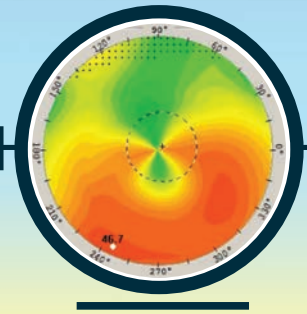
RCCL®
REVIEW OF CORNEA & CONTACT LENSES

MAY/JUNE 2019

THE IRREGULAR CORNEA

GETTING ASTIGMATISM IN FOCUS



WITH ADVANCED IMAGING, PAGE 16

ALSO: ARVO 2019 HIGHLIGHTS • HOW CONTACT LENS WEAR DISRUPTS THE TEAR FILM

CooperVision®

brighten each day.
prescribe a high-oxygen lens with a low-oxygen price.

clariti® 1 day

Give your patients a fresh perspective with clariti® 1 day, a full family of breathable, affordable silicone hydrogel lenses. **prescribeclariti.com**

contents

Review of Cornea & Contact Lenses | May/June 2019

departments

features

The Dry Eye-Neuro Link

A recent study suggests nerve dysfunction may be the root cause of dry eye symptoms in some patients with migraines.[1]

Researchers evaluated symptoms and signs of dry eye—including those suggestive of nerve dysfunction—in 250 individuals, including 31 who met International Classification of Headache Disorders criteria for migraine based on a validated screening.[1]

The study found individuals with migraine were significantly younger and more likely to be female compared with the controls. Patients with migraine also had more severe dry eye symptoms and ocular pain compared with the control group.

Individuals with migraine had a different dry eye symptom—but a similar dry eye sign—profile compared with controls, researchers said. This suggests dry eye symptoms in those with migraine may be driven by nerve dysfunction, not ocular surface abnormalities.[1]

HYPERSENSITIVE CORNEAS

Short tear film break-up time dry eye (sBUT), a subcategory of evaporative dry eye, may significantly affect patient complaints of ocular pain, new study found.[2] Patients with sBUT dry eye—an sBUT of <5 seconds, a normal Schirmer test and few epithelial lesions—were hypersensitive to corneal pain, suggesting corneal hyperalgesia could partly account for subjective symptoms in patients with sBUT dry eye.[2]

The study enrolled 60 patients with sBUT dry eye and 46 healthy controls. Patients with sBUT dry eye had higher corneal pain sensitivities than healthy subjects but similar corneal tactile sensations. In the 36% of patients with sBUT dry eye and corneal hyperalgesia, defined as a pain sensitivity ≥40mm, the team observed a strong significant correlation between the subjective pain score and the objective corneal pain sensation. For the entire cohort they found a weak positive correlation between the subjective pain score and the objective corneal pain sensation.[2] RCCL

Contact Lens Rule Update

The Federal Trade Commission (FTC) is seeking additional input on its next phase of proposed changes to the Contact Lens Rule. Elements of the latest proposal:

- Prescribers must satisfy the "Confirmation of Prescription Release" with a signed confirmation statement by the patient; a prescriber-retained copy of the prescription signed by the patient; a patient-signed copy of the sales receipt confirming they received the prescription; or proof that they received a digital copy.
- Prescribers must give a copy to the patient's designated agent upon request.
- Robocall information must be delivered slowly, at a reasonable volume and allow prescribers to repeat it.
- A seller must send the prescriber a verification request with the manufacturer name or brand if different than the one specified.
- Sellers must provide a way for patients to present their prescriptions directly to the seller.

FTC seeks additional public comment on proposed changes to the contact lens rule. www.ftc.gov/news-events/press-releases/2019/05/ftc-seeks-additional-public-comment-proposed-changes-contact-lens. May 2, 2019. Accessed May 14, 2019.

1. Farhangi M, Diel R, Buse DC, et al. Individuals with migraine have a different dry eye symptom profile than individuals without migraine. Br J Ophthalmol. April 30, 3019. [Epub ahead of print].

2. Tagawa Y, Noda K, Ohguchi T, et al. Corneal hyperalgesia in patients with short tear film break-up time dry eye. The Ocular Surface. 2019;17(1):55-9.

RCCL® REVIEW OF CORNEA & CONTACT LENSES

11 Campus Blvd., Suite 100
Newtown Square, PA 19073
Telephone (610) 492-1000
Fax (610) 492-1049

Editorial inquiries: (610) 492-1006
Advertising inquiries: (610) 492-1011
Email: rccl@jobson.com

EDITORIAL STAFF

EDITOR-IN-CHIEF
Jack Persico jpersico@jobson.com
MANAGING EDITOR
Rebecca Hepp rhepp@jobson.com
ASSOCIATE EDITOR
Catherine Manthorp cmanthorp@jobson.com
ASSOCIATE EDITOR
Mark De Leon mdeleon@jobson.com
CLINICAL EDITOR
Joseph P. Shovlin, OD, jpshovlin@gmail.com
ASSOCIATE CLINICAL EDITOR
Christine W. Sindt, OD, christine-sindt@uiowa.edu
EXECUTIVE EDITOR
Arthur B. Epstein, OD, artepstein@artepstein.com
CONSULTING EDITOR
Milton M. Hom, OD, eyemage@mminternet.com
GRAPHIC DESIGNER
Ashley Schmouder aschmouder@jhihealth.com
AD PRODUCTION MANAGER
Scott Tobin stobin@jhihealth.com

BUSINESS STAFF

PUBLISHER
James Henne jhenne@jobson.com
REGIONAL SALES MANAGER
Michele Barrett mbarrett@jobson.com
REGIONAL SALES MANAGER
Michael Hoster mhoster@jobson.com
VICE PRESIDENT, OPERATIONS
Casey Foster cfoster@jobson.com

EXECUTIVE STAFF

CEO, INFORMATION SERVICES GROUP
Marc Ferrara mferrara@jhihealth.com
SENIOR VICE PRESIDENT, OPERATIONS
Jeff Levitz jlevitz@jhihealth.com
SENIOR VICE PRESIDENT, HUMAN RESOURCES
Tammy Garcia tgarcia@jhihealth.com
VICE PRESIDENT, CREATIVE SERVICES & PRODUCTION
Monica Tettamanzi mtettamanzi@jhihealth.com
VICE PRESIDENT, CIRCULATION
Emelda Barea ebarea@jhihealth.com
CORPORATE PRODUCTION MANAGER
John Caggiano jcaggiano@jhihealth.com

BAUSCH + LOMB
See better. Live better.

BALANCE

POWER AND SIMPLICITY

Zenlens™

*#1 DOCTOR-PRESCRIBED SCLERAL LENS**

SIMPLIFIED FITTING
with SmartCurve™ technology

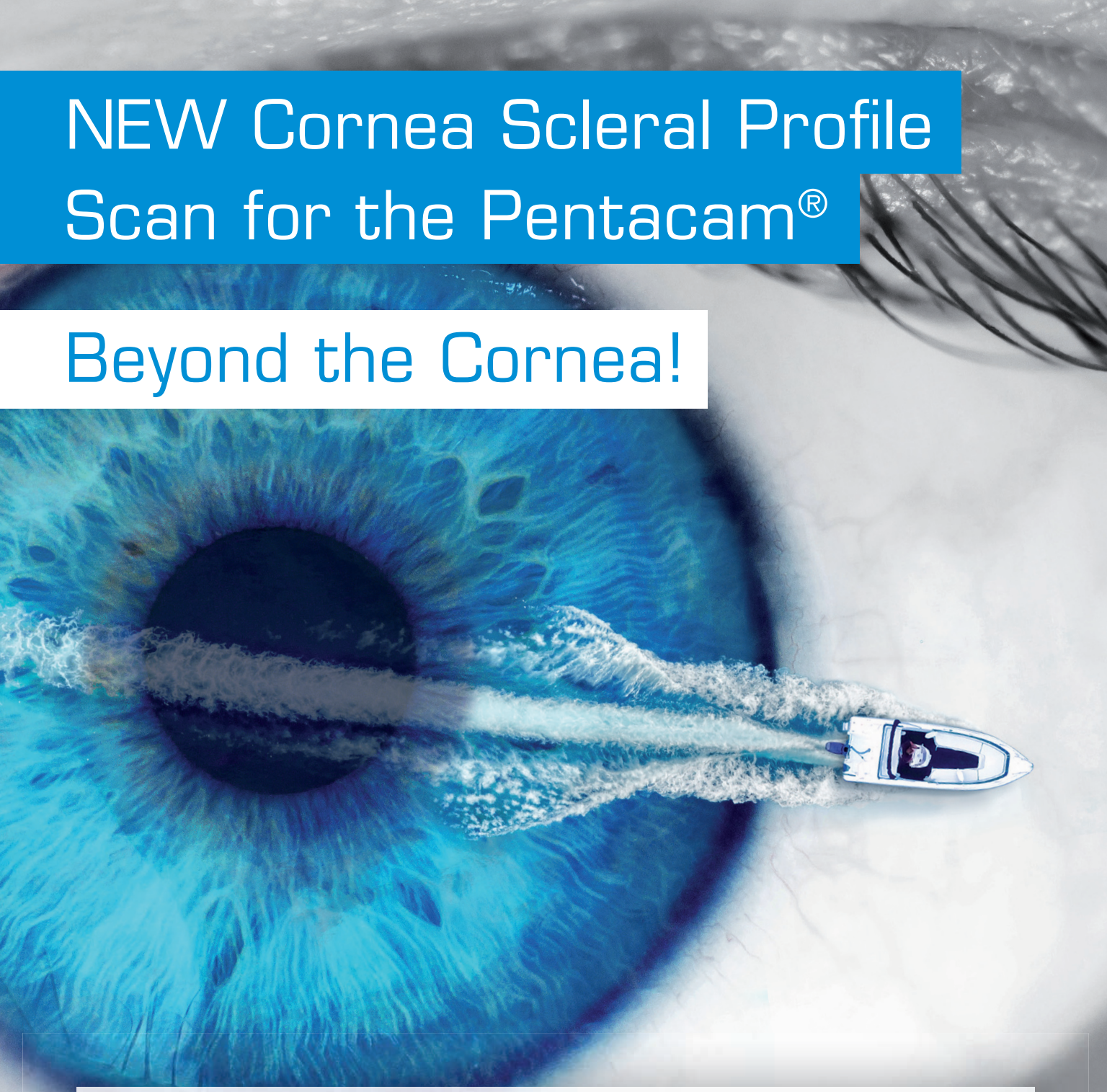
FCLSA-CERTIFIED CONSULTANTS
offer individualized support

EXPANDED OFFERINGS
with Tangible® Hydra-PEG® and Zen™ Multifocal

*Based on US lens sales between December 2018 and February 2019.

NEW Cornea Scleral Profile Scan for the Pentacam®

Beyond the Cornea!



The new Pentacam® CSP Report measures, where others are just estimating

Measure beyond past boundaries when fitting scleral lenses. The new CSP Report creates 250 images within the measuring process. The tear film independent measurement with automatic release allows coverage up to 18 mm with the same fixing point.

Contact OCULUS today for more details!

Toll free 888-519-5375 Follow us!
ads@oculususa.com www.oculususa.com

OCULUS®

By Joseph P. Shovlin, OD

The Mystique of Conjunctivochalasis

Be vigilant when examining the entire ocular surface to avoid confusion.

It's likely that, at one point or another, every eye care provider has diagnosed dry eye and eventually discovered that the masquerader conjunctivochalasis (CCh) was actually the cause of their patient's discomfort. How many times have we placed punctal plugs in the inferior punctum with no relief from symptoms—sometimes making the symptoms even worse? CCh is just one of several mechanical conditions that affects the ocular surface, and most providers commonly overlook it.

