

# The neglected refractive interface: Impact of the tear film on refractive cataract surgery outcomes

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Neda Shamie, MD

## ASCRS Clinical Survey results highlight treatment trends

In the 2014 ASCRS Clinical Survey, most anterior segment surgeons report that, prior to surgery, less than 20% of their cataract surgery patients have ocular surface disease (OSD) requiring treatment beyond artificial tears.

However, evidence suggests that this estimate is too low. For example, in the P.H.A.C.O. study, more than 60% of patients presenting for routine cataract surgery had very rapid tear breakup time, and about half had central corneal staining.<sup>1</sup>

## Current state of dry eye treatment in cataract practices

by Neda Shamie, MD

Corneal staining (either central or peripheral) is the main differentiating factor between level 1 dry eye, which can be managed with artificial tears, and level 2, to which anti-inflammatory drops should be added.<sup>2</sup> As a result of this underestimation, surgeons may be missing opportunities to improve outcomes by treating OSD before surgery.

There were a number of other interesting responses related to dry eye from the 2nd annual ASCRS Clinical Survey, which drew responses from more than 1,500 ASCRS members. About two-thirds of respondents were unsure of the international Dry Eye Workshop (DEWS) or the Tear Film and Ocular Surface Society (TFOS) guidelines for treating dry eye and meibomian gland disease, indicating that many may not be aware of the suggested treatment protocols for a level 2 patient.

Thus far, few have implemented advanced point-of-care diagnostics into their office protocols for screen-

ing for OSD, and nearly 40% say they see no value in incorporating advanced testing. About 90% agree that staining and TBUT are useful in diagnosing OSD, while 25% to 50% believe that new techniques such as MMP-9 testing, lipid layer interferometry, and osmolarity testing will increase diagnostic accuracy.

Eighty-eight percent agree or strongly agree that mild to moderate dry eye significantly affects postoperative satisfaction in cataract and refractive patients, and 87% agree or strongly agree that ocular surface inflammation is a key mechanism in the pathogenesis of dry eye disease.

The survey indicates that rates of presbyopia-correcting IOL use have doubled since the 2013 survey, now making up 7.2% of cataract cases (up from 3.4% in 2013) and are expected to at least double again over the next 3 years. When combined with toric IOLs, that means premium lenses could soon make up nearly one-quarter of all cataract procedures. The treatment of OSD

will be increasingly important in order to achieve the postoperative vision and satisfaction these premium IOL patients expect.

In the following articles, our panel of experts will discuss the role of the tear film in refractive cataract surgery and ways that we can address dry eye to potentially improve our patients' visual function after surgery.

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### Educational Objectives

Ophthalmologists who participate in this activity will:

- Describe how preoperative dry eye and tear film problems have a cascading effect on refractive cataract surgery, with significant consequences for surgical planning;
- Discuss the contributions of the tear film to optical image quality and how changes in tear film structure can alter the eye's refraction, directly impact the visual quality following cataract surgery, and have particular optical and satisfaction consequences for presbyopia-correcting and toric IOL patients; and
- Integrate more reliable, compliant, and impactful therapeutic approaches to support the integrity of the ocular surface in patients undergoing advanced IOL surgery.

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Marjan Farid, MD

## The tear film: The neglected refractive interface

by Marjan Farid, MD

**The tear film is the most critical refractive interface and must be maintained for optimum postoperative visual outcomes**

**T**he tear film is the eye's first and most important refractive interface; however, refractive cataract surgeons may take its role for granted. Tear film irregularities can cause significant aberrations and visual distortions, affecting visual quality after refractive cataract surgery.

### Tear film structure

The eye contains three refractive interfaces—the precorneal tear film, cornea, and lens.

Approximately two-thirds (40 D) of the eye's optical power is derived from the cornea—including the tear film—and one-third from the lens (20 D), for a total power of about 60 D in the relaxed eye.

When we examine the refractive index of each layer of the cornea, the greatest change in refractive index occurs between the air and tear film.<sup>1</sup>

The tear film has three layers: the lipid layer, which prevents tear evaporation; the aqueous layer, the bulk of the tear film that contains the immune mediators; and the mucin layer, which helps the tear layer adhere to the ocular surface.

The tear film thickness ranges from 6 to 20  $\mu\text{m}$ . If the film is smooth and uniform, it has minimal effect on the optical power of the cornea; however, the tear film thickness may vary depending on aqueous deficiency or aqueous evaporation.

When the tear film becomes irregular, variations in the anterior radius and optical power may occur. Variable powers on the optical surface can induce significant higher order aberrations, and patients may have symptoms of diplopia, starbursts, glare, and shadowing.

