

Figure 1. Dr. Lee performing measurements of corneal biomechanics with Ocular Response Analyzer at PVI in 2008 (Left). Dr. Quan performing the measurements at PVI today (Right).

Corneal Elasticity: an Essential Preoperative Measurement to Insure LASIK Safety and Accuracy

“The Cornea is Not a Piece of Plastic” wrote Dr. Cynthia Roberts, a Professor of Biomedical Engineering at Ohio State University, in a frequently cited *Journal of Refractive Surgery* editorial eighteen years ago (Roberts C, The cornea is not a piece of plastic. *Journal of Refractive Surgery*. 2000;16(4):407-413). This statement seems self-evident. Anyone who’s ever performed applanation tonometry or simply pressed on their own eye knows that cornea feels flexible and elastic. Anyone who’s ever seen the effects of radial or astigmatic keratotomy in a patient understands that peripherally-placed incisions can induce central corneal flattening only if the cornea is a flexible entity that bends in response to the these incisions.

Yet these observations are often ignored when patients are evaluated to determine their suitability to undergo LASIK safely. Corneal shape and thickness are mapped and measured with topography and tomography. Many devices exist to gather such information. They include placedo-disc topographers, scheimpflug tomographers (Pentacam), slit-scanning topographers (Orbscan), ultrasound pachymeters, and optical coherence tomographers (Zeiss and Optovue). All of these devices, however, treat the cornea as a piece of transparent plastic, ignoring its biomechanical properties. Corneal biomechanical response to surgery is inferred from its appearance and its thickness, rather than measured directly. When we see an inferior steepening, for example, or pachymetry that indicates a thin cornea, we infer that this cornea may be predisposed to thinning after LASIK. In such patients we may recommend PRK or no laser vision correction at all. What about the patients with normal appearing corneal maps and normal pachymetry? Corneal thinning post-LASIK, although very rare, has been reported in such patients as well. To avoid such complication, mapping the cornea and measuring its thickness is not enough. Inferring corneal biomechanics from its appearance is not enough. Corneal biomechanics need to be measured directly to avoid operating on normal looking corneas that may be too weak, too deformable, or too elastic to undergo LASIK safely.

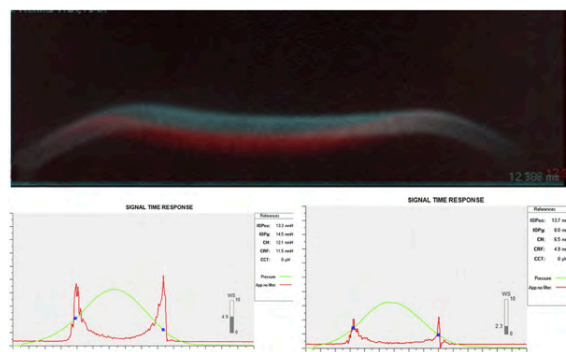


Figure 2. Overlapped images measured with dynamic Scheimpflug analyzer from a normal cornea (blue) and a keratoconic cornea (red), both with similar IOPcc from dynamic bidirectional applanation (13.3 mm Hg for normal cornea and 13.7 mm Hg for keratoconic cornea) and similar CCT. Keratoconic cornea is more deformable than normal cornea (Roberts, C. Concepts and misconceptions in corneal biomechanics. *J Cataract and Refract Surg*. 2014;40(6):862-869).

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In her article, “The Cornea is Not a Piece of Plastic,” Dr. Roberts also demonstrates that laser vision correction induces some relaxation of the corneal lamellae outside the treatment zone. This process, she argues, may contribute to the refractive outcome independently of the actual tissue removal. It is, therefore, imperative, that we not only determine whether the patient’s cornea is strong enough to remain strong after some lamellae have been relaxed by the laser, but we may also need to factor in this relaxing effect into the treatment nomogram when we program the laser for each patient. Corneal biomechanical values may need to be included in the regression analysis formulas we use to generate treatment nomograms.