As we age, CCh, or loose redundant conjunctiva, becomes a common sign of ocular surface degradation.[1] Its etiology is certainly multifactorial. In addition to age, a history of dry eye, allergies (eye rubbing), certain medications and previous surgeries are risk factors for CCh and can cause a wide variety of symptoms.[2] Symptoms can be non-specific with an insidious onset, which is why CCh is often confused for dry eye.[2]

It's fascinating that some of the worst cases (with significant pleating and prolapse) I've ever seen are totally asymptomatic, yet some with only minimal CCh inferiorly have tremendous discomfort from the mechanical irritation and disruption of their tear film.[2,3]

In its most severe forms, CCh can cause blurred vision, mucus discharge, fatigue, dryness, tearing and subconjunctival hemorrhage.[2] Epiphora secondary to CCh is thought to be due to two distinct causes: (1) reduplicated folds of conjunctiva disrupt the tear lake or (2) the conjunctiva causes a mechanical blockage of the inferior punctum.[1] These two cases keep inflammatory cytokines (IL-6 and IL-8) on the ocular surface, increasing the chances of MMP activation and discomfort. An additional breakdown of conjunctival elasticity and progression of CCh is possible.[1]

An interesting study performed in 2015 at a Veterans Affairs hospital showed the location of CCh to be important. The study analyzed the relationship between CCh and symptoms and signs of dry eye.[3]

Patients with nasal CCh had the most severe symptoms by OSDI scores when compared with patients with CCh elsewhere or no CCh at all. Nasal CCh patients also had a more abnormal tear film with decreased Schirmer scores, increased meibomian gland dropout and increased eyelid vascularity.[3] Those with nasal CCh experienced more throbbing and light sensitivity than those with non-nasal CCh.[3]

Placing a finger on the area that the patient describes as being painful and having them look up and down will reproduce the characteristic pain and aid in a helpful diagnosis.[4]

TREAT AND MANAGE

Most often, the extent of signs and symptoms that present to the office affects how we manage CCh. Some patients with very dramatic presentations might have no complaints and require no treatment, just observation. If the patient is symptomatic, topical agents, such as artificial tears, antihistamines and steroids, are a reasonable approach.

The goal is to reduce any disruption of the tear film and inflammatory chemical mediators. Using ointment and patching at night may provide some relief if the CCh is severe.[1] Also address all additional confounders, including any ocular-related allergy, meibomian gland disease and blepharitis.

Surgery is a reasonable option when targeted medical management fails. Several approaches to offer patients are conjunctival excision with Tisseel (fibrin sealant, Baxter Healthcare), conjunctival fixation to the sclera (incisional glue), amniotic membrane transplantation and superficial thermocautery.[2] Radiofrequency treatment will generally be less traumatic to the ocular surface than thermocautery. Re-establishing the fornix is key to avoid scarring and the development of a cicatricial entropion.[1]

So, is CCh its own clinical entity, a masquerade of dry eye or just an extension of it, since the eye can only respond with so many symptoms? Regardless of what camp you fall in, this is a condition that can't be missed but unfortunately often is.

CCh remains the most common reason for recurrent subconjunctival hemorrhages, causes a wide range of symptoms, including significant tearing, burning and irritation in many older patients, and is easily treated in-office. The mystique remains, but, fortunately, we have good remedies to treat CCh when not overlooked. RCCL

1. Bert BB. How to manage conjunctivochalasis. Rev Ophthalmol. 2017;24(9):36-38.

2. Lozano AFI, Larrazaabal LI. Conjunctivochalasis. eyewiki.aao.org/Conjunctivochalasis. Last modified March, 13, 2019. Accessed April 1, 2019.

3. Chhadva P, Alexander A, McClellan, et al. The impact of conjunctivochalasis on dry eye symptoms and signs. Invest Ophthalmol Vis Sci. 2015;56(5):2867-71.

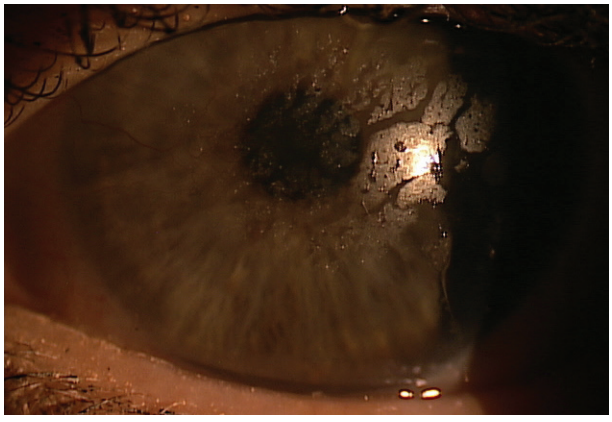
4. Hovanesian J. March 2019. Personal communication.

By Robert Ensley, OD, and Heidi Miller, OD

Spirits in the Material World

What a lens is made of has huge implications for your ability to achieve a successful fit.

Scleral gas permeable contact lenses have seen a surge in popularity over the past decade, but they have been evolving since the late 19th century. Practitioners, past and present, learn the options at their disposal and make the best choices for their patient's benefit. Follow in their footsteps and be cognizant of the various factors that make up today's GP lens materials.



Patients with ocular surface disease or an unstable tear film may suffer from poor surface wettability.

Glass remained the primary material used to design contact lenses from 1887 until 1936, when William Feinbloom manufactured a scleral lens that combined glass and plastic to make the lens thinner and easier to wear.[1]

In 1948, Kevin Tuohy's patent for what would become the first corneal contact lens described a lens made from polymethyl methacrylate (PMMA).[1] The lens design had blunt edges and fitted flatter than current methods but rested entirely on the corneal surface. PMMA remained the primary rigid lens material until the introduction of the more oxygen permeable silicone-based lens in 1979.[1]

MODERN MATERIALS

To improve the nonexistent oxygen permeability (Dk) of PMMA lenses, silicone side branches were added to the methacrylate monomer, increasing the space between the polymer chain and allowing for an increased flow of oxygen.[1,2] While lenses made from this silicone/acrylate (S/A) copolymer have a higher Dk, silicone is inherently hydrophobic, which may result in poor wettability and a surface prone for deposition. Wetting agents and crosslinking agents can also be added to the polymer to attract water molecules and increase the rigidity, respectively.[1]

The next generation of GP lenses added fluorine, which, in addition to being more resistant to deposition, also aids in oxygen transmission.[1] Fluoro-silicone/acrylate (F-S/A) materials have less silicone, allowing increased stability of the lens while still retaining a high level of oxygen permeability. Their specific characteristics vary, but the vast majority of GP materials being used today are F-S/A polymers.

MATERIAL PROPERTIES

Designing GP lenses is a fully customizable process. Base curve, diameter and power are paramount to an order, and material choice can easily become an afterthought. To choose a material, a basic familiarity with material properties is essential.

Oxygen permeability. When classifying GP lenses based on Dk, they can be split into three categories: low Dk (25 to 50), high Dk (51 to 99) and hyper Dk (≥100).[1]

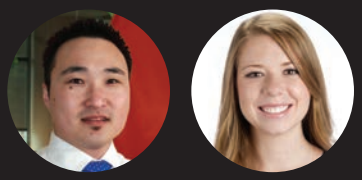
However, the amount of oxygen transmission through an individual lens is also dependent on the thickness of each lens (Dk/t). If lenses are made with identical materials and Dk values, the Dk/t will decrease with increasing center thickness.

Surface wettability. This refers to how well the tear film spreads across the contact lens surface. Disruption or evaporation of the tear film from the anterior surface can increase deposition and may affect both the quality of vision and comfort of the lens.

Similar to the effect of a reduced tear break-up time, a GP lens that does not have an even tear layer will cause fluctuating vision that is often described as foggy or smeared. *In vitro*, wettability is measured by the wetting or contact angle. For GP lenses, the wetting angle is measured by captive bubble technique.

When a GP lens is submerged in water, the wetting angle is formed between the surface of the lens and an air bubble placed on the surface by a syringe. A wetting angle of zero would be a completely wettable surface, so lower wetting angles are desirable.[3] Nevertheless, wetting angles and clinical performance don't always correlate, since tear film chemistry can affect lens wettability.

Even with lower wetting angles, patients with ocular surface disease or an unstable tear film may



still suffer from poor wettability. These patients may benefit from the addition of Hydra-PEG (Tangible Science) coating.

Specific gravity and refractive index. Specific gravity (SG) is the ratio of the density of a solid, in this case the GP lens, to the density of equal volume of water (SG=1.00) at the same temperature. Materials with a higher SG will therefore have a greater mass. Changing the SG can affect the lens mass by up to 20%.[4]

Similar to spectacle lenses, a GP lens with a higher refractive index (RI) will be thinner, which can reduce lens mass. A higher RI can also produce a higher add power on a front surface aspheric multifocal.[5]

Hardness and modulus. The hardness of plastics, including GP lenses, can be measured using the Rockwell R or Shore durometer methods. The two tests measure the resistance to indentation from various weighted loads. Although neither test can predict strength or scratch resistance, they can suggest a higher degree of durability. Shore hardness can also serve as a general indicator for modulus.[6] Modulus describes the flexibility of a material, with a higher modulus resulting in a stiffer lens. Lower modulus lenses may cause flexure, especially on an astigmatic cornea.

CHOOSING A MATERIAL

While there is no algorithm for choosing a material, the approach will typically differ between scleral lenses and corneal GPs. For scleral lenses, oxygen permeability and surface wettability are arguably the most important considerations for choosing a material. Maintaining corneal health should be at the forefront of every scleral fit, especially with diseased and compromised corneas. The larger diameter lens will vault over the cornea, and the stagnant fluid reservoir will slow the diffusion of oxygen, depending on the varying amount of clearance beneath the lens.

Hyper-Dk materials are chosen as a default, but certain ocular conditions where hypoxia is of greatest concern, such as post-penetrating keratoplasty or limbal stem cell deficiency, will require the highest oxygen permeability available. Higher-Dk lenses tend to have less silicone, therefore tend to have a lower modulus and lower durability. Depending on the thickness of the lens and the haptic system, these lenses may be more prone for flexure or torsion.

Advise patients with scleral lenses on the proper care regimen to avoid scratching the lens surface or warping the lens. The greater surface area of scleral lenses also increases the importance of surface wettability.

With corneal GPs, pay attention to the patient's ocular anatomy, tear film, refractive error and visual demands. Lens centration, comfort and optics tend to be more important factors leading to a successful outcome. Tear exchange will often mitigate the need for a hyper-Dk material, but Dk must be considered when dealing with high refractive errors. High myopic powers will have a thinner center thickness, so a lower Dk lens may provide a more stable fit. Conversely, high hyperopic lenses will be thicker, making a higher Dk more appropriate to increase Dk/t.

Lens thickness may also affect lens mass, which can be increased or decreased by changing SG and RI. To improve centration, a high-riding, lid-attached fit may need a larger, heavier lens, while a low-riding or interpalpebral fit may need a lens with less mass. Despite the smaller surface area, if patients have a poor tear film or have trouble with their cosmetics, wettability and deposition can be an equal nemesis to corneal GPs.

If plasma treatments or Hydra-PEG are considered, keep in mind that not all cleaning and care regimens are compatible with these. If patients are set in their ways with an abrasive cleaning regimen or tap water rinse, choosing a material with lower silicone may improve the wettability before adding plasma treatments or Hydra-PEG.

Unfortunately, experience will remind us there is no material that can be universally used for every patient, but understanding each one's properties can help us make the best choice. RCCL

1. Bennett ES. Gas-permeable material selection. In: Bennett ES, Henry VA, eds. Clinical Manual of Contact Lenses. 4th Ed. Philadelphia, PA: Lippincott, Williams & Wilkins; 2014:89-111.

2. Musgrave CSA, Fang F. Contact lens materials: A materials science perspective. Materials. 2019;12(2):261.

3. Campbell D, Carnell SM, Eden RJ. Applicability of contact angle techniques used in the analysis of contact lenses, part 1: comparative methodologies. Eye Cont Lens. 2013;39:254-62.

