

According to a study by Trattler et al., more than 70% of our patients arriving for a cataract evaluation may have at least moderate dry eye disease.[1]

OSD is so common in our older population that chronic dry eye can damage the subbasal nerve plexus, resulting in a neurotrophic component. Therefore, they will not experience irritation or foreign body sensation even if they have significant staining.

If OSD is not detected and managed before cataract and refractive surgery, it may adversely impact postoperative visual outcomes.

Preoperative examination

Although it is important to establish a standardized protocol to identify OSD, it does not need to be complicated.

All of our new patients—especially patients who are being evaluated for cataract surgery—complete a dry eye questionnaire. We specifically like the SPEED questionnaire, which is a bit shorter than the OSDI questionnaire.

Next, our technicians ask patients about their blurred vision, specifically to tease out any intermittently blurred vision—one of the most common clinical symptoms of dry eye. They also ask about the quality of their vision and whether their vision worsens with prolonged activity, such as driving, watching television, or reading. Cataracts can cause glare and impair vision, but if patients have fluctuating visual symptoms, need to blink frequently, or have excessive tearing, OSD is probably the cause.

Based on results from these questions, our technicians perform tear osmolarity testing, which is very useful in determining the stability of their overall tear film, as well as a range of different non-contact assessments (see sidebar), which are used to simultaneously assess keratometric measurements and the pre-corneal tear film quality.

Research by Epitropoulos et al. demonstrated that K readings varied significantly in patients with hyperosmolar eyes compared with those that were normal.[2] Furthermore, among hyperosmolar eyes, there was a greater percentage of eyes with at least a 1.0 D difference in anterior corneal astigmatism, which was statistically significant. If OSD is not detected and treated before surgery, it will adversely affect preoperative measurements and IOL selection.

When I review a corneal topography, my attention is focused on two images: the axial image to assess the regularity of the corneal astigmatism and the actual corneal exposure of the capture, and the Placido disc image in order to review the regularity of the mires. If the quality of the mires appears smudged or they are distorted, I'm immediately concerned about the accuracy of the topography as significant OSD is likely present. Some topography systems have built-in software that will display the surface regularity indices, which can also highlight distortions of the ocular surface that can be from dry eye disease.

Disparity between the keratometric values from different devices or between the two eyes may also represent OSD, which directs a closer slit lamp ocular surface exam. I thoroughly examine the ocular surface and evaluate the lids, everting and expressing them, trying to assess meibomian gland function. Another essential step is vital dye staining using lissamine green and fluorescein strips, particularly after some of the dye has disappeared, in order to check for both positive and negative staining of the corneal surface.

Expanding OSD testing options

In addition to administering a symptom questionnaire, asking a few targeted questions, and performing a thorough clinical examination, clinicians may turn to additional tests to diagnose ocular surface disease (OSD).

Anterior segment optical coherence tomography (OCT) measures the tear film height, area, and conjunctivochalasis. With Placido disc topography, the quality of the mires allows me to gauge their preoperative surface before we instill drops in their eyes.

Surgeons also may consider MMP-9 testing, which provides an objective measure of inflammation and dry eye disease. I generally perform this test as a follow-up to the tear osmolarity, and to ascertain the presence of inflammation despite the patient's current treatment regimen. However, even patients with severe symptoms may not have positive results. Sambursky et al. has shown that 30 to 40% of cases of "dry eye disease" may not be driven by very high numbers for inflammatory mediators.[3] If patients have severe symptoms but normal MMP-9 results, I look for other causes for their symptomatology, such as lid tarsal fibrosis, ABMD, or conjunctival chalasis.

Because many dry eye cases have an MGD component, meibomography is one of our most useful tests and has been a tremendous advancement in OSD diagnosis and management. If we find significant meibomian gland atrophy, we know patients need a higher level of therapy and intervention to improve the existing gland function. Meibomography is also helpful in examining the anatomy and structure of the meibomian glands, especially if they are truncated or appear very congested. We can perform this in conjunction with expressing the glands to assess the quality of the meibum.