Recently, American Academy of Ophthalmology added a “Corneal Biomechanics” section to its on-line learning module (http://eyewiki.aao.org/Corneal_Biomechanics). The section has also been added to the most recent Practicing Ophthalmologists Learning System (American Academy of Ophthalmology. Refractive Management/Intervention: Corneal biomechanics Practicing Ophthalmologists Learning System, 2017 - 2019 San Francisco: American Academy of Ophthalmology, 2017). According to the section, “the biomechanics of the cornea affect its functional responses and greatly impact vision. The physical composition of the cornea gives it viscoelastic properties, meaning it exhibits elements of both elasticity and viscosity. While various methods have been devised to study the biomechanics of the cornea, only the Ocular Response Analyzer (ORA) allows direct analysis of corneal biomechanical properties in the clinic. Successful corneal treatments depend on interactions between biological and biomechanical factors and their impact on surrounding ocular tissues.” Furthermore, “as the only device capable of measuring corneal biomechanics in the clinical setting, the ORA is useful in diagnosis and prognosis after refractive surgery. Understanding the interactions between biomechanics and functionality will allow better screening and more effective treatment of” refractive errors.

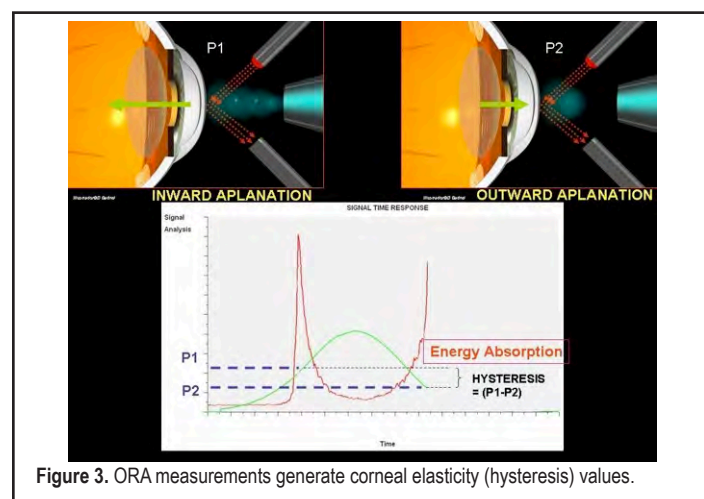
May 2018 issue of *Optometry Times* emphasized the importance of measuring each patient’s corneal biomechanical properties prior to LASIK in the article “Technology helps to diagnose corneal ectasia,” by Jim Owen, OD, MBA, FAAO.

Currently, ORA is the only FDA approved technology to measure corneal biomechanics. At Pacific Vision Institute, we are one of only a few practices in the US to use Ocular Response Analyzer to assess patients’ corneal viscoelastic properties prior to LASIK. If patients have low corneal hysteresis and/or low corneal resistance factor, we advise against LASIK and recommend PRK or a non-corneal refractive surgery, such as ICL or refractive lens exchange.

We have been using this technology in our preoperative assessment of patients for more than a decade. As a result, we have accumulated a large volume of valuable data to help guide patients toward the safest and most effective procedure that’s right for them.

How does it work?

Just as with the noncontact tonometry (NCT), the ORA uses a brief puff of air to apply pressure to the cornea. Unlike NCT, however, the air pressure is not as strong and is better tolerated by the patient. The patient is seated in front of the machine and fixates on the green light. An automated alignment system positions an air tube in front of the corneal apex. An air puff is applied to the cornea. The air pulse causes the cornea to move inward into slight concavity before returning to the normal curvature. A graph is created that has two parts: a green curve and a red curve (**Figure 3**). The green curve corresponds to the air pulse pressure and the red curve corresponds to the corneal movement. The first peak on the red curve coincides with the pressure it takes to applanate the cornea inward (P1). This is analogous to an NCT measurement. The second



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peak on the red curve coincides with the pressure exerted by the cornea as it moves out, under the decreasing pressure of the air pulse (P2). Four measurements are done for each eye. If the cornea is irregular or moves abnormally, the peaks may be lower, wider, or otherwise irregular. Patients with keratoconus and other corneal thinning pathologies not only have lower peaks, but the peaks look irregular. **Figure 4** demonstrates dynamic ultra high speed infrared scheimpflug image detecting corneal movement in response to air puff.

What does it measure?