4. Ghormley NR. Specific gravity–does it contribute to RGP lens adherence? Int Contact Lens Clin. 1991;18:125.

5. Bennett ES. GP insights: how high index GP materials will impact your practice. CL Spectrum. February 2009.

6. MatWeb material property data. Shore (durometer) hardness testing of plastics. www.matweb.com/reference/shore-hardness.aspx. Accessed March 19, 2019.

Highlights from ARVO 2019: ABSTRACT REVIEW

Get the scoop on new research that may change your approach to many aspects of anterior segment care.

By *Review of Optometry* staff

The annual Association for Research in Vision and Ophthalmology (ARVO) meeting is always a boon for the eye care profession. Clinicians gain access to an entire year's worth of research—which can be both exciting and daunting. Here, we have selected studies we feel may be most impactful for practicing optometrists and reviewed a handful of abstracts. While the new tools, therapies and management strategies recapped here only give a small taste of the findings showcased in Vancouver, even this brief showcase—15 abstracts in all—packs in many exciting new ideas.

KERATOCONUS

Several researchers took a close look at the pathophysiology and management of keratoconus:

Pathophysiology. A team of researchers found that keratoconus patients with a European background presented with less severe indicators of disease compared with keratoconus patients of Indian or Asian descent. This observational study recruited keratoconus patients from public and private ophthalmology clinics in Australia, Hong Kong and India. The team evaluated 1,472 eyes of 736 patients. Of these, 55% were European, 18% were Asian, 18% were Indian and 9% were other ethnicities.[1]

While researchers found no statistical difference in age of onset between European patients compared with each of the other ethnic groups, they did note that Indians tended to be older at onset. The team observed that the mean anterior corneal curvature was flatter among Europeans, and the spherical equivalent was least severe. The mean corneal pachymetry was thinner among Indians than Europeans and Asians at the apex and the thinnest location.[1]

"These findings have important clinical implications when interpreting studies from different regions and contribute to the understanding of risk factors and future management strategies of keratoconus," the study authors conclude.[1]

"A global registry would be helpful to define additional differences that may aid in patient management," says Joseph Shovlin, OD, of Northeastern Eye Institute in Scranton, PA.

Management. Researchers recently found that patients who wear scleral contact lenses for keratoconus had a significantly lower risk of requiring keratoplasty, which may warrant the lenses' wide-scale use for the condition.[2] The team noted that 2.03% of patients wearing scleral lenses required keratoplasty, compared with 6.82% of those who did not wear scleral lenses.[2] Lens wear was also associated with a 72.7% decreased risk of requiring keratoplasty.[2] They add that other factors associated with an increased risk for keratoplasty included black race (vs. white), younger age and lower socioeconomic status of a participant's residential neighborhood.[2] "Scleral lenses have changed the treatment paradigm in managing patients with non-inflammatory thinning disorders, such as keratoconus, primarily because they provide exceptional comfort and vision," says Dr. Shovlin. "Most transplants are a result of patients not achieving comfort or adequate vision with contact lens correction."

Investigators from Japan say accelerated corneal collagen cross-linking (A-CXL) has the added benefit of causing less haze and fewer long-term risks of continuous flattening. Doctors and patients alike have reason to prefer the A-CXL protocol, they feel, because it reduces procedure time, as long as outcomes aren't compromised relative to conventional CXL.[3]

The team of researchers looked at 22 eyes of 21 progressing keratoconus patients who underwent epithelium-off CXL treatment. Twelve eyes of 11 patients underwent conventional CXL, which involves a 0.1% riboflavin instillation and a 3.0mW/mm^2 UVA irradiation for 30 minutes. The other 10

underwent A-CXL, which uses a higher-intensity 18mW/mm^2 UVA irradiation for only five minutes.[3]

While best-corrected visual acuity (BCVA), thinnest corneal thickness and corneal endothelial cell densities were similar between the two groups, steepest K values were significantly different, with the conventional CXL patients showing more flattening compared with the A-CXL patients at one year—and the difference increased through the five-year study period. Also at five years, 58.3% of the conventional CXL group had flattening Ks of more than 1D—none in the A-CXL group exhibited the same finding. Finally, corneal densitometry was significantly higher after conventional CXL than A-CXL from one month to one year after the procedure.[3]

"With similar efficacy, the abbreviated/shorter version should be employed to reduce risk," says Dr. Shovlin.

Another study discovered that significant changes in the inflammatory molecular profile occur at least one month after CXL. Researchers from Mexico found decreases in proinflammatory cytokines, especially metalloproteinase-9 (MMP-9), c-reactive protein (CRP) and interleukin-19. The study assessed 40 eyes of 20 patients, of which 20 underwent A-CXL. Researchers analyzed patients one day, one week, one month and three months after the procedure. After one month, they found a more-than-twofold decrease in specific cytokines in patient tears. More proinflammatory cytokines also began to decrease by three months. Researchers believe studies with longer follow-up will help prove whether these changes last and how they correlate with clinical outcomes.[4]

A study conducted in Germany suggests practitioners examine keratoconus patients at regular intervals, especially five years after performing CXL, to recognize and re-treat progression early. Researchers defined a satisfactory response to CXL as a postoperative Kmax stabilization of an increase of more than 2D or any decrease in Kmax. They analyzed 168 eyes of 131 patients who were treated with standard CXL.[5]

After CXL, median K2 increased by 0.1D after one year but decreased over the remaining 10-year postoperative period by 0.85D. Mean apical corneal thickness decreased by 11µm, 9µm and 3µm after three, seven and 10 years, respectively. Mean BCVA significantly increased by 0.14 after two years and by 0.15 after five and 10 years. One, seven and 10 years post-CXL, 87.8%, 81.1% and 66.7% of eyes met the responder criteria, respectively. The researchers re-treated four eyes. There were no complications in repeating CXL, and keratoconus stabilized afterward.[5]

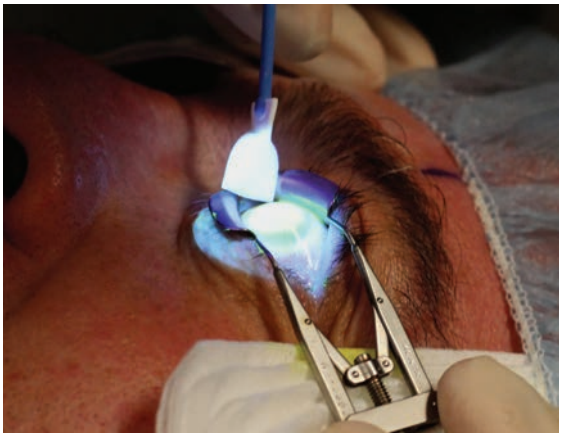


Photo: Marshall Ford, MD, Pacific Cataract and Laser Institute

A-CXL, which uses a higher UVA irradiation for a shorter amount of time, was found to have fewer risks of corneal flattening.

OTHER CORNEAL COMPLICATIONS

To help differentiate keratoconus from pellucid marginal degeneration (PMD), Iranian researchers found that four fundamental parameters could be considered as diagnostic signs to characterize all stages of PMD, including subclinical disease:[6]

1. An inferior flattening island, defined as the flattening area surrounded by steep areas inferior to the horizontal axis.
2. An apple-shaped pattern formed by mean power area as a yellow strip.
3. Superior flattest area, defined as the presence of the flattest area at the superior quadrant.
4. Against-the-rule irregular astigmatism (flat meridians at 45 to 135 degrees).

Additionally, the investigators noticed that measuring the extent of the inferior flattening island could be helpful for staging PMD and identifying early PMD. Based on these parameters, investigators were able to differentiate 36 cases of PMD from keratoconus.[6]

"Some patients with keratoconus have similar features depending on the level of severity," says Dr. Shovlin. "The most definitive way to differentiate would be to look at higher-order aberrations where PMD has a high level of trefoil and keratoconus has more vertical coma in general."

Pterygia are more common on the nasal side of the cornea than the temporal side—15 times more likely, to be precise. But researchers aren't quite sure why. One group found that total UV irradiation in the nasal limbus is not greater than in the temporal limbus, contrary to popular belief. The team created

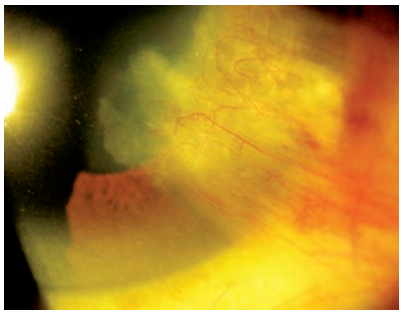


Photo: Andrew Gunwood, OD

One study disproved the popular peripheral light–focusing effect theory for pterygia formation.

a corneal model using custom software and the corneal surface and UV refractive index data from a previous study to simulate the impact of the UV across the cornea.[7]

"This study essentially rules out the peripheral light focusing effect theory for pterygia formation," explains Dr. Shovlin. The researchers offer an alternative explanation: that the temporal-to-nasal flow of tears over the UV-exposed cornea causes the accumulation of toxins on the nasal limbus.[7]

"If this theory is correct, additional ocular surface disorders may be explained by the temporal-to-nasal tear flow dynamics to facilitate drainage to the punctal area," adds Dr. Shovlin.

DRY EYE

Many of the dry eye advances presented at ARVO focused on new diagnostic tools:

A new hyperspectral imaging method can measure the mucoaqueous layer thickness as well as other tear film functions. The tear film imager (TFI) is designed to give doctors objective and observable measures to aid the diagnosis and management of dry eye disease (DED). The TFI, which takes approximately 40 seconds, can measure patients' aqueous layer thicknesses and averages at a nanometer level. Additionally, it can measure the lipid layer thickness at a sub-nanometer level and establish average thickness and lipid break-up time (LBUT).[8]

The international team of investigators found that the TFI method could accurately diagnose DED with 87% sensitivity and 88% specificity. Of particular interest, the reproducibility of the mucoaqueous layer thickness measurement, which has not been evaluated with any prior technology, was significantly correlated with Schirmer scoring, and the LBUT scoring was significantly correlated with tear break-up time (TBUT) scoring.[8]

To measure a patient's tear osmolarity, clinicians now have two options: the Tearlab osmometer and the I-Pen (I-Med Pharma) osmometer. However, they should be careful to avoid using the readings interchangeably. Researchers from Ludwig Maximilians University in Munich have found that the I-Pen provides significantly higher osmolarity results compared with the Tearlab device. The team studied 51 healthy subjects—none of whom had clinically evident dry eye—with each device. They speculate that the location of the testing—tear meniscus vs. the palpebral conjunctiva—could account for the difference.[9]

If clinicians use Tearlab's cut-off value of 308mOsm/l for normal osmolarity, 98% of the study participants would be considered normal, compared with only 68% when testing with the I-Pen. Thus, the researchers conclude that doctors should consider using a higher cut-off value (between 316mOsm/L and 320mOsm/L) when testing patients with the I-Pen.[9]

To help optometrists and ocular surgeons better anticipate iatrogenic dry eye in their patients, Italian researchers built a new clinical tool, the Ocular Surface Frailty Index (OSFI). The noninvasive, low-tech procedure can help predict postoperative DED, allowing surgeons and comanaging optometrists to perform useful personalized preoperative risk assessments. This new method includes 20 clinical factors to assess preoperatively that help to uncover any health deficits relevant to dry eye.[10]

Researchers identified three distinct categories: mild frailty (OSFI ranging from 0 to 161), moderate frailty (162 to 322) and severe frailty (more than 323). Of the total study participants, 16.2% developed DED within one month after surgery, and the rate significantly increased from 10.2% to 38.1% from the lowest to the highest frailty category. They also discovered that OSFI (but not age and gender) was significantly associated with postoperative DED onset.[10]

"This is a great example of precision medicine delivered in a personalized fashion by providing a frailty risk assessment to predict the likelihood of adverse conditions occurring after a surgical procedure," says Dr. Shovlin.