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

The greatest change in refractive index occurs between air and the precorneal tear film, making the tear film critical to the optical power of the eye.

Blinking temporarily restores the tear film, mixing the tear components and spreading the tear evenly across the ocular surface. However, between blinks the aqueous evaporates and the tear film degrades and becomes irregular.

Research has demonstrated the effects of tear film irregularity on

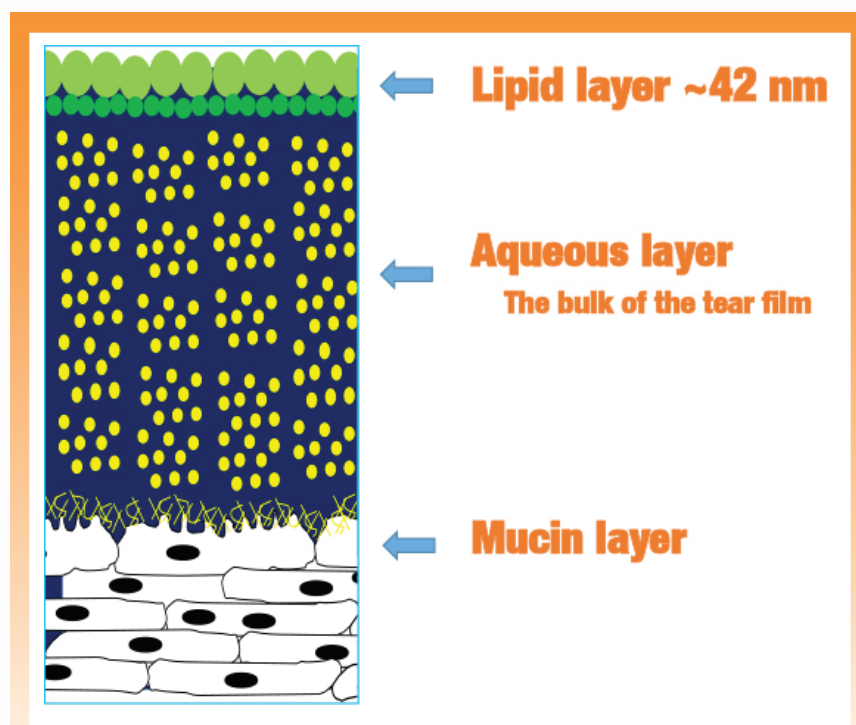
vision. According to Benito and colleagues, double-pass retinal imaging demonstrated that increased light scatter in patients with dry eye worsens the image quality.<sup>2</sup>

In addition, in retinal vessel contrast studies, Tutt et al. reported that tear film irregularities reduce retinal image quality by 20% to 40%.<sup>1</sup>

Furthermore, topography studies showed the tear breakup time during 15-second intervals between blinks reduced visual acuity by 6%.<sup>3</sup>

Although image quality is highest immediately after a blink, image quality degradation and higher order aberrations occur more quickly between blinks in dry eyes compared with normal eyes.<sup>4,5</sup>

In an era when patients spend more time viewing mobile phones, computer monitors, and other electronic screens—and blinking less—dry eye has become more prevalent, negatively affecting patients' quality of life.



Structure and composition of the tear film

### Effects of cataract surgery

Cataract surgeons often underappreciate the effects of cataract surgery on refractive surfaces.

Patients seeking cataract surgery are already at high risk for dry eye. They are usually older and experiencing hormonal changes, whether they are perimenopausal women or men with reduced testosterone levels. Patients' systemic medications may dry the ocular surface, and their diets may be deficient in omega-3 fatty acids.

There are also multiple factors that play a role before, during, and after surgery.

After preoperative dilation and instillation of anesthetic drops, patients may wait as long as an hour with minimal blinking due to corneal anesthesia, resulting in ocular surface keratitis or punctate keratitis by the time they arrive in the operating room.

Intraoperatively, mild corneal trauma and micro-erosions may occur, resulting from the lid speculum placement and exposure.

Using conjunctival impression cytology in patients who had cataract surgery, Oh et al. found a significant loss of goblet cell density that did not recover 3 months later.<sup>6</sup> The longer the surgery, the greater the decrease in goblet cell density. Patients' tear breakup time and corneal sensitivity also decreased at day 1 but recovered by 1 month.