- **Corneal hysteresis (CH)** is the difference between inward and outward pressure of the cornea. CH is a function of corneal viscous damping properties, i.e. energy absorption capabilities. Patients with keratoconus have low CH values, typically less than 8. Values above 10 are considered normal. A high value in a patient with obvious keratoconus on topography indicates the weak spot in the cornea is not where the measurement was taken. In these eyes, the irregular appearance of the peaks on the ORA graph will be noted. In normal eyes, right and left eye values are highly correlated. Corneal radius and astigmatism are not correlated with CH. Central corneal thickness (CCT) correlation with CH is weak. CH is age-independent.
- **Corneal resistance factor (CRF)** is calculated by the machine using P1 and P2 values. The equation puts more emphasis on P1 than P2. CRF is, therefore, more heavily weighted by the corneal elastic properties. Normal values for CRF are similar to those for CH. In weaker corneas, such as keratoconus, for example, CRF values are depressed more than CH values. In patients with glaucoma, CRF values are close to normal, but CH values are lower.
- **CH – CRF** difference is another parameter for analyzing corneal strength. Studies demonstrate that patients with keratoconus have CH values higher than CRF values (CH-CRF difference is positive), while this finding is rare in normal patients and in patients with glaucoma. This parameter could be used as a sensitive screening tool. IOP measuring true IOP, regardless of corneal characteristics.
- **Corneal compensated IOP (IOPCC)** is calculated using a combination of P1 and P2 ($IOP_{cc} = P2 - (0.43 \times P1)$). It is a measurement that is designed to reduce the effect of corneal thickness and its other properties on IOP measuring process. This IOP value has been reported to remain constant after refractive surgery. It is perhaps a more accurate measure of true IOP than CCT-adjusted IOP. CRF shows to be more of a factor in IOP testing than corneal thickness. There isn't always a direct correlation between CCT and CRF. A thick cornea doesn't necessarily mean the CRF is high as well.
- **Goldman correlated IOP (IOPG)** is the average of P1 and P2. It is higher than IOPcc in more rigid corneas and lower than IOPcc in more flexible corneas. ■

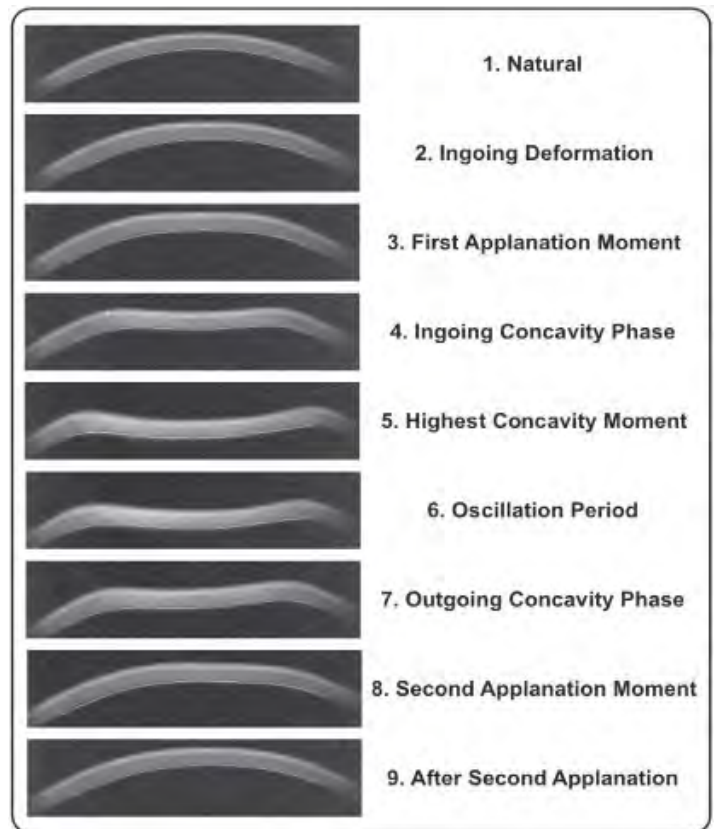
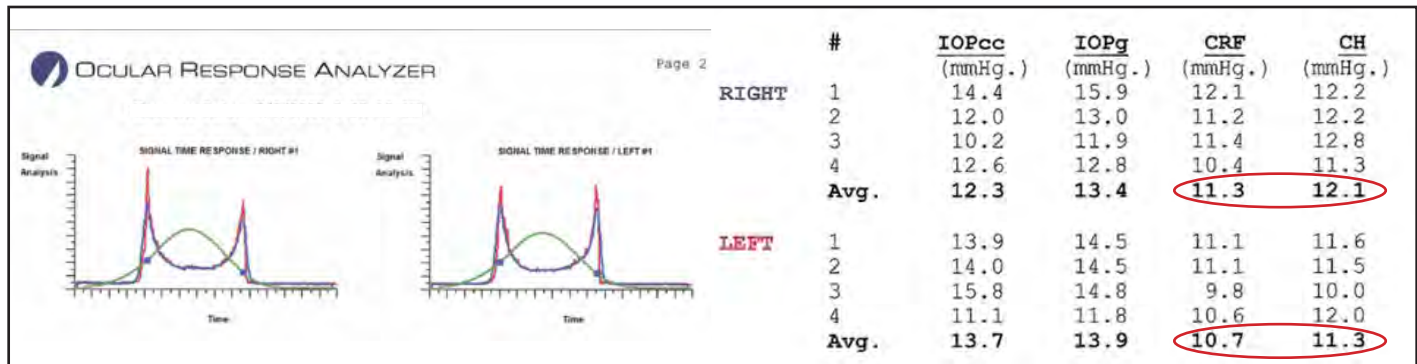