A new approach to identifying DED measures the physical properties of the tear film, particularly the effective extensional viscosity, which researchers measured using acoustic rheometry. The Melbourne-based team found this metric is compromised in DED. In addition, a lower effective extensional viscosity is associated with more severe DED, and a moderate positive correlation existed between effective tear film extensional viscosity and noninvasive TBUT. The authors believe their results support the utility of tear effective extensional viscosity as a novel test for diagnosing DED in clinical practice.[11]

"Other fields in healthcare have used rheometry, and this

CLEAR CARE® PLUS
SUCCESS MADE SIMPLE

William Townsend, OD, FAAO

Advanced Eye Care
Canyon, TX

Dr. Townsend was compensated by Alcon for his participation in this testimonial.

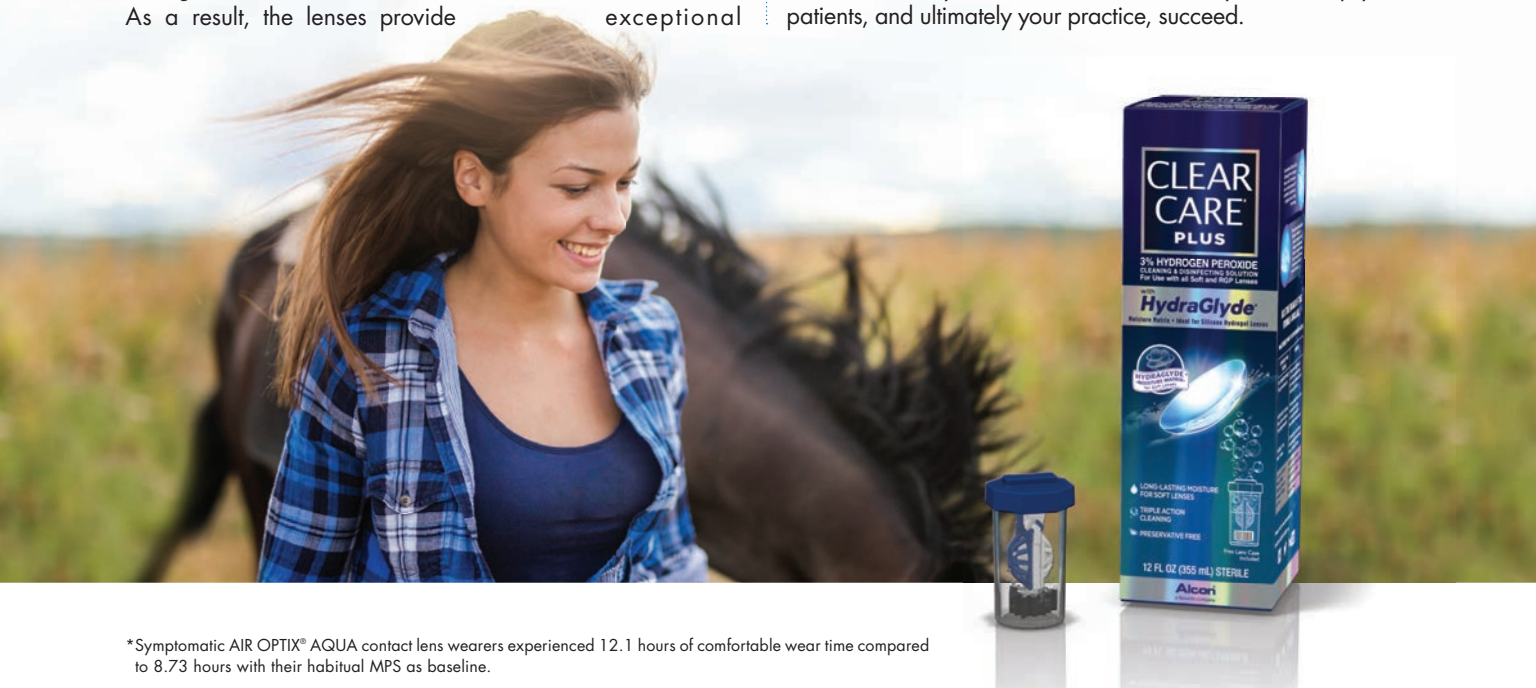
My practice is located in a hot and dry part of the country, where seasonal changes and dry environments pose a significant challenge for my patients to maintain comfortable contact lens wear. For instance, with summer upon us, my patients are engaging in more outdoor activities like long walks, horseback-riding and hiking. Such activities expose them to dry air and can really take a toll on their contact lens wearing experience. While I recommend lenses with materials and surface technologies designed to help increase my patients' comfort, I truly believe that the right lens care solution can go a long way in making contact lens wear more comfortable. To me, particularly for all of my weekly and monthly replacement lens-wearing patients, that solution is CLEAR CARE® PLUS.

What makes CLEAR CARE® PLUS stand out is the wetting agent, HydraGlyde® Moisture Matrix, which envelops the lens in long-lasting surface moisture,[1,2] and makes lenses feel like new.[3] As a result, the lenses provide exceptional end-of-day comfort.[4] For these very reasons, I myself was an early user of CLEAR CARE® PLUS and was very impressed by how comfortable my eyes felt throughout the day. When I recommend CLEAR CARE® PLUS to my patients, they notice it as well. Many of them tell me that when they use CLEAR CARE® PLUS, they are able to wear their lenses (regardless of brand) for a full day without discomfort, which complements a recent study that showed an increase of 3 hours of comfortable wear time per day after using CLEAR CARE® PLUS for 30 days.[4]*

> One of my nature-loving patients raved about how she can participate in outdoor activities for long periods of time without her lenses getting dry and uncomfortable.

One of my nature-loving patients raved about how she can participate in outdoor activities for long periods of time without her lenses getting dry and uncomfortable. Especially in our climate, my patients' success with CLEAR CARE® PLUS is a true testament that the product delivers outstanding all-day comfort.[4]

My patients love how their lenses feel with CLEAR CARE® PLUS, and I can rest assured that it gives my patients exceptional protection against ocular infections while being easy for them to use.[3,5,6] At the end of the day, satisfied patients can translate into a successful practice, and CLEAR CARE® PLUS is the lens care solution that will help make that happen. By recommending that they clean and disinfect their lenses daily with CLEAR CARE® PLUS, you will help your patients, and ultimately your practice, succeed.



*Symptomatic AIR OPTIX® AQUA contact lens wearers experienced 12.1 hours of comfortable wear time compared to 8.73 hours with their habitual MPS as baseline.

References 1. Muya L, Scott A, Alvord L, Nelson J, Lemp J. Wetting substantivity of a new hydrogen peroxide disinfecting solution on silicone hydrogel contact lenses. Poster presented at the British Contact Lens Association 39th Clinical Conference & Exhibition, Liverpool, UK, May 29-31, 2015. **2.** Alcon data on file, 2014. **3.** Alcon data on file, 2016. **4.** Alcon data on file, 2016. **5.** Gabriel M, Bartell J, Walters R et al. Biocidal efficacy of a new hydrogen peroxide contact lens care system against bacteria, fungi, and Acanthamoeba species. *Optom Vis Sci*. 2014;91:E-abstract 145192. **6.** Alcon data on file, 2014.

SEE LOOK FEEL

Sponsored by Alcon A Novartis Division

technology may be employed someday as a device marker for identifying DED and stratifying it by severity," notes Dr. Shovlin.

A long-term, high-fat diet may reduce the lacrimal gland's tear secretion ability, which in turn could cause dry eye, a new study claims. The investigation included mice that were given either a standard or high-fat diet for different durations over one to four months. After one month, the study found mice on the high-fat diet had decreased tear secretion.[12]

This type of diet could induce lipid peroxidation, inflammatory cell infiltration, mitochondria damage, an increase in cell apoptosis and proliferation inhibition in the lacrimal gland. This could result in aqueous tear secretion decrease, which may induce dry eye, the researchers said.[12]

"Inflammation and associated structural morbidity has been shown to be evident in many DED studies, including this one, and continues to drive home the point that inflammation is both the cause and effect of DED," explains Dr. Shovlin. "Diet influences many aspects of health, including influences in biomarkers in even more morbid diseases."

CONTACT LENSES

Researchers from the Brien Holden Vision Institute presented new findings that suggest a patient's comfort in contact lenses affects their visual satisfaction—and vice-versa. For non-presbyopic patients wearing single vision lenses, changes in vision satisfaction affected their comfort rating, but changes in comfort didn't necessarily impact their vision ratings. The opposite seems to be true for those wearing multifocal designs. Changes in their ocular comfort during lens wear led to changes in their vision rating more than vision changes impacted their comfort ratings.[13]

"Consideration of participant characteristics, visual stimulus and contact lens comfort needs to be accounted for when assessing overall contact lens experience," explains Dr. Shovlin. "Probably not too unexpected, ocular comfort is of greater significance in non-presbyopic lens wearers, while vision satisfaction is of greater significance in the presbyopic group."

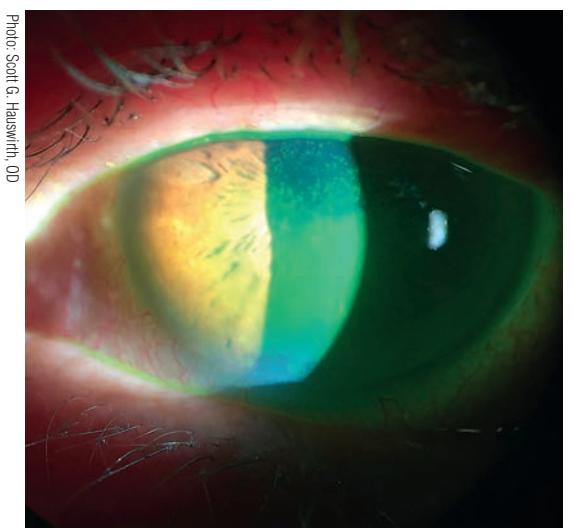


Photo: Scott G. Hauswirth, OD

A cytokine coating for soft lenses could provide sustained dry eye treatment.

University of Pittsburgh researchers developed a cytokine coating for silicone hydrogel lenses they believe could provide a sustained treatment for dry eye. Interleukin-4 (IL-4) has been shown to polarize macrophages from the inflammatory M1 phenotype—which is prevalent in DED—to the anti-inflammatory M2 phenotype. IL-4 can be incorporated into a nanometer-thick coating to mitigate the foreign body reaction to implantable polypropylene mesh, but the application to other devices has not yet been established, the study observes.[14]

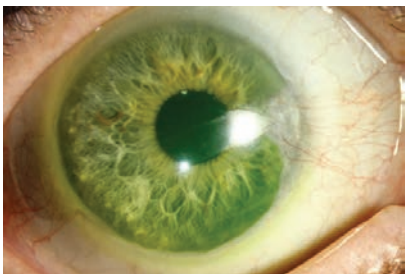


Photo: Christine Sindt, OD

Patients who wear sclerals for keratoconus had a lower risk of requiring keratoplasty.

The study found a uniform and conformal blue stain remained on lenses dipped in oppositely charged polymers (compared with control lenses), which shows successful application of the polymeric coating to the lens, investigators said. Additionally, IL-4 release kinetics from a coated lens incubated with enzymes showed a sustained release of IL-4 over several days, the researchers noted. There was little release of IL-4 from a coated lens in the absence of enzymes, indicating the coating was degraded primarily by enzymatic means, the study noted. "Our results support the hypothesis that our polymeric IL-4 releasing coating can be applied to contact lenses with a resulting sustained release of drug over days vs. the transient burst release seen with eye drops," the investigators wrote in their abstract.[14]

TECH ADVANCEMENTS

Treatments for corneal blindness are limited by a high rate of complications and may not be as effective in cases of severe ocular surface damage. With this in mind, researchers invented an intraocular implant that projects light directly onto the retina, bypassing

the damaged cornea—an alternative approach for treating corneal opacity. The device captures light via an external camera and then wirelessly sends data to an intraocular microdisplay.[15]

They found that the intraocular projector can restore vision in people blinded by corneal opacity, possibly providing a more accessible solution to those who may not be ideal candidates for cornea transplantation or keratoprosthesis. The researchers successfully constructed four functioning implants (9.5mm x 7mm x 7mm). With a lens placed 4mm from the microdisplay (focal length of 3mm), they found that the devices produced a visual acuity of up to 20/127.[15]

"This device appears to provide high levels of functional vision with few complications and should be a viable alternative for patients who are at high risk for failure with currently available surgical options," Dr. Shovlin says.