Benzalkonium chloride (BAK) and proparacaine in the topical anesthesia and eye drops significantly affect epithelial cell integrity and tear function.<sup>7,8</sup>

Surgical incisions may disrupt corneal innervation (see sidebar) and increase the inter-blink interval.<sup>9</sup>

After surgery, postoperative drops containing BAK may cause additional surface toxicity, and dry eye disease may worsen if patients decrease or stop using artificial tears. Meibomian gland dysfunction may worsen if they discontinue their warm compresses and lid hygiene.

### Conclusion

Because the tear film is the first and most important refractive interface in the eye, surgeons need to be aware of how irregularities affect image quality. Evaporation, dry eye, long blink intervals, and perioperative factors all can worsen irregularities and vision quality.

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## Limbal relaxing incisions and corneal sensitivity

Astigmatic incisions used in refractive cataract surgery can reduce corneal sensation, further contributing to dry eye.

In the CLEAR Trial by Donnenfeld et al., which analyzed the first 20 patients returning for a 3-month visit after clear corneal extraction with 2 limbal relaxing incisions (LRIs), patients had a significant reduction in Cochet-Bonnet corneal sensitivity in regions adjacent to the LRIs and center of the cornea (Table 1).<sup>1</sup>

In this prospective, multicenter, observational trial, which included patients older than 50 years without dry eye, uncorrected visual acuity and best corrected visual acuity improved after cataract surgery and LRIs. At baseline, prior to the surgery, corneal sensation was >50 mm in all 5 regions in all eyes, but at week 1 one-fifth of patients had severely reduced corneal sensation (<25 mm). Corneal sensitivity was still reduced at 1 month, but returned to near-normal levels 3 months after surgery.

### Reference

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	% of patients with corneal sensation <25 mm			
	Baseline	Week 1	Month 1	Month 3
Area 1 (Center)	0	10.5	10.5	5.3
Area 2 (Center of LRI 1)	0	21.5	15.8	5.3
Area 3 (Center of LRI 2)	0	21.5	15.8	0
Area 4 (90° from LRI 1)	0	0	5.3	10.5
Area 5 (90° from LRI 2)	0	0	5.3	0