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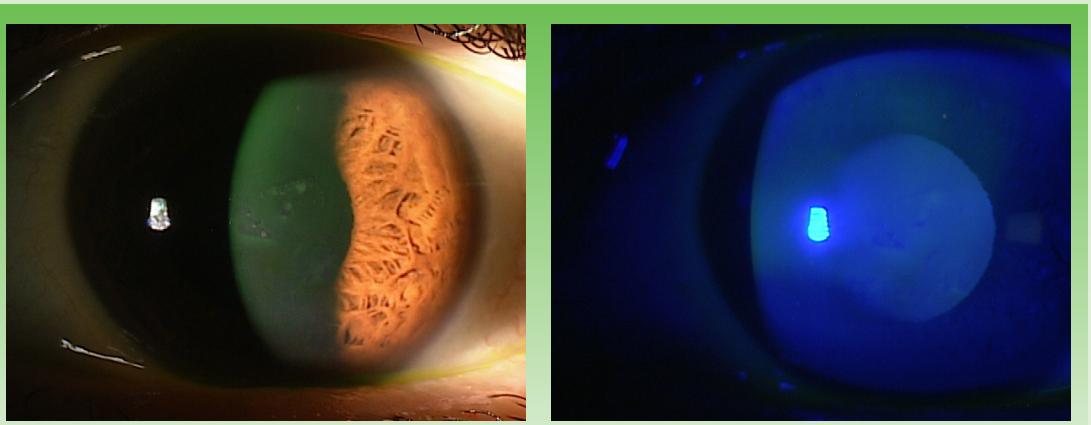

Figure 1. Slit lamp image of central ABMD. The fluorescein dye demonstrates negative staining centrally over the ABMD.

The negative staining is at least equally important as positive staining because it represents a mechanical cause of OSD, including anterior basement membrane dystrophy (ABMD) and nodular degeneration. These diseases not only skew keratometric values, but also lead to a very quick tear break-up time and exacerbate fluctuating vision (Figure 1).

Symptomatic vs. asymptomatic

Patients' symptoms may not correlate with staining. Young patients can have very mild staining because they often produce reflex tears and compensate, but they may have disproportionately severe symptoms. In such cases, tear osmolarity and MMP-9 testing can help qualify the level of dry eye disease.

Older patients can be asymptomatic for classic symptoms but have significant corneal staining. This may result from medications, chronic progressive dry eye, or different disease states. As we know, diabetes causes peripheral neuropathy, decreasing sensation.

In my experience, older patients often display more of the classic symptoms when meibomian gland dysfunction represents a more significant component of their dry eye disease.

Although vision fluctuation is the major complaint in older patients, those with MGD complain most often of redness and a burning sensation, particularly upon awakening. It is worse in the morning because overnight the lid margin remained along the ocular surface without blinking away inflammatory mediators. This is also different from the sharp pains of recurrent corneal erosion syndrome (RCES) that are part of the differential diagnosis of ocular discomfort that is worse in the morning, but I do see that posterior blepharitis patients have greater anterior basement membrane dystrophy and RCES.

Therefore, older patients with a predominant MGD component to their mixed dry eye disease will have more symptoms.

Surgical planning for advanced technologies

If patients have corneal staining and plan to have advanced technology IOL implantation or femtosecond laser-assisted cataract surgery, I prescribe topical steroids fairly early in the process and an anti-inflammatory, such as cyclosporine, particularly for long-term treatment of dry eye. I ask them to return in three to four weeks to repeat preoperative measurements. I also offer a package with an additional discount on LipiFlow thermal pulsation because, in my experience, dry eye can worsen in about one in three patients after surgery.

Conclusion

Many patients with OSD have marginally compensated eyes. They may be able to tolerate it, with few symptoms, but surgery may exacerbate OSD and symptoms. Therefore, we need to take a number of steps to identify OSD and manage it preoperatively, which will help us improve results and improve patient satisfaction.

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differences in intraocular lens (IOL) power calculations.[2]

Donnenfeld et al. reported that patients with tear hyperosmolarity that remained untreated before LASIK were more likely to have worse visual outcomes.[3]

According to research by Albietz et al., patients with chronic dry eye who had LASIK were more likely to experience refractive regression.[4]

Examining impact

In this monograph, noted experts will discuss the influence of OSD on cataract and refractive outcomes, the consequences of an unstable tear film, and strategies for diagnosing asymptomatic and symptomatic OSD.

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Impact of ocular surface disease on topography, aberrometry, and astigmatism correction decisions

by Edward Holland, MD

Practice pearl: Even if a patient does not have true astigmatism, we may see astigmatism created by dry eye, resulting from aqueous tear deficiency or meibomian gland dysfunction. Therefore, astigmatism may be mismanaged based on an erroneous keratometry or topography reading. Likewise, we may choose an incorrect spherical power.