This remarkable body of research continues to broaden horizons for practitioners and provide useful knowledge beneficial for the patients under their care. This is just a sampling of the findings presented at ARVO—the conference boasted so much more worth exploring. Check out ARVO's full listing of abstracts to see for yourself the other latest advances in disease pathophysiology, diagnosis and management. RCCL

1. Sahebjada S, Chan E, McGuinness M, et al. Assessment of clinical parameters by ethnicity in patients with keratoconus: a multi-country study. ARVO 2019. Abstract 321.

2. Ling JJ, Mian S, Stein JD, et al. Impact of scleral contact lens use on risk of requiring corneal transplantation for keratoconus. ARVO 2019. Abstract 4779.

3. Kato N, Negishi K, Sakai C, et al. Five year outcomes of corneal collagen crosslinking: accelerated crosslinking induces less corneal haze and less continuous corneal flattening compared to conventional crosslinking. ARVO 2019. Abstract 313.

4. Mendoza-Garcia DLT, Del Valle CP, Robles-Contreras A, et al. Corneal crosslinking effects on tear inflammatory mediators in patients with keratoconus. ARVO 2019. Abstract 336.

5. Seifert F, Seufert F, Hommes D, et al. Ten year results after corneal collagen crosslinking with riboflavin and UV-A irradiation (CXL) for keratoconus—when to repeat CXL? ARVO 2019. Abstract 339.

6. Safi S, Jafarinasab M, Feizi S, et al. A new topographic "quad signs" for diagnosis and grading of pellucid marginal degeneration. ARVO 2019. Abstract 2104.

7. King-Smith P, Mauger T, Begley C, Tankam P. Does the peripheral light focusing effect explain the strong nasal location preference of pterygia? ARVO 2019. Abstract 4701.

8. Gefen R, Segev F, Geffen N, et al. A new hyperspectral imaging method to evaluate dry eye disease—3D-WLT study results. ARVO 2019. Abstract 6780.

9. Messmer EM, Schaumberger MM, Proglinger S, Koenig SF. Evaluation of tear film osmolarity using Tearlab and I-Pen osmometry. ARVO 2019. Abstract 6773.

10. Villani E, Marelli L, Lucentini S, et al. The Ocular Surface Frailty Index as a predictor of dry eye onset after cataract surgery. ARVO 2019. Abstract 6776.

11. Downie LE, Lee J-H, Makrai E, et al. A novel approach to identifying dry eye disease using acoustically-driven microfluidic extensional rheometry. ARVO 2019. Abstract 4189.

12. He X, Zhao Z, Bu J, et al. High fat diet induced functional and pathological changes in lacrimal gland. ARVO 2019. Abstract 1416.

13. Diec J, Naduvilath TJ, Tilia D, Bakaraju RC. The relationship between vision and comfort in contact lens wear. ARVO 2019. Abstract 6366.

14. Jhanji V, Nolfi A, Kulkarni M, et al. Polyelectrolyte multilayer coating for delivery of IL-4 from contact lenses for dry eye disease. ARVO 2019. Abstract 262.

15. Fan V, Rosenblatt M, Sun M, et al. Intraocular microdisplay projection system for treating corneal blindness. ARVO 2019. Abstract 4697.

Getting Astigmatism in Focus with Advanced Imaging

Visual rehabilitation with contact lenses for patients who suffer from irregular corneas was a hit or miss, and often frustrating, endeavor. These patients typically were told that the only option available to them was corneal gas permeable contact lenses (GPs).

For fittings, practitioners used keratometry findings as a starting point and followed up with diagnostic GPs and a fluorescein evaluation. With the advent of today's advanced technologies, we are able to measure the shape of the cornea and the ocular surface with high precision, thus providing a far greater understanding of the disease state and an improved direction to better fit our patients.

We can also now evaluate visual performance with and without contact lenses in ways that were only available in the optics laboratory in the past. This article highlights cases that have incorporated many of the available advanced ophthalmic technologies that have made great strides in clinical success and efficiency.

PLACIDO-BASED CORNEAL TOPOGRAPHY

This imaging technology uses information processed from concentric rings reflected off of the anterior ocular surface in order to calculate corneal curvature. Since the reflection is actually off of the tear layer, its stability or instability will have a dramatic effect on the outcomes. The separation of the concentric rings helps calculate inferred corneal curvature. The closer the rings are to each other, the steeper the curvature is at that location. The cumulative analysis of corneal curvature data then creates a topography map. Curvature data is an excellent way to infer the optical characteristics of the visual system since the majority of refraction takes place at the anterior ocular surface interface.

Evident in these subsequent case examples, one can analyze curvature data of the anterior cornea in order to predict refractive performance. Still, there are some significant limitations to information obtained from Placido-based corneal topography that often hinder our understanding of the disease state. These include, among others, an inability to measure the posterior cornea or the global corneal thickness.

ANTERIOR SEGMENT OCT AND CORNEO-SCLERAL PROFILING

Tomography is a two-dimensional representation of a three-dimensional structure. Ocular tomography provides imaging and analysis of multiple "slices" of the cornea and anterior segment. Specifically, Scheimpflug tomography uses a photographic imaging technology to provide a 360° analysis.

Anterior segment ocular coherence tomography (AS-OCT) can also provide similar imaging with even greater resolution in order to measure such structures as the epithelial corneal thickness. The two technologies are able to measure anterior and posterior corneal surfaces as well as a global area of corneal thickness.

Corneo-scleral profile analysis provides a detailed description of the anterior surfaces of the cornea and the sclera (*Figure 1*). With the increased popularity of scleral lenses, corneo-scleral profiling is revolutionizing our understanding of anterior segment shape and our ability to design lenses that contour, with great precision, a surface that is now known to be quite asymmetric.

CASE 1: IS IT PMD?

A 53-year-old woman was referred to our practice from a local optometrist for advanced contact lens management based upon a suspected diagnosis of pellucid marginal degeneration (PMD). The optometrist found significant against-the-rule astigmatism and performed Placido-based corneal topography, which reportedly found what has been described as a "crab claw" or a "kissing dove" pattern. Physical examination of the patient revealed

ABOUT THE AUTHOR

Dr. Eiden is the president and medical director of North Suburban Vision Consultants in Illinois and the president and cofounder of the International Keratoconus Academy.

Four cases provide insight into **diagnosing** and **managing** patients with the latest options.

By S. Barry Eiden, OD

no evidence of inferior thinning in the perilimbal zone of the cornea. There was evidence of mild Vogt's striae (grade 1) located inferiorly and paracentrally along with a mild and partial inferior Fleischer's ring. No corneal scarring was found. Manifest refraction revealed a highly myopic astigmatic refractive error (-5.00 -6.00x70) with a best-corrected visual acuity of 20/20-2.

In order to better understand the corneal condition, Scheimpflug-based corneal tomography was performed using the Pentacam (Oculus) instrument (*Figure 2*). Looking at the axial curvature display first revealed PMD's classic crab claw/kissing dove pattern; however, the elevation displays on the anterior and posterior cornea were quite typical of keratoconus. More importantly, the global pachymetry display showed that the thin point of the cornea was located coincident with the apex of the cone in an inferior paracentral position. In true PMD, the thinning of the cornea would be located inferiorly in the far periphery of the cornea, corresponding to an area about one to two inches from the limbus.

Another interesting observation in this case is the regularity of corneal curvature within the pupillary zone. Although six diopters of corneal astigmatism was measured by Pentacam via "Sim Ks," there was almost no irregularity to the pattern. As such, it was no great surprise that we were able to achieve very good visual acuity with manifest refraction. Contact lens management then allowed my team to consider using soft contact lenses. In fact, we were able to fit the patient in a custom toric multifocal contact lens (SpecialEyes near center progressive toric multifocal) and obtain 20/20 distance and 20/25 near visual acuity.

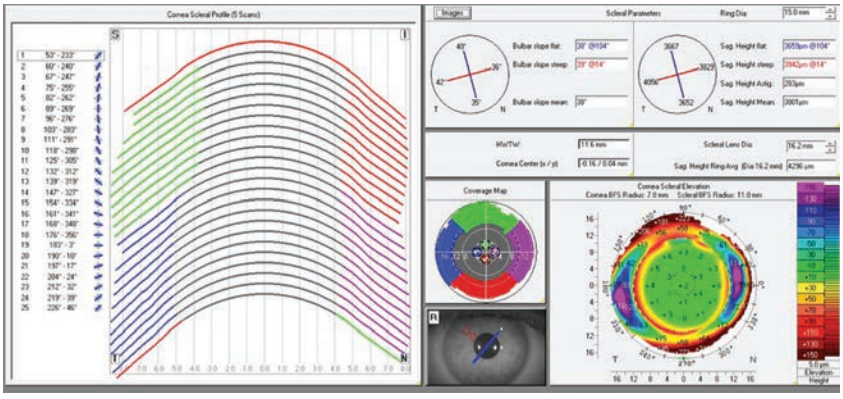


Fig 1. Corneo-scleral profile software from Pentacam tomography system.

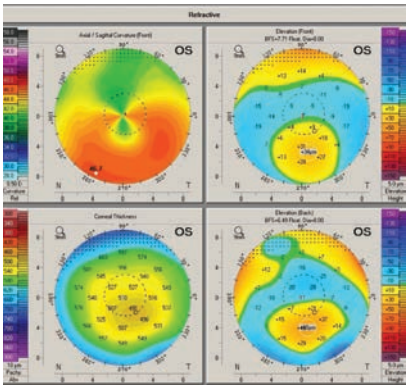


Fig 2. The upper right axial or curvature map of the anterior cornea shows the "crab claw" or "kissing dove" pattern.

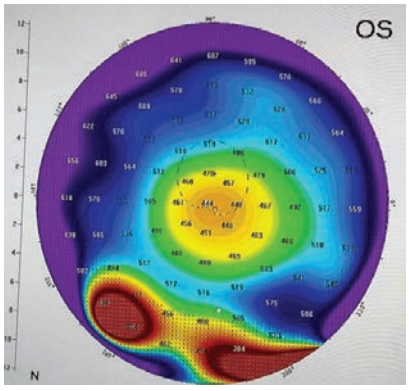


Fig 3. Global pachymetry display from Pentacam with area in true PMD shows the band of inferior peripheral corneal thinning.

Image: Tom Arnold, OD

Scheimpflug corneal tomography provides true elevation data from the anterior and posterior corneal surfaces as well as corneal curvature data (derived from elevation measurements). Additionally, it is able to measure global corneal thickness from limbus to limbus. This technology allows the clinician access to comprehensive information about the entire corneal structure. Beyond corneal measurements, Scheimpflug corneal tomography is also able to image out to the scleral surface (providing corneo-scleral profile data) and posteriorly as well to provide information and data

regarding the anterior chamber, iris and crystalline lens.