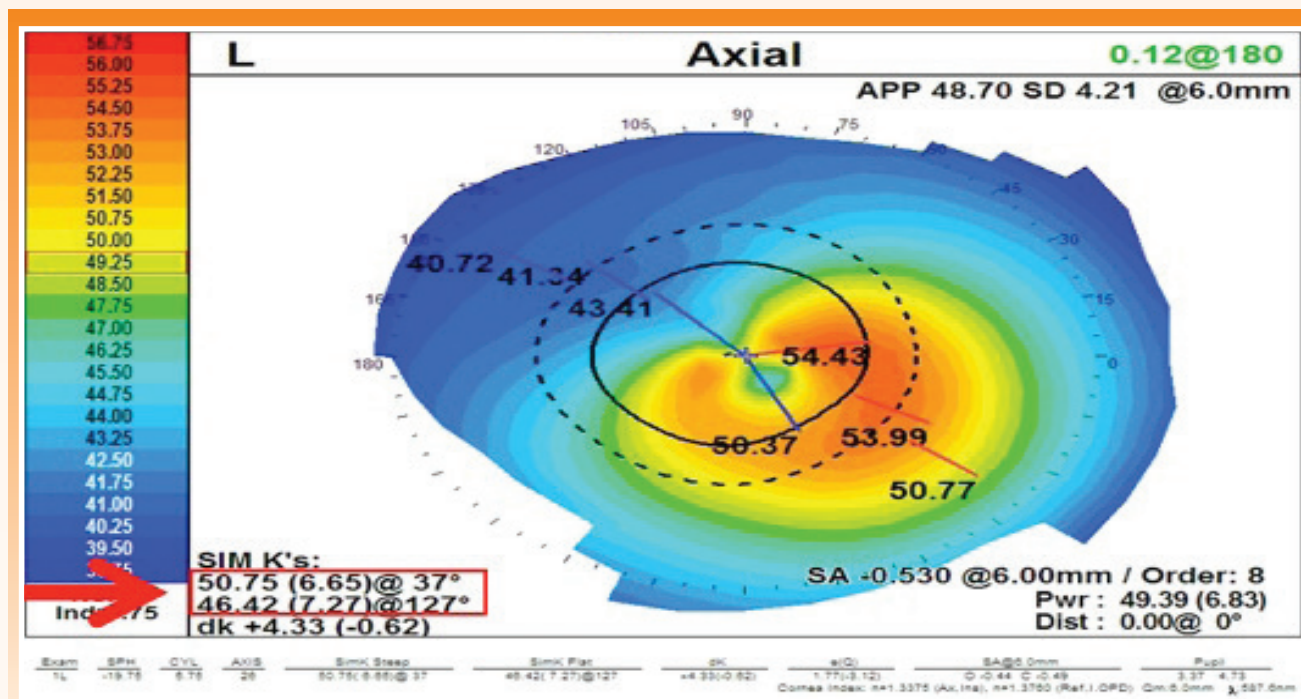
Table 1: LRIs and dry eye



Cynthia Matossian, MD, FACS

## Preop planning and postop outcomes in patients with dry eye

by Cynthia Matossian, MD, FACS



A patient with -11 D myopia had a very ectatic cornea. The initial calculations showed an SN6AT8 to be ideal with minimal residual astigmatism (0.1 D); after tear film and cornea stabilization 2 months later, his calculations indicated the need for an SN6AT9 with a residual corneal astigmatism of 1.5 D.

### Preoperative calculations may be misleading if performed before dry eye is treated

Ocular surface disease can have a cascading effect on refractive cataract surgery. If surgeons neglect the tear film, significant consequences may result, affecting surgical data and planning and the patient's visual outcome.

Therefore, it's important that we understand the impact of dry eye and treat it before beginning preoperative calculations.

### Effects on preoperative measurements

Dry eye may affect keratometry, topography, wavefront imaging, and intraocular lens (IOL) power calculation. Therefore, I aggressively treat ocular surface disease before performing preoperative calculations (see sidebar). Occasionally this may cause a significant delay, but in most cases I am able to schedule biometry within a few weeks.

If surgeons do not identify ocular surface disease before

refractive cataract surgery and delay measurements until after treatment for dry eye, patients may be dissatisfied with their outcomes.

A recent patient was treated with preservative-free artificial tears for 2 weeks. When she returned for her preoperative cataract measurements, however, she had 1.5 D cylinder and her ocular surface remained irregular. I further delayed her preoperative calculations and intensified her treatment, prescribing loteprednol gel and cyclosporine ophthalmic emulsion 0.05%, and oral omega-3s in addition to her preservative-free tears. Approximately 2 weeks later, her ocular surface had improved significantly and her cylinder had decreased to 0.7 D.

If I had not delayed the patient's measurements, her IOL power calculations would have been incorrect and she would have been unhappy with her visual outcome.

In a case managed by **William Trattler, MD**, based on the patient's keratometry measurements, lens power calculations suggested a 20 D Tecnis multifocal IOL was required; however, Dr. Trattler opted to treat the patient's ocular surface before repeating the biometry.

After ocular surface treatment, the optimal IOL power changed to 21 D. If the initial 20 D IOL had been implanted, the patient would have had a 1 D refractive surprise with a multifocal IOL and would not have been satisfied with the surgical outcome.

### Impact of dry eye on surgical planning

Dry eye also affects surgical decisions when correcting astigmatism.

A gas permeable contact lens wearer with -11 D myopia had a very ectatic cornea, with pellucid marginal degeneration.

The patient was displeased when asked to stop wearing his contact lenses until his K readings stabilized. After the K readings stabilized, the patient had more than 4.5 D astigmatism, but had surgery not been delayed until the K readings and ocular surface stabilized, calculations would have indicated an SN6AT8 with minimal residual astigmatism (0.1 D).

After the tear film and cornea stabilized, he needed an SN6AT9 with a residual corneal astigmatism of 1.5 D, which had to be factored into his implant calculation. I

performed a mini-monovision procedure, targeting -1 D in his left eye in view of his residual cylinder. His outcome was successful and the patient is incredibly satisfied.

Dry eye also may influence decisions when planning a lens exchange or enhancement.

A patient relied on a single contact lens for her near vision needs. Another ophthalmology office performed her preoperative measurements immediately after she removed her contact lens, and the ophthalmologist chose a toric IOL for a pseudoastigmatism pattern created by her contact lens.

When she presented at my office, the patient was very dissatisfied with her outcome, which prevented her from driving or seeing clearly. I

explained her toric lens and implanted a monofocal IOL since she had less than 0.5 D of cylinder.

### Engaging the patient

When ocular surface disease is diagnosed, cataract surgeons should show patients evidence of their dry eye disease so patients understand that they have a pre-existing condition that needs to be treated not only before surgery but may require ongoing treatment post surgery. If you engage patients and help them see that they're improving by showing them sequential images, they are more likely to adhere to their prescribed regimen. They may achieve their optimal state more quickly by being encouraged with their progress.