–Edward Holland, MD

Improved OSD diagnosis and management can lead to better postoperative outcomes

Ocular surface disease (OSD) can significantly impact many aspects of refractive and cataract surgery, including preoperative measurements, surgical planning, and intraocular lens (IOL) selection. However, OSD is often undiagnosed and undertreated.[1]

By improving detection and treatment of OSD, surgeons can obtain more accurate preoperative measurements and achieve better outcomes.

Impact on measurements

Before cataract surgery, OSD may significantly affect keratometry, A-scan, and topography measurements, affect the selected IOL power and astigmatism management, and determine whether a presbyopic IOL is suitable for a specific patient.

Even if a patient does not have true corneal astigmatism, a false recording of astigmatism may occur due to dry eye from aqueous tear deficiency and/or meibomian gland dysfunction. Therefore, astigmatism may be mismanaged based on an erroneous keratometry or topography reading.

One of the more common complaints of patients with OSD is vision fluctuation, which often results from evaporative dry eye caused by meibomian gland dysfunction. Patients with a significant cataract may not notice the fluctuation preoperatively. If a clinician fails to diagnose OSD, the patient's quality of vision will be reduced significantly and the patient will blame the dry eye associated fluctuation in vision on the IOL or inadequate surgery. This situation is exacerbated by the multifocal lens.

Therefore, it is essential to recognize dry eye and treat these patients preoperatively, especially if considering a premium IOL.

Red flags

The diagnosis of dry eye can often be made prior to the patient being examined by the surgeon. Technicians should be trained to understand the findings of dry eye on the preoperative testing and alert the clinician when IOL calculations may be abnormal because of OSD. On standard keratometry, this may result in irregular mires. On topography, OSD may result in areas of steepening or flattening within the readings that are not respective of a single meridian. Dry eye can result in inferior steepening mimicking forme fruste keratoconus.

In a cross-sectional study of 100 symptomatic dry eye subjects and 35 normal subjects, Cui et al. assessed the corneal epithelial thickness in dry eye patients.

> *"Visual outcomes from multifocal IOLs are very dependent on an excellent ocular surface."*
>
> *–Edward Holland, MD*

The study reported patients with higher dry eye severity grades had thinner superior (p=0.017) and minimum (p<0.001) epithelial thickness.[2]

Discrepancies in the various measurements, such as keratometric readings, biometry, and topography, commonly are a sign of OSD. If there is significant OSD with corneal staining with fluorescein or staining of the conjunctiva or corneal epithelium with lissamine green, it is advisable to aggressively manage the dry eye and potentially delay cataract surgery, especially if the patient plans to receive a premium IOL.

Additionally, hyperosmolarity has been shown to affect the measurements of astigmatism and IOL power in that dry eye may cause physicians to overestimate corneal astigmatism and affect the management of astigmatism.[2] However, if the dry eye is managed, one may find that the amount and location of the astigmatism may be significantly less, it may not be present, or it may be present at a different axis.

Conversely, we may not detect astigmatism because the dry eye masks it. When we optimize the ocular surface we may see astigmatism.

Patient selection

If a patient has chosen a premium IOL—either a toric IOL or presbyopia-correcting IOL—and expects excellent visual outcomes but has corneal staining, we frequently delay surgery to manage the OSD and repeat testing so measurements will be more accurate. The patient will be frustrated with the dry eye diagnosis but not frustrated with the surgeon. However, if OSD is detected but not treated before surgery, the patient will be dissatisfied with the visual outcome and often blame the surgeon, not the dry eye.

We do not delay all surgery in patients with OSD. If we have a situation in which an elderly patient has clinical findings of dry eye and is eager for surgery, we will diagnose and treat the OSD, but we may elect not to delay surgery if he or she is receiving a monofocal IOL. However, even in this patient, aggressive treatment of the OSD will significantly improve the patient's vision.

Postoperative correction

OSD also impacts postoperative decisions. The most common reason to exchange an IOL is patient dissatisfaction with a multifocal IOL or if astigmatism was under- or overcorrected. Visual outcomes from multifocal IOLs are very dependent on an excellent ocular surface. In the vast majority of cases, dissatisfied multifocal IOL patients who are referred to me are unhappy because of OSD. Overwhelmingly, if we optimize the ocular surface, most patients will be pleased with their vision and the IOL will not need to be exchanged.