This case is an excellent example of the vast majority of instances where anterior corneal curvature maps show what was formerly thought to be PMD. From clinical experience, the overwhelming majority of cases with these curvature patterns have actually been true keratoconus when we look at elevation and global pachymetry results found from corneal tomography. One study described this phenomenon exquisitely.[1] When true PMD is found, the clinician will see a band of inferior corneal thinning typically located 1mm to 2mm in from the inferior limbus.[1] In addition, if one expands the area displayed on the global pachymetry map from a typical 8mm or 9mm to 12mm in cases of true PMD, one will now see the band of inferior thinning found in this disease (*Figure 3*). Wavefront aberrometry has also been suggested as a means to differentiate keratoconus from PMD. One study assessed higher-order aberrations and found greater amounts of vertical coma in keratoconus and greater amounts of trefoil in patients with PMD.[2] Another suggested that increases in coma-like aberrations of the cornea reflect the subclinical progression of PMD over the years.[3]

CASES 2 & 3: IS IT UNILATERAL KERATOCONUS?

A 57-year-old female was referred for contact lens management from an ophthalmology group based on a /diagnosis of unilateral keratoconus of the right eye. The referring doctor performed no corneal imaging. Diagnosis was based on biomicroscopy and manual keratometry in addition to a positive family history of keratoconus. Biomicroscopy revealed Fleischer's ring OD and grade 1 Vogt's striae (no scaring) OD and entirely normal OS.

Manifest refraction found best spectacle acuity OD at 20/30+ and OS at 20/15. Scheimpflug corneal tomography (Pentacam) revealed OD a classic keratoconus pattern of mild-moderate degree. The OS image revealed an inferior steep zone on anterior curvature but a normal central area. Elevation maps found a normal anterior elevation but an abnormal posterior elevation along with a borderline abnormal progression of global corneal thickness from center to periphery (*Figure 4*).

Abnormal posterior corneal shape and abnormal corneal thickness distribution or thickness progression are considered two of three critical diagnostic findings for keratoconus.[4] Aberrometry (Nidek OPD-Scan III) measured visual performance and found significant elevation of high-order aberrations

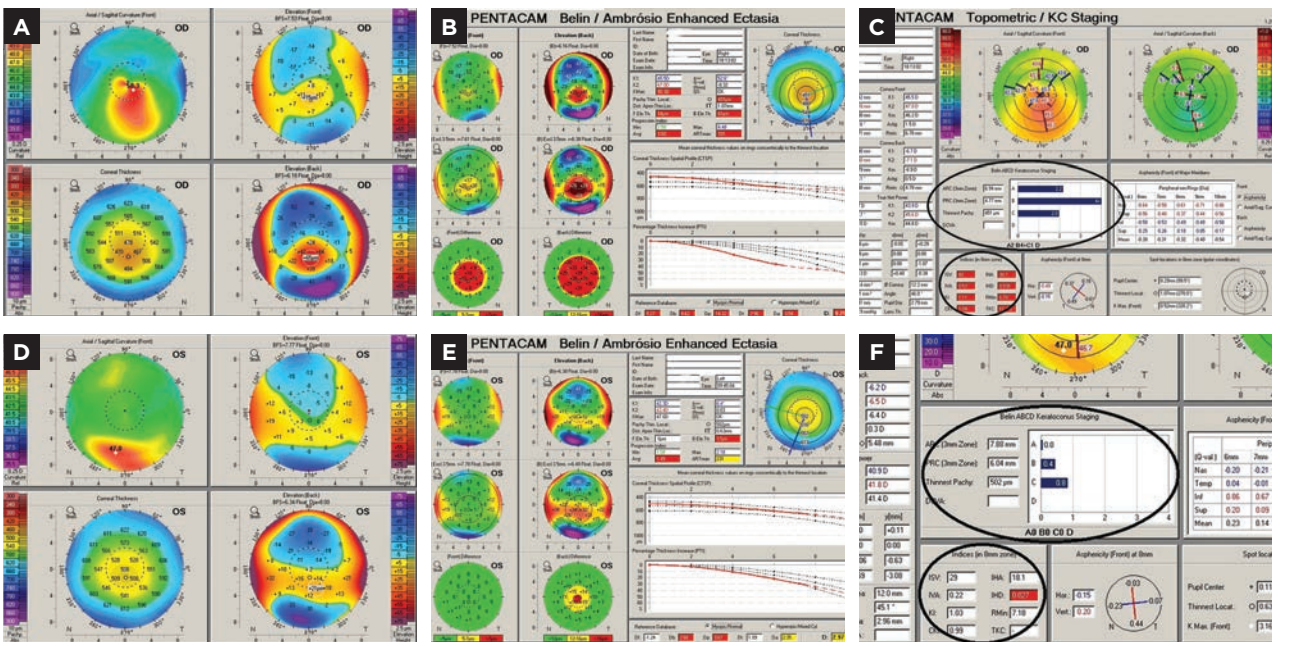


Fig 4. (a) Pentacam 4-Map Refractive Display OD with keratoconus patterns. (b) Pentacam Belin Ambrosio Ectasia Display OD with strongly positive ectasia detection. (c) Topometric Display OD shows strong keratoconus staging and abnormal keratoconus indices derived from the anterior corneal surface. (d) Refractive Display OS with inferior axial steepening, normal anterior elevation, mildly abnormal posterior elevation and what would appear to be normal corneal thickness. (e) Ectasia Display OS shows normal anterior elevation, abnormal posterior elevation and borderline corneal thickness distribution/progression with a statistically normal minimal corneal thickness reading. (f) Topometric display OS shows normal keratoconus staging values and anterior corneal keratoconus indices.

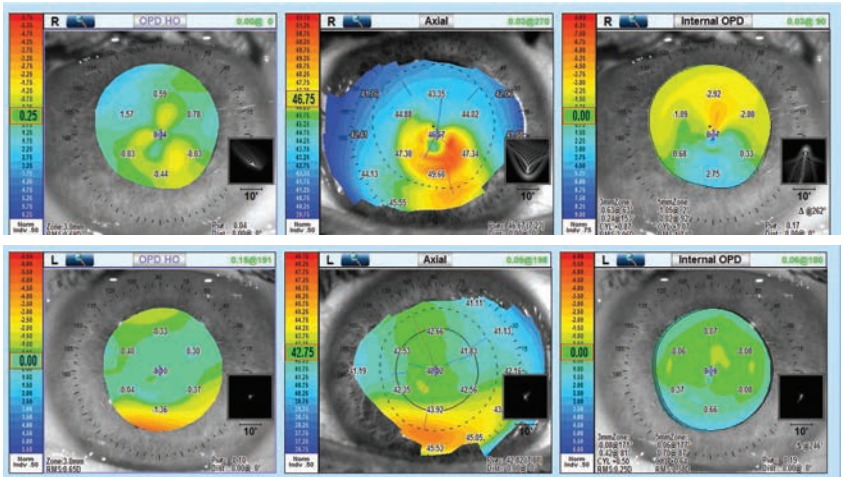


Fig 5. (Top) Aberrometry OD shows elevation of high-order aberrations of total, anterior corneal and internal. (Bottom) Aberrometry OS shows normal high-order aberration findings of all three.

(anterior corneal, internal and total aberrations) OD; however, OS had normal levels of high order aberrations, thus corroborating the excellent vision quality found with manifest refraction (*Figure 5*).

Aberrometry detects high-order aberrations that are found in keratoconus and can be present even in the presence of 20/20 visual acuity. As such, aberrometry has been shown to be influenced by early keratoconus as long as there is some shape anomaly of either the anterior or posterior cornea within the pupillary zone. In this case, corneal shape OS was entirely normal within the pupillary zone. The patient was subsequently successfully fit into corneal GP lenses with a posterior aspheric shape to provide presbyopic correction. Though it may be considered normal, the left eye surely suggests that the condition is bilaterally asymmetric. Based on the patient's age, there was a relatively low risk for progression, but annual monitoring of tomography has been performed.

A 42-year-old male was examined who had also been diagnosed and managed with what was thought to be unilateral keratoconus of the left eye for a number of years. Based on sequential Scheimpflug corneal tomography (Pentacam), there was no demonstrable progression in the left eye and no development of clinically detectable keratoconus in the left eye over this period of time (*Figure 6*). However, performance of AS-OCT allowed us to measure corneal epithelial thickness and produce an epithelial thickness map.

Variability of epithelial thickness across the cornea has been shown to be significantly greater in keratoconus compared with normal corneas.[5] A typical pattern often develops where there is epithelial thinning over the cone apex with a surrounding "donut" of epithelial thickening, but epi-thickness variability will show, earlier in the disease, an increase even before developing this pattern. In this case, although the Pentacam was found to be significantly abnormal OS and normal OD, there was a noted asymmetric bilateral increase in epi-thickness variability found with AS-OCT (*Figure 7*). Continued work in this area will tell us whether this indication of bilateral keratoconus might be found earlier in the course of the disease.

With the advent of corneal cross-linking and our ability to control keratoconus progression, early detection of disease and of progression have become critical in our ability to preserve vision. Detection of the disease and of its progression are dependent on both our definition of the disease and available diagnostic technologies.

Decades ago, classic biomicroscopic findings, scissors reflex with retinoscopy and distorted manual keratometry detected keratoconus. In fact, reports on the prevalence of keratoconus based on these diagnostic criteria likely have dramatically underestimated how common the condition actually is.[6] With the introduction of Placido-based corneal topography, eye care practitioners began to detect keratoconus at earlier stages where former diagnostic criteria were absent. Subsequent studies of keratoconus prevalence that included topographic findings resulted in significantly higher rates.[7]

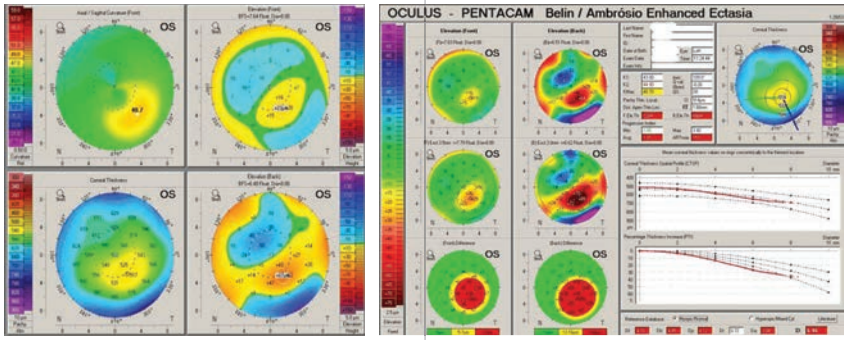


Fig 6. (Left) Pentacam OS 4-Map Refractive Display shows classic keratoconic patterns. (Right) Ectasia Display OS shows strongly positive ectasia detection.

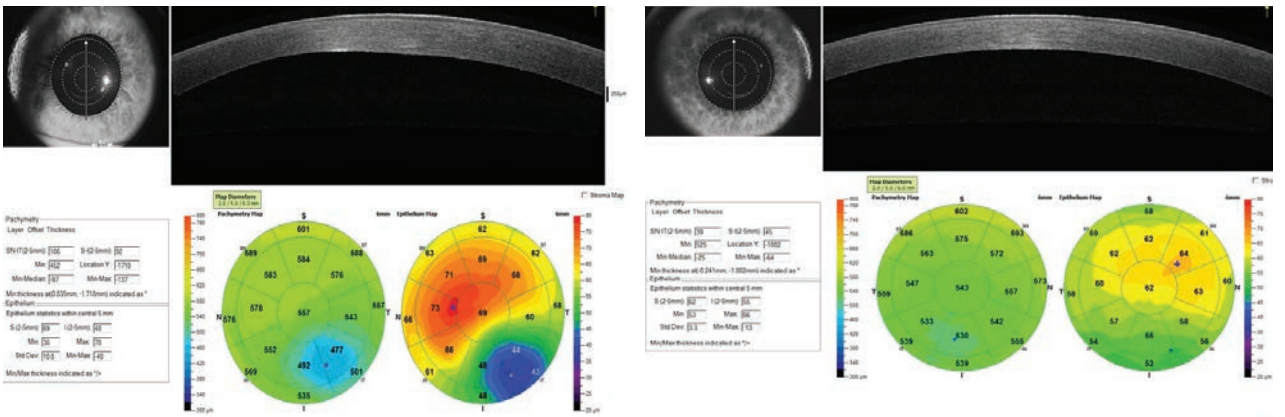


Fig 7. Pachymetry Display. (Left) OS shows abnormal global corneal thickness and a classic pattern of thinning of the epithelium over the cone apex and surrounding epithelial thickening. (Right) OD shows normal global corneal thickness but abnormal epithelial thickness distribution.