One of our patients had no complaints of dry eye, but his Placido disk image with OPD3 showed a very erratic surface and irregular mires. I showed him the results of his ocular surface testing. If explanation of pre-existing ocular surface disease is unclear, patients may mistakenly blame their surgeon or procedure for causing their dry eye.

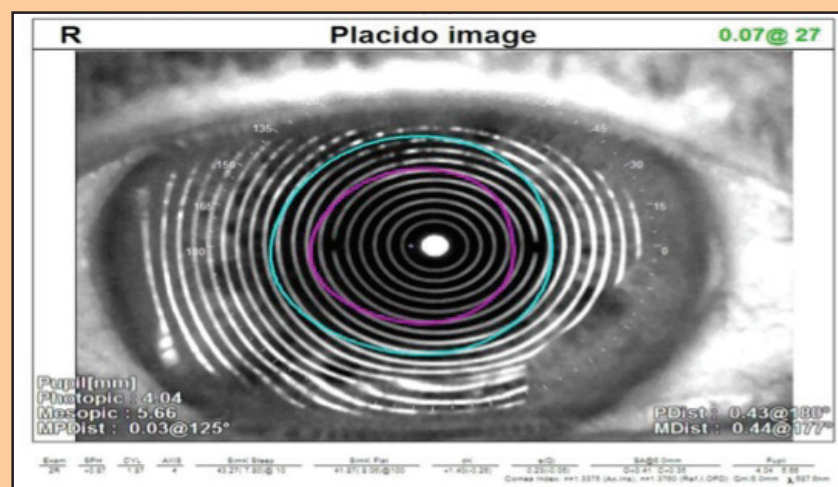
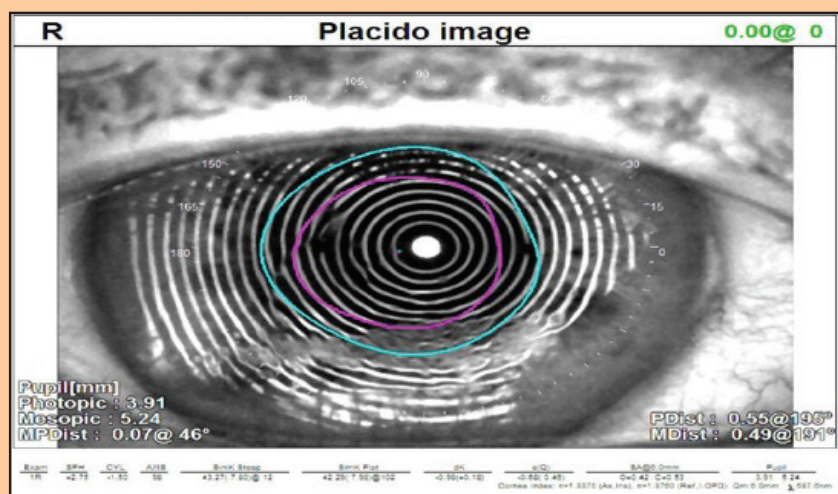
In addition, it is important to set patients' expectations. We told a patient with Salzmann's corneal dystrophy that the cornea should be treated before we could calculate her IOL power. However, the patient declined additional surgery, even after I explained that her refractive outcome would be less predictable. This unpredictability made her a poor candidate for an advanced technology implant.

### Conclusion

For the best refractive outcomes, it is important to optimize the patient's ocular surface before performing preoperative measurements and calculations, separating the surgical testing appointment from the cataract consult. A good quality tear film is critical for accurate measurements and more predictable refractive outcomes.

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## Assessing and treating the ocular surface preoperatively



In a patient with abnormal mires on her Placido disk (left), 1 month after I began treatment with cyclosporine ophthalmic emulsion 0.05%, her results were greatly improved (right). Therefore, I was confident the IOL calculations would bring her much closer to my refractive target.

Thorough assessment of the tear film is necessary before proceeding with preoperative calculations.

To evaluate the ocular surface, we begin with the OSDI questionnaire. I perform tear osmolarity on all of my patients, and we recently began using the InflammDry test, which detects MMP-9, a marker of inflammation. In addition, we use the Sjögren Test, a blood test used to detect Sjögren's disease if warranted.

I also use lissamine green dye to examine the uptake on the eyelid margin, the conjunctiva and cornea. (Before preoperative testing, contact lenses must be discontinued for 2 to 4 weeks.)

I personalize ocular surface treatment to each patient, depending upon severity. In addition to preservative-free artificial tears 4 times a day, I may prescribe oral omega-3 supplements. I prescribe the triglyceride form, which is absorbed more readily. I also may prescribe cyclosporine ophthalmic emulsion 0.05%, azithromycin ophthalmic solution 1.5%, and loteprednol 0.5% (gel or ointment), and warm compresses as often as possible.