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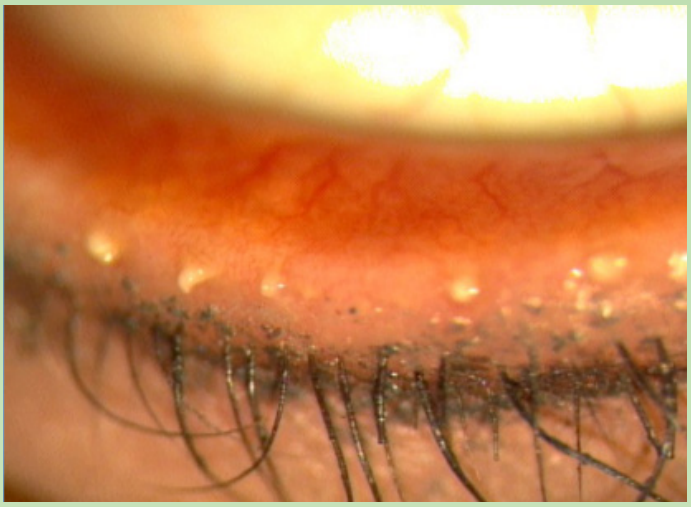
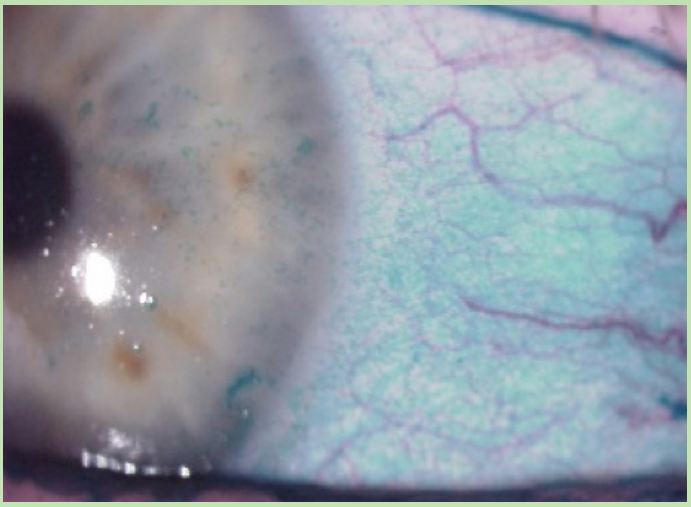
The perils of ignoring OSD in refractive cataract patients



Case 1. Meibomian gland disease; note thickened meibum and gland dropout



Case 2: Lissamine green staining of the intrapalpebral bulbar conjunctiva

To obtain the optimal results from cataract and refractive surgery, it is important to detect and treat OSD before performing preoperative measurements. OSD can affect measurement accuracy, impacting postoperative visual outcomes.

In case 1, a 65-year-old man with visually significant cataracts, without a history of previous ocular surgery or disease, complained of burning and itching eyes that were worse in the morning. On the dry eye questionnaire, he noted fluctuating vision, chronic "red eyes," and watering eyes.

Keratometry and topography showed irregular astigmatism. Osmolarity was 310 and 328; MMP-9, negative; tear break-up time, 5 seconds; and Schirmer's, 12/16 mm. During the examination, mild inferior corneal staining occurred, and inspissation of the meibomian glands and thickened meibum were noted. Meibography showed truncation and loss of meibomian glands.

Meibomian gland disease was diagnosed, and the patient was treated with artificial tears, topical azithromycin qhs, oral omega-3 supplementation, and LipiFlow thermal pulsation therapy. Preoperative biometry was performed 1 month later.

In case 2, a 64-year-old woman with visually significant cataracts was interested in a multifocal IOL. She had severe dry eye symptoms that began acutely several years previously. She had been treated with numerous artificial tears and topical cyclosporine. She also had severe dry mouth and mild aches and pains that began before the dry eye symptoms. Her osmolarity was 318 and 327; MMP-9, positive; tear break-up time, 12 seconds; meibomian gland expression, normal; and Schirmer's, 1/4 mm; she showed severe corneal and conjunctival staining. In addition, her Sjö test had positive results.

Primary Sjögren's disease with severe aqueous deficiency dry eye was diagnosed. She was treated with loteprednol 0.5% qid. Two weeks after topical steroid induction, topical cyclosporine A was started. Punctal occlusion was performed on all lids.