Figure 4. Scheimpflug images extracted from a series of 140 images of a cornea deforming under an air puff from the dynamic Scheimpflug analyzer (Roberts, C. Concepts and misconceptions in corneal biomechanics. J Cataract and Refract Surg. 2014;40(6):862-869).

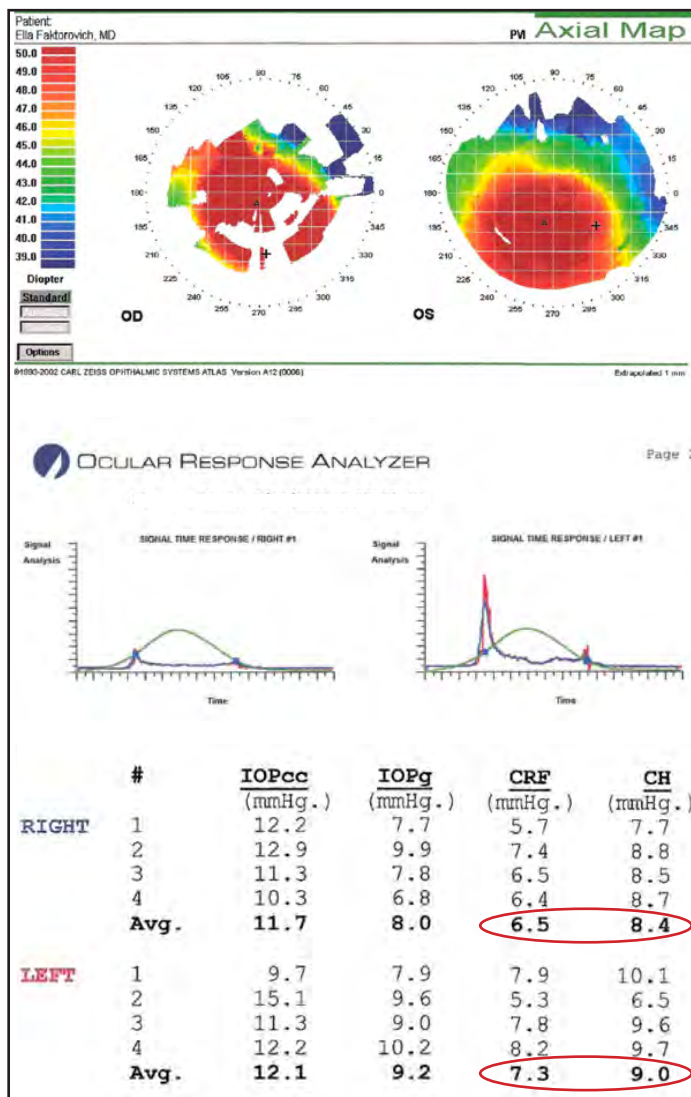
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Clinical applications in screening refractive surgery candidates