Eric D. Donnenfeld, MD

## Therapeutic protocols for the refractive cataract patient

by Eric D. Donnenfeld, MD

### To optimize refractive cataract surgery outcomes with the latest technologies, surgeons first need to address the tear film

This is in some ways the golden age of ophthalmology, presenting endless opportunities with extraordinary technology, including aspheric intraocular lenses (IOLs), multifocal and accommodating IOLs, custom ablations, femtosecond laser cataract surgery, and more. As a result, cataract surgery and refractive surgery are merging into a single entity.

However, the benefits of these advances are lost without a normal ocular surface. The tear film is the most important refracting surface of the eye, and vision quality begins with a healthy tear film.

Therefore, carefully examining and treating the tear film are key. By aggressively addressing dry eye before, during, and after surgery,

cataract surgeons are not changing the focus of their practice but laying the groundwork to potentially optimize postoperative outcomes.

#### Identifying dry eye

Dry eye has become an epidemic as a result of medications, nutritional deficiencies, and other factors.

Many of our patients have marginal dry eye before cataract surgery, complaining of minor eye fatigue. Because they don't see any corneal staining, most surgeons aren't too concerned about these corneas.

Although there is a myth that dry eye patients are unhappy after cataract surgery, unhappy patients are actually marginally compensated before surgery. Cataract surgery, including necessary medications and incisions, increases corneal anesthesia—pushing the patient from being marginally compensated to having overt dry eye. In these cases, patients often attribute their postoperative dry eye symptoms to their surgeons.

Furthermore, as we increasingly use femtosecond lasers to create arcuate incisions, many more of these patients will exhibit dry eye

symptoms because it was not managed appropriately before surgery.

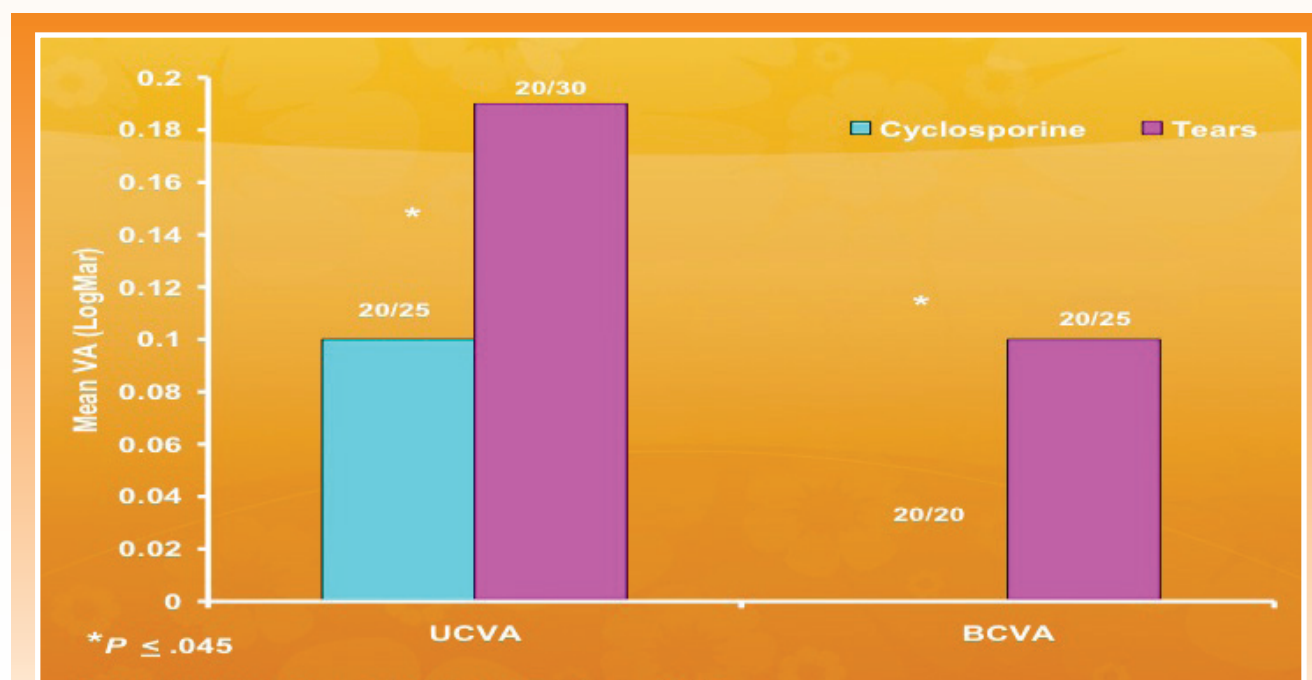
We must diagnose dry eye before surgery, treat the patient appropriately, and develop a therapeutic plan to reduce postoperative dry eye and avoid postoperative dissatisfaction.