We educated the patient about Sjögren's disease and referred her to a rheumatologist for a systemic workup and possible systemic therapy and to a dentist for an examination and oral hygiene recommendations. Surgery was delayed until preoperative testing results improved. Because she had persistent corneal staining, we did not recommend a multifocal IOL.

The contribution of the tear film to vision and ocular comfort

by Marjan Farid, MD

Practice pearl: In the preoperative setting, always pause and evaluate the tear film prior to surgical planning. Ocular surface instability is the leading cause of the unhappy refractive cataract or laser patient. By taking that pause and treating dry eye disease prior to surgery, you can significantly improve your postoperative outcomes and patient satisfaction.

–Marjan Farid, MD

Preoperative, intraoperative, and postoperative factors influence the tear film

The tear film plays a key role in visual outcomes and patient satisfaction after cataract and refractive surgery. If tear film abnormalities remain undetected and untreated, they can alter preoperative measurements that can significantly affect postoperative refractive outcomes as well as cause postoperative discomfort and pain.

Examining the tear film

The eye has three refractive interfaces: the pre-corneal tear film, cornea, and lens. The total optical power of the relaxed eye is 60 D; the corneal power (including the tear film) accounts for two-thirds and the lens power one-third.[1]

The greatest change in the index of refraction occurs between the air and tear film, giving the tear film the greatest optical power of any ocular surface (Figure 1).[2] It consists of three layers: the lipid, aqueous, and mucin layers (Figure 2). The anterior radius of the curvature is 7.8 mm, and the thickness ranges from 6 to 20 µm.[3] Aqueous deficiency or evaporative dry eye produces tear film irregularity and can cause optical power changes throughout the cornea. Variable refractive powers on the ocular surface will cause significant higher-order aberrations.

Blinking restores the tear film briefly, mixing tear components and spreading tears across the surface. Between blinks, however, aqueous evaporates and the tear film thins and becomes irregular. Dry eye worsens these effects, reducing visual acuity and increasing higher-order aberrations.[3,4]

Using double-pass retinal imaging, Benito et al. demonstrated that increased light scatter in patients with dry eye degrades image quality.[5] Retinal vessel contrast studies by Tutt et al. showed that tear film irregularities can reduce retinal image quality by 20 to 40%.[2] In addition, topography studies by Németh et al. indicated that tear break-up during a 15-second pause between blinks reduced visual acuity by 6%.[6]

"Patients having cataract surgery are already at high risk of dry eye because of their age, hormonal changes, and medications."

–Marjan Farid, MD

Increased risk

Preoperative diagnosis of OSD is important in patients having LASIK because dry eye is one of the most frequent adverse effects of the procedure.[7,8] Lee et al. reported that tear secretion decreased more after LASIK vs. PRK 6 months after surgery and stressed that dry eye treatment is essential after refractive surgery.[9]

Additionally, patients having cataract surgery are already at high risk of dry eye because of their age, hormonal changes, and medications. In addition, their diets may be deficient in omega-3 fatty acids.

The surgical process also contributes to dry eye and irritation. The cornea and tear film can dry during preoperative dilation because the eyes are open and anesthetic drops decrease the blink rate. Mild surgical trauma to the cornea may result from the lid speculum or minor abrasion. Benzalkonium chloride (BAK) and proparacaine in the anesthesia and topical drops affect endothelial cell integrity and tear function.[10,11]

In addition, surgical incisions may disrupt corneal innervation and lengthen the interval between blinks.[12] In a prospective multicenter observational trial, Donnenfeld et al. reported that Cochet-Bonnet corneal sensitivity decreased most in regions adjacent to limbal relaxing incisions (28 to 31%), which returned to near-normal levels at month three.[13]

In a study of 48 eyes that had cataract surgery, goblet cell

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Conclusion

OSD is very common in all patient populations, but it is extremely common in cataract patients. It is a common cause of patient dissatisfaction with refractive and cataract surgery. Therefore, it is critical to diagnose and manage OSD before surgery to obtain optimal outcomes. Proper diagnosis and treatment can improve surgeons' ability to choose the correct IOL type and power and improve postoperative results.