Today we are developing diagnostic technologies, such as Scheimpflug corneal tomography, AS-OCT with epithelial thickness mapping and clinically applicable aberrometry, that further push the boundaries of early detection. Beyond this, efforts are being made in corneal biomechanics and genetic screening to identify patients with pre-clinical keratoconus and those at high risk for its development.[8,9]

CASE 4: OUT TO THE CONJUNCTIVA

A 64-year-old Caucasian male was referred by a cornea group and their affiliated optometrist to manage a case of scleral lens intolerance of the right eye. The patient had a history of bilateral radial keratotomy (RK). He initially had good vision for over 20 years but gradually noticed that his right eye vision had become progressively blurry and distorted with increased glare and light sensitivity. The patient had a secondary LASIK procedure and developed what he said was a post-operative "infection" that resulted in progressive visual distortion. Subsequently, he developed bilateral cataract and had surgery.

Scheimpflug tomography showed non-orthogonal irregular astigmatism and significant anterior corneal elevation asymmetry but no evidence of ectasia. Mapping of the global pachymetry and epithelial thickness found significant epithelial thickness variation but no evidence of post-surgical ectasia. Specular microscopy revealed a reduced cell count and cellular morphological anomalies of size and shape; however, the cell count was over 1,000. As such, concerns for fitting a scleral lens in terms of oxygen transmissibility existed but did not absolutely contraindicate scleral lens wear (*Figure 8*).

The patient was fit in multiple traditional scleral designs but had noticed progressive discomfort and reduced wearing time. Ultimately, the patient was referred to our practice for consideration of impression scleral prosthetic treatment (EyePrintPro). The impression was scanned using a 3D printing scanner that created a detailed corneo-scleral 3D model, from which an initial prosthetic device was designed (*Figure 9*).

At follow-up after initial dispensing, biomicroscopy discovered areas of inferior/inferior-temporal conjunctival injection. The patient reported progressive lens awareness in the associated areas as wearing

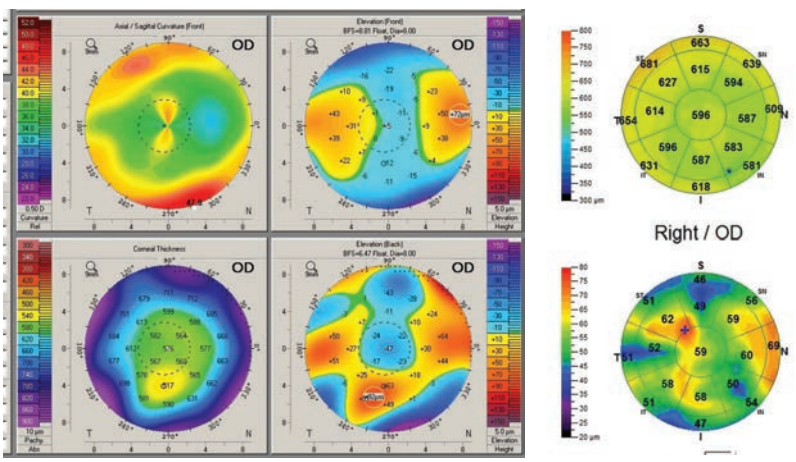


Fig. 8. Post-RK/LASIK. (Left) Pentacam 4-Map Refractive Display shows non-orthogonal irregular astigmatism within the pupillary zone and significant anterior elevation asymmetry. (Right) OCT pachymetry map shows significant irregularity of the epithelial thickness but no evidence of ectasia.

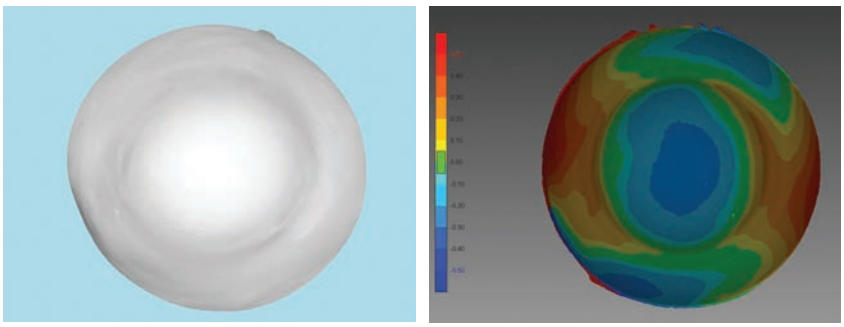


Fig 9. (Left) A 3D printed model from an initial EyePrint impression is used to design the customized prosthetic. (Right) This corneo-scleral profile map is also constructed from the 3D printed impression.

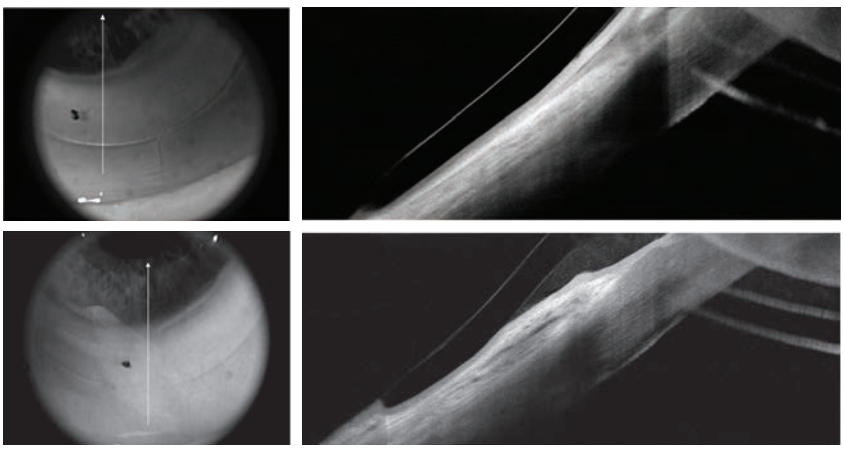


Fig 10. (Top) Post-RK/LASIK OCT with EyePrint prosthetic device in place shows impingement of the inferior conjunctiva due to conjunctival redundancy and chalasis. (Bottom) Same area following chalasis surgery without loose conjunctival entrapment.

time increased. Careful observation noted inferior and temporal conjunctivochalasis and inferior/inferior temporal entrapment of redundant conjunctiva under the lens edge (*Figure 10*). Numerous attempts at design modification failed to resolve the problem. A referral was made to our oculoplastic surgeon, who performed conjunctival patch removal with amniotic graft to address the chalasis. Following healing, reapplying the EyePrint device provided significantly improved comfort and vision.

Corneo-scleral profile measurements are now becoming clinically available to anterior segment and contact lens professionals. These measurements have shed light on the complexity of the scleral surface shape and have led to the development of advanced scleral lens designs that better contour to the entire anterior ocular surface.[10] New instruments, such as the Eaglet Eye Surface Profiler (Eaglet Eye) and the sMap 3D (Precision Ocular Metrology), and software developments like the CSP Pentacam software bring the measurement of corneal and scleral shape into the hands of eye care professionals.

The ability to take an ocular surface impression, as is possible with the EyePrint system (EyePrint Prosthetics) expands the ability to create a detailed model with precision that is unmatched. With these tools, we can now develop scleral lenses and scleral prosthetic devices that can contour even the most irregular ocular surfaces. That being said, conditions of the ocular surface, such as conjunctivochalasis, can continue to challenge ocular comfort and lens fitting success.[11] In certain cases, surgical intervention is the best option to address the issues of chalasis and to allow patients to return to comfortable and effective contact lens wear.[12]

Advancements in imaging technologies have significantly improved our ability to both diagnose and manage corneal and other anterior segment diseases. Investing in such technologies provides a return of investment that goes far beyond the financial accounting—it results in better care for our patients. ■

1. Belin MW, Asota IM, Ambrosio R Jr, Khachikian SS. What's in a name, keratoconus, pellucid marginal degeneration and related thinning disorders. Am J Ophthalmol. 2011;152(2):157-62.

2. Pepose J. Wavefront aberrations in patients with keratoconus and pellucid marginal degeneration. Invest Ophthalmol Vis Sci. 2004;45(13):2893.

3. Kamiya K, Hirohara Y, Mihashi T, et al. Progression of pellucid marginal degeneration and higher-order wavefront aberration of the cornea. Jpn J Ophthalmol. 2003;47(5):523-5.

4. Gomes JA, Rapuano CJ, Belin MW, Ambrósio R Jr; Group of Panelists for the Global Delphi Panel of Keratoconus and Ectatic Diseases. Global consensus on keratoconus and ectatic diseases. Cornea. 2015;34(4):359-69.

5. Kanellopoulos A, Asimellis G. OCT corneal epithelial topographic asymmetry as a sensitive diagnostic tool for early and advancing keratoconus. Clin Ophthalmol. 2014;8:2277-87.

6. Kennedy RH, Bourne WM, Dyer JA. A 48-year clinical and epidemiologic study of keratoconus. Am J Ophthalmol. 1986;101(3):267-73.

7. Godefrooij DA, de Wit GA, Uiterwaal CS, et al. Age-specific incidence and prevalence of keratoconus: a nationwide registration study. Am J Ophthalmol. 2017;175:169-72.

8. Bao F, Geraghty B, Wang Q, Elsheikh A. Role of corneal biomechanics in the diagnosis and management of keratoconus. In: Alió J, ed. Keratoconus: recent advances in diagnosis and treatment. Cham, Switzerland:Springer;2017;141-50.

9. Bykhovskaya Y, Margines B2, Rabinowitz YS. Genetics in Keratoconus: where are we? Eye Vis (Lond). 2016;3:16.

10. van der Worp E. A Guide to Scleral Lens Fitting, Version 2.0 [monograph online]. Forest Grove, OR: Pacific University; 2015. commons.pacificu.edu/mono/10. Accessed March 17, 2019.

11. Meller D, Tseng SC. Conjunctivochalasis: literature review and possible pathophysiology. Surv Ophthalmol. 1998;43(3):225-32.

12. Marmalidou A, Kheirkhah A, Dana R. Conjunctivochalasis: a systematic review. Surv Ophthalmol. 2018;63(4):554-64.

Fitting the Irregular Cornea: NUTS AND BOLTS

Here's a beginner's guide to help you get started.

By Lindsay A. Sicks, OD

Once you realize you are dealing with an irregular cornea, how do you feel? Scared? Excited? Nervous? Perhaps all of the above?

If you're an eye care practitioner who is energized by the challenge of improving vision for patients who cannot see well with spectacles, then you might already be familiar with some of the lenses in our arsenal.

On the other hand, if you are a little more hesitant or are looking to expand your options for irregular cornea patients, here is a primer on the examination information you should be gathering and the lens options worth considering.

EXAM DATA

Examining any patient with an irregular cornea starts with obtaining an extensive case history. While it's important to understand a patient's current complaints in detail, it also benefits us to know their past ocular surgical procedures and contact lens wear history.

With regards to a patient's complaints, assessing their level of blur, halos, glare, flare and difficulties with night vision can uncover telling information.

Using tomographic or topographic maps can assist in evaluating the tear film and the cornea's front and back surface characteristics.

After a careful manifest refraction, consider whether the patient is experiencing any anisometropia, aniseikonia or both with spectacles, as this will bolster your case for prescribing medically necessary correction with contact lenses.

Ocular dryness history should also be explored, preferably with a validated questionnaire that can be repeated at subsequent office visits to evaluate any changes in signs and symptoms over time.