#### Preoperative assessment to drive treatment

To practice smarter, we need to rely on physician extenders who can help us manage patients comprehensively, providing us with more time to speak with the patient about dry eye treatment for better clinical results.

In our practice, we provide a dry eye questionnaire to our patients. If they affirmatively answer three of the questions, our technicians proceed with dry eye testing.

Testing enables us to diagnose dry eye accurately the first time and select therapy effectively. I believe osmolarity testing is the lynchpin, but the InflammDry MMP-9 test is also extraordinarily important. Positive results definitively indicate inflammatory dry eye, which we must treat with cyclosporine ophthalmic



Use of cyclosporine versus artificial tears resulted in significantly better visual acuity.

Source: Donnenfeld, Roberts, Perry et al. ARVO 2007 Poster B1041

emulsion 0.05%; however, negative results may mean the patient has a milder case that still may require cyclosporine treatment.

Patients with Sjögren's syndrome are most in need of inflammatory therapy, but their cases often have been misdiagnosed or undiagnosed for decades. We now use the Sjögren blood test, which includes markers for Sjögren's syndrome, in patients younger than 50 with dry eye, those with significant dry eye at any age, or those with dry eye that does not respond to treatment. In my practice, 50% of results are positive, in which case I refer the patient to a rheumatologist. I also explain to these patients that long-term therapy with cyclosporine is the only long-term therapy that will work.

In addition, LipiView lipid layer interferometry helps identify meibomian gland disease.

### Treating dry eye preoperatively

In many cases, artificial tears do not adequately treat dry eye. We accelerate therapy in patients with signs or symptoms of dry eye, elevated osmolarity, positive MMP-9 results,

a history of LASIK or PRK, collagen vascular or autoimmune disease, or a surgical plan including arcuate incisions or limbal relaxing incisions.

My preoperative strategy includes preservative-free artificial tears 4 times a day, as well as loteprednol twice a day and cyclosporine twice a day. Loteprednol reduces the sting from cyclosporine, and cyclosporine enhances corneal nerve regeneration.<sup>1</sup> In patients we studied, cyclosporine treatment for 1 month before and 2 months after cataract surgery with multifocal IOLs resulted in better visual acuity and contrast sensitivity after surgery.<sup>2,3</sup>

Combination immunomodulation hastens the response to therapy, allowing patients to see results more quickly. I continue loteprednol for 1 month. (Because it is a steroid, long-term use is not recommended.)

Patients may benefit from oral omega-3 supplements; however, in my experience, all omega 3 supplements are not equal. Some tricyclic forms absorb very well.

Punctal occlusion also is effective, but anti-inflammatory therapy should be initiated first so inflam-

matory residue is not trapped in the eye. In addition, warm compresses and lid scrubs play a role.

If the ocular surface has not been corrected after treatment, you will need to talk with the patient about alternatives.

### Intraoperative measures

For patients with dry eye, I specifically choose surgical techniques to reduce dry eye after surgery.<sup>4</sup> For example, in eyes with low amounts of cylinder, rather than penetrating incisions, I use intrastromal ablations, which are associated with a lower incidence of dry eye because they are below the neural plexus.

In patients with moderate dry eye, I may implant a toric lens rather than creating arcuate or limbal relaxing incisions.

In addition, I minimize drops containing benzalkonium chloride, reduce the amount of anesthetic drops, and use more viscoelastic or balanced salt solution.

### Postoperative strategies

Everyone has dry eye after cataract surgery. Some patients may

not notice it because severing the corneal nerves decreases pain and irritation. The most common symptom is visual fluctuation because of disruption of the corneal surface. When patients voice this complaint, we should consider treating dry eye more aggressively until it is proven otherwise.

On postsurgical day 1, I prescribe preservative-free tears every 2 hours. I prescribe preservative-free tears during the first week, lubricating ointment at night as needed, and cyclosporine for at least 3 months after surgery, until the patient's eyes are fully healed.