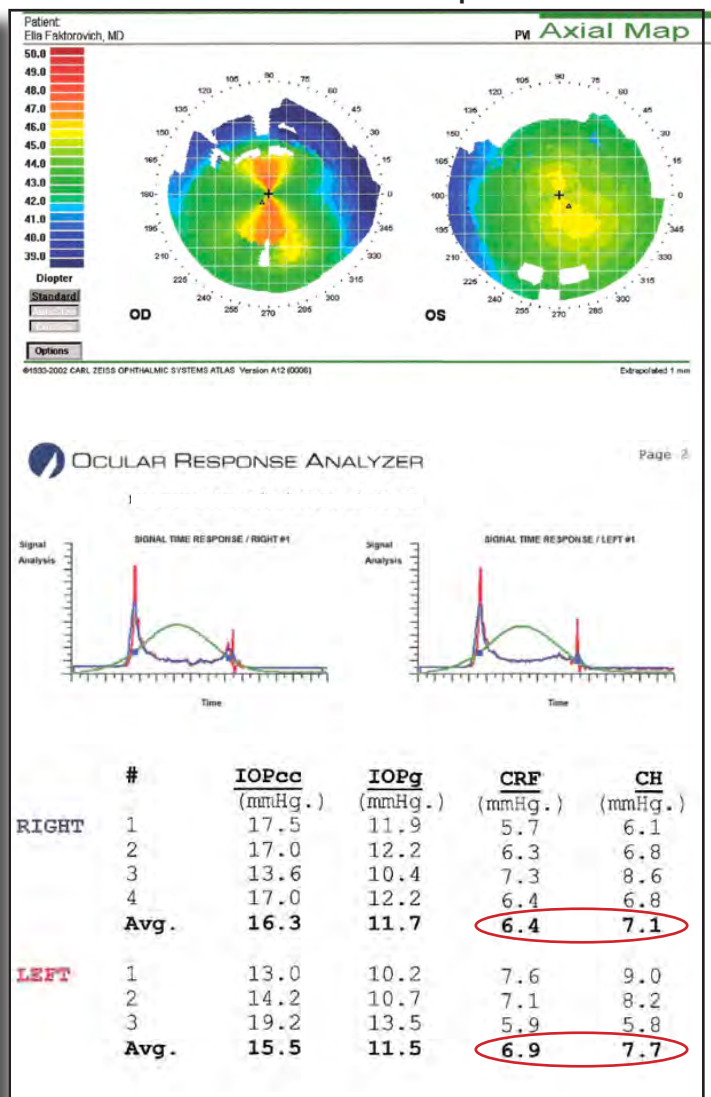
Normal



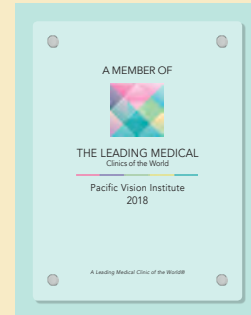
Keratoconus



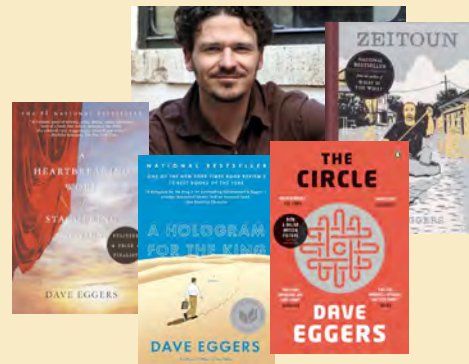
Keratoconus suspect



- Pacific Vision Institute becomes the only clinic in Northern California (and one of only 10 in the United States) to be selected for inclusion into a prestigious network of the **The Leading Medical Clinics of the World**. PVI is honored to be included among such top ophthalmology clinics as Duke University Eye Center and Wills Eye Hospital.



- Pulitzer-prize award finalist author and screenwriter, Dave Eggers, undergoes LASIK with Dr. Faktorovich at PVI



- Pinterest co-founder, Evan Sharp, undergoes LASIK with Dr. Faktorovich at PVI



- Dr. Faktorovich textbook, "Femtodynamics: A Guide to Laser Settings and Procedure Techniques to Optimize Outcomes with Femtosecond Lasers" is reviewed in the American Journal of Ophthalmology. The reviewers conclude that Femtodynamics is "a must-read book for any refractive surgeon who want to know more about using femtosecond lasers...for corneal flap."



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OPTOMETRISTS AND OPTOMETRY STAFF WHO RECENTLY HAD LASIK and PRK AT PVI



Dr. Diana Pham (Hyperoptics Optometry, San Francisco)

Procedure: PRK

Preop Rx: OD: -5.50-2.25x167, OS: -8.25-1.50x006



Dr. Patricia Le (Pacific Rims Optometry, San Francisco)

Procedure: LASIK

Preop Rx: OD: -4.00-1.75x010, OS: -3.75-2.25x167



Alexa Joseph (Through the Hayes Optometry, San Francisco)

Procedure: LASIK

Preop Rx: OD -6.75-0.25x180, OS -7.00DS



Maria Valdez (Dr. Jeffrey Lem Optometry, San Francisco)

Procedure: LASIK

Preop Rx: OD: -9.75-1.75x180, OS: -8.75-2.00x175



Bea Nguyen (Eyes on You Optometry, San Francisco)

Procedure: LASIK

Preop Rx: OD: -7.25-1.50x173, OS: -6.50-1.50x008

Counselor's Corner



Q: How long is the recovery after PRK?