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	Refractive index
Air	1.00
Tear film	1.34
Cornea	1.38
Aqueous humor	1.33
Crystalline lens	1.41
Vitreous humor	1.34

Figure 1. Refractive index

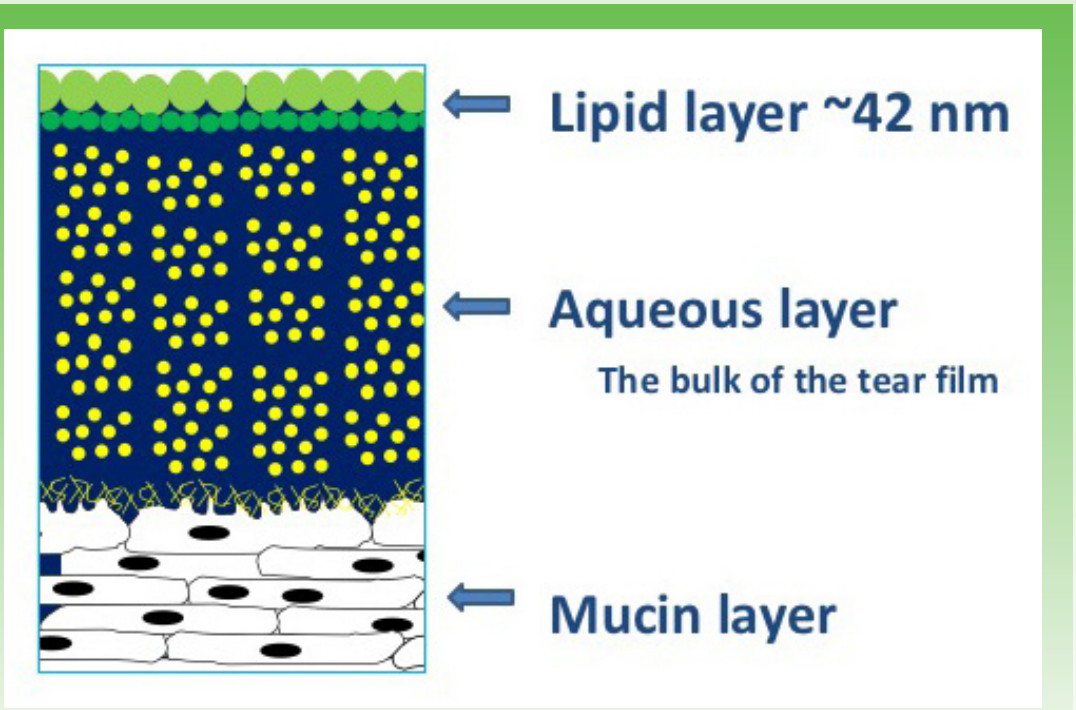

Figure 2. Tear film structure and composition

density decreased significantly, as demonstrated on conjunctival impression cytology, and it did not recover three months after surgery.[14] This reduction was highly associated with time in surgery.

Furthermore, BAK-containing postoperative drops may cause additional surface toxicity, eye disease may worsen if patients stop or decrease their topical treatments, and meibomian gland disorder may worsen if patients stop using warm compresses and lid hygiene.

Conclusion

The tear film is the first and most important refractive interface in the eye. Irregularities may result from dry eye, evaporation, or long between-blink intervals, degrading image quality and affecting patient comfort and refractive outcomes after surgery.

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The ocular surface: The first refractive interface of the eye

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CME questions (circle the correct answer)

1. Based on Dr. Yeu's article, _____ may be useful in determining the cause of red eyes and burning that is worse in the morning in older patients.
a. Meibography
b. Optical coherence tomography
c. Sjögren's testing
d. SPEED questionnaire

2. According to Dr. Schallhorn, ocular surface disease may affect preoperative surgical measurements, potentially resulting in _____.
a. Refractive regression
b. Incorrect IOL power calculations
c. IOL rotation
d. Severe discomfort

3. Based on Dr. Farid's article, _____ associated with ocular surface disease may result in higher-order aberrations.
a. Increased goblet cell density
b. Irritation
c. Increased light scatter
d. Increased blinking

4. Based on Dr. Holland's article, a patient with severe dry eyes, severe dry mouth, and muscle aches is tested for:
a. Tear osmolarity
b. Sjögren's syndrome
c. Tear break-up time
d. All of the above

5. According to Dr. Holland, when patients are referred to him because they are dissatisfied with their premium IOLs, _____ produce(s) satisfaction in most patients.
a. IOL rotation
b. Ocular surface optimization
c. IOL exchange
d. Limbal relaxing incisions

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