### Conclusion

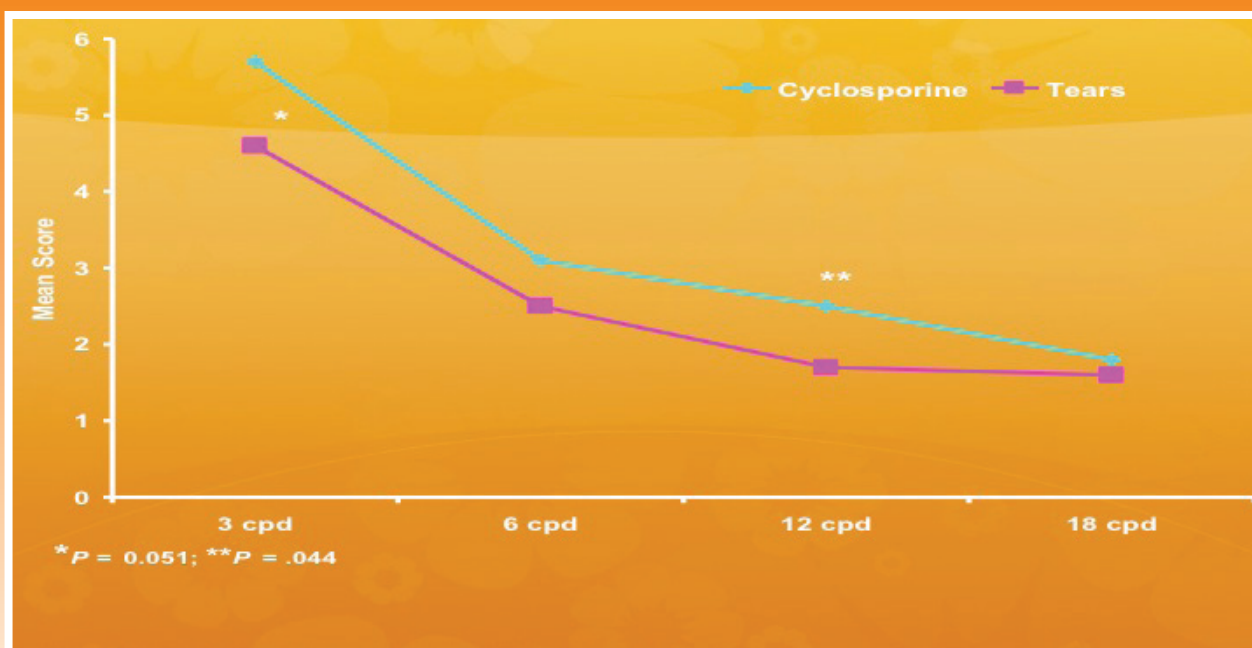
As cataract surgeons, we all strive to provide the most favorable visual outcomes, and the most effective way to do that is to manage dry eye, which is very common and underdiagnosed.

Dry eye adversely affects visual function—but it is reversible and we can prevent progression, ultimately improving the outcome of refractive cataract surgery.

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Cyclosporine improved contrast sensitivity under mesopic conditions without glare.

Source: Donnenfeld, Roberts, Perry et al. ARVO 2007 Poster B1041

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**CME Questions (Circle the correct answer)**

**1. According to the authors, what is the most common symptom of dry eye after cataract surgery?**

- a. Severe discomfort
- b. Foreign body sensation
- c. Visual fluctuation
- d. Excessive tears

**2. Where does the greatest change in refractive index occur?**

- a. Between the air and the tear film
- b. Between the crystalline lens and vitreous humor
- c. Between the tear film and cornea
- d. Between the aqueous humor and crystalline lens

**3. In the CLEAR Trial by Donnenfeld et al., which step during cataract surgery decreased corneal sensitivity?**

- a. Capsulorhexis
- b. Prolonged phaco time
- c. Limbal relaxing incisions
- d. Instillation of antibiotic and anti-inflammatory drops

**4. Which of the following tests can be used specifically to identify the presence of inflammation in the tears?**

- a. Osmolarity testing
- b. Sjögren's syndrome test
- c. Tear film interferometry
- d. Schirmer's test

**5. Which of the following is not a useful application of Placido disc imaging?**

- a. Abnormal mires can identify ocular surface problems
- b. Gets the patient engaged with diagnosis and treatment
- c. Clearly identifies location of dystrophies
- d. Identifies whether surface problems are due to aqueous deficiency or meibomian gland dysfunction

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To claim credit, please fax the test and fully completed form by February 28, 2015 to 703-547-8842, email to [GPearson@ascrs.org](mailto:GPearson@ascrs.org), or mail to: EyeWorld, 4000 Legato Road, Suite 700, Fairfax, VA 22033, Attn: September 2014 CME Supplement

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