A: During the first several days after your procedure, you may experience eye irritation, tearing, and some burning sensation that should be relieved with medication, such as ibuprofen, for example. Dr. Faktorovich has developed

a treatment plan designed to improve comfort after PRK. She is considered an expert in the field of corneal healing, having published many studies in the field, including, most recently in the Journal of Cataract and Refractive Surgery, a recommendation for the best protocol to enhance patient comfort after the procedure. Many of our patients can do their usual activities within several days after PRK. During the first week after PRK, vision can be somewhat blurry, but functional. Most of our patients report being able to carry on their usual activities, including driving in familiar areas. Some drive from San Francisco to the Silicon Valley and back. They may need to temporarily increase the font size and contrast on their screens. Just as with LASIK, we recommend you don't get water in your eyes for one week after PRK, but you can do your usual exercise during this time. ■

Refractive Advisor



Q: My patient asked my opinion about SMILE procedure. How should I advise him?

A: SMILE (Small Excision Lenticular Extraction) involves making two passes with a femtosecond laser in the cornea. The surgeon then manually pulls out the excised piece of corneal tissue through a small incision in the cornea. A potential advantage of SMILE over LASIK is the smaller side cut incision which could, theoretically, result in improved eye comfort during the initial recovery time. The smaller side cut has also led some to believe that SMILE could be as safe as PRK in patients with thinner and/or irregular corneas. Clinical experience and clinical studies have not supported these hypothesized advantages. Most importantly, the vision outcomes after SMILE are inferior to those of LASIK and PRK, especially topography-guided. Results of a randomized studies comparing topography-guided LASIK and SMILE for treatment of myopia and myopic astigmatism favored topography-guided LASIK. At 12 months, 100% of LASIK-treated eyes achieved UDVA of 20/20 compared

with 81% of eyes in the SMILE group (Kanellopoulos, AJ. Topography-Guided LASIK Versus Small Incision Lenticule Extraction (SMILE) for Myopia and Myopic Astigmatism: A Randomized, Prospective, Contralateral Eye Study. J Refract Surg. 2017 May 1;33(5):306-312.) The disparity favoring LASIK was even greater at higher levels of UDVA (20/16 and 20/10). SMILE is not FDA approved for correction of astigmatism. With LASIK and PRK, we routinely correct 0.5D of astigmatism or more in 70% of our patients. With SMILE, there is also little control of centration during treatment. This may lead to decentered treatments, resulting in glare, haloes, and induced astigmatism. In addition, corneal tissue sometimes tears on removal. This results in irregular astigmatism and loss of vision. Such tear is more likely in lower corrections, where the corneal piece is thinner. Since these patients often have 20/15 and even 20/10 best corrected vision, they expect excellent vision postop. Furthermore, the suction that holds the eye is weak and easily lost while the corneal piece is being excised. Any patient movement or lid squeezing can break the suction. This can result in decreased vision outcomes. ■



SAVE THE DATE:

16th Annual San Francisco Cornea, Cataract, and Refractive Surgery Symposium



When	-	Sunday, January 27th, 2019
Where	-	Four Seasons Hotel, San Francisco, CA
Audience	-	Bay Area optometrists

Overview

The San Francisco Cornea, Cataract, and Refractive Surgery Symposium - founded in 2001 - is dedicated to advancing the professions of optometry and ophthalmology through exchange of clinical and scientific knowledge and skills. The Symposium was one of the first educational events in the United States to introduce a collaborative approach to patient care by optometrists and ophthalmologists.

Over the years, more than 100 nationally renowned specialists have taught at the Symposium, including department chairs and faculty in academic centers, leaders of large practices throughout the country, scientists at major pharmaceutical and technology companies, and individuals at the forefront of business communities. The Symposium has been profiled in major optometric and ophthalmic publications, including Primary Care Optometry News and Ocular Surgery News.

The Symposium agenda for 2019 includes up-to-date topics on the use of the latest diagnostic and treatment strategies for managing ocular disease. For the first time in its 16 year history, the Symposium will also include a hands-on skill transfer workshop in techniques of ocular surface disease management.

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