A quick inquiry into the patient's vocation and hobbies can automatically steer your evaluation toward certain lens designs. For example, a truck driver may require a gas permeable (GP) lens for best acuity while driving. A retired patient, though, may desire a part-time wear option where acuity may not be as crucial for a successful outcome.

A critical look at a patient's dexterity, hygiene and potential for lens handling limitations can help you determine whether to include or exclude certain lens modalities from the start or recommend additional assistance. For example, an elderly patient with rheumatoid arthritis may not be able to manipulate their fingers to apply and remove a lens as easily. A patient with a tremor may not be able to steady their hands long enough to handle a lens. To help, assistive devices exist that can come in handy when patient handling on insertion or removal presents a challenge.

Your initial physical examination of a patient should include measuring best-corrected acuity (if the patient currently wears spectacles or contact lenses), a pinhole acuity, if indicated, and uncorrected visual acuity (usually taken after any entering lenses are assessed). Following a fresh manifest refraction, you will have another measure of best-corrected spectacle acuity.

Contact lens patients should have a pair of backup spectacles in case they ever find themselves in a situation where they cannot wear their lenses, especially so they do not feel tempted to over-wear them.

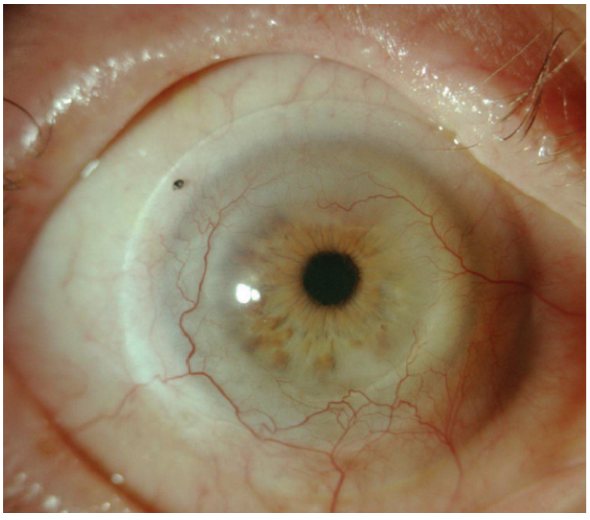
Patients will often express a desire for a backup pair of spectacles if given the option, even if their vision is not as crisp as it is with their contact lenses. If the patient has a high amount of anisometropia in their manifest refraction, it might be useful to trial frame the result obtained and cut the sphere, cylinder powers or both down until you achieve the best balance of tolerable anisometropia and best visual acuity.

Other entering data to consider when choosing a contact lens modality include: pupil size, horizontal

ABOUT THE AUTHOR

Dr. Sicks is an assistant professor at the Illinois College of Optometry and serves as a clinical attending in the Cornea Center for Clinical Excellence at the Illinois Eye Institute. She lectures and participates in research on specialty contact lenses.

visible iris diameter, vertical fissure width, corneal status (e.g., ectasia, scarring, transplant status, sutures, dystrophy, ocular surface disease, endothelial cell count), lens status (e.g., cataract, intraocular lens, aphakic), conjunctival abnormalities (e.g., pinguecula, pterygium, conjunctivochalasis) and lid abnormalities (e.g., ptosis, dermatochalasis, rosacea, meibomian gland dysfunction). Pay careful attention to the best-corrected visual acuity and any comorbidities, such as retinal abnormalities, glaucoma or previous ocular surgeries (e.g., glaucoma bleb or tube), which can also inform the fitting process moving forward.



This 61-year-old Eastern European male presented with a chemical burn in his right eye after an industrial accident. The patient was only able to achieve a fluctuating 20/50 acuity with a corneal GP lens and was experiencing difficulty with adaptation because he only wore the lens in one eye. Today, he sees 20/25 out of a scleral lens in the right eye.

If ocular surface disease is present, treating it prior to commencing lens wear is a must; however, patients with severe ocular surface disease, especially in the presence of other irregular corneal findings, often benefit from scleral lens wear to help treat and manage their condition.[1,2]

For patients with a history of corneal transplant, obtaining a baseline endothelial cell count and a pachymetry value is recommended prior to lens fitting. This will allow you to monitor the health of the graft in the presence of the lens, modify the lens or lens wearing schedule or refer the patient for further surgical intervention if indicated based on changes in the health of the transplant.[3,4]

Corneas with endothelial cell densities below 1000cells/mm^2 are at an increased risk for swelling and decompensation.[5] Chronic endothelial decompensation occurs when endothelial cell density is between 400cells/mm^2 to 700cells/mm^2.[5,6] When fitting these patients, consider if the visual benefit of a scleral lens is worth the risk of decompensation or if a lens with a smaller diameter, greater tear exchange and better oxygen transmission would be more beneficial.

Further analyzing the endothelial cell count scan can also help predict the risk associated with a scleral lens; specifically, a coefficient of variation <30% and a hexagonality value >50% bode well for fitting success.[7]

Pachymetry measurements also assist with assessing endothelial cell function. An increase in pachymetry of more than 20µm to 40µm after scleral lens removal is concerning.[7,8] Post-keratoplasty patients fit with scleral lenses require close follow-up to monitor for signs of hypoxia and rejection or failure.

LENS OPTIONS

Sometimes the contact lens solution for an irregular cornea is as simple as a soft sphere or toric lens that you likely already have in a trial lens set in your office. This is an easy and straightforward fix for a patient's reduced vision. These lenses have planned short-interval replacement schedules and, if lost, ripped or torn, can easily be switched out for a new lens.

If a patient needs powers outside the available parameters, or if the patient has a larger or smaller horizontal visible iris diameter than average, a custom soft design may be indicated.

Many custom soft lens designs are available in quarterly replacement schedules, and some are available on a monthly replacement basis. These fits are straightforward, and key characteristics include lens coverage, centration and movement. Timely follow-up visits can confirm the lenses are being used properly and the fit is not causing any harm to the eye.

In lenses with quarterly or longer replacement cycles, a hydrogen peroxide-based solution may provide better deposit resistance and a more comfortable, preservative-free lens wearing experience.

If the vision achieved with standard soft contact lens designs is not acceptable, it may be because the corneal irregularity is too great. In this case, a specialty lens design for the irregular cornea may be necessary. Designs of this type are available for both prolate ectasias and oblate post-surgical corneal profiles. They generally correct vision in one of two ways, either by increasing center thickness to mask irregular astigmatism or by using aspheric designs to limit aberrations.

The lenses can have center thickness values ranging from 0.4mm to 0.6mm to accommodate corneal

irregularity, although newer "thin" designs are closer to 0.2mm in thickness. These thin designs can even out tear distribution underneath the soft lens with better draping to improve peripheral fit and are more ideal for low cone, pellucid, post-graft and post-surgical cases due to their increased oxygen transmissibility.[9]

Various irregular cornea soft lens designs may also incorporate toricity to help with any residual astigmatism present in the over-refraction. These lenses are available in traditional hydrogel materials and latheable silicone hydrogel material to increase oxygen transmissibility and reduce the risk of hypoxia and neovascularization. They are great options for mild to moderate irregularity and for patients hesitant to try a GP lens.[10]

It is important to set visual acuity expectations with patients prior to trying these designs, as acuity may not be as good as that achieved with corneal GP designs (although sometimes it is just as good, if not better).

In the office, perform a careful over-refraction and pay attention to lens cylinder axis and any rotation that may be present on the diagnostic lens to ensure the best visual outcome. Some specialty soft lens designs are fit with the assistance of sodium fluorescein that has a high molecular weight; however, with the current difficulty in sourcing such fluorescein, make sure you return to the laboratory's specific fitting guide for the particular lens you're working with, as some of the lens fitting characteristics and troubleshooting options are unique to each design.

In patients with corneal irregularity, a corneal GP lens design is often the easiest and most cost-effective way to achieve optimal visual acuity. Indeed, in patients with a post-transplant eye, it may also be the most physiologically favorable design if fit properly to facilitate good tear exchange and oxygen transmissibility.

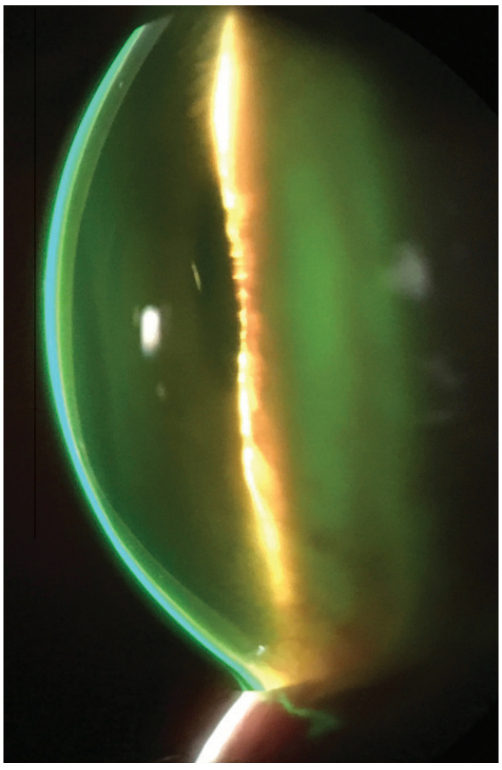


Photo: John Gelles, OD

Fluorescein pattern of a scleral lens on an eye with keratoconus.

If you're fitting a specialty GP lens design for the irregular cornea, the steep keratometry reading is often a good starting point; however, the best strategy is to follow the manufacturer's fitting guide and use the sodium fluorescein pattern and over-refraction to guide the fitting process.

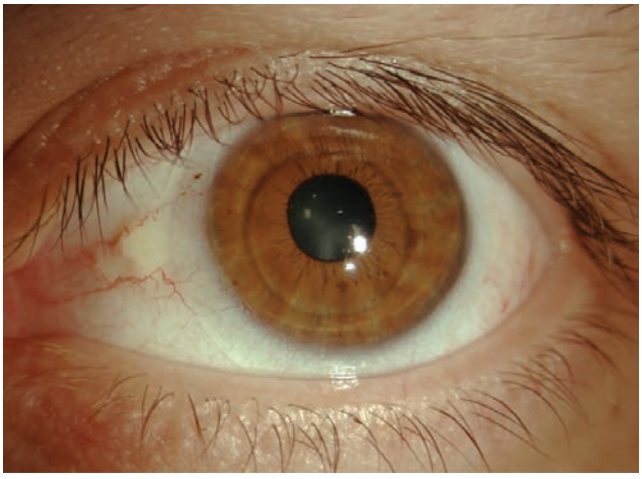
Many designs have unique characteristics that allow you to independently flatten or steepen different areas of the lens to achieve the optimal fit. Acquiring slit lamp photos, videos or both and calling a laboratory consultant can also help alleviate potential doubts and answer questions so that you can continue on your way.

Piggybacking a GP lens on top of a soft lens is also an option but is sometimes forgotten by fitters. Soft contact lenses can cushion the cornea and improve GP lens stability, centration or both. A piggyback can also be a bridge that keeps a patient in a more cost-effective corneal GP lens design and prevents them from having to transition to hybrid or scleral lenses.

Practitioners should independently assess the fit of each lens (soft and GP) for movement and keep in mind that the soft contact lens clinically only contributes about 20% of its power to the system.[11,12]

Fitters should also be attentive to the overall oxygen transmissibility of the lens system. For optimal oxygen transmissibility, silicone hydrogel soft lens designs are preferred. It may be cumbersome, however, for patients to have to handle and care for two lenses per eye instead of one. This can be streamlined somewhat with the recommendation of a hydrogen peroxide-based care system and one case for each set of lenses or a daily disposable silicone hydrogel soft lens option.

Hybrid contact lenses have a GP lens center surrounded by a soft lens skirt. These designs provide excellent visual acuity due to the GP center and ensure patient comfort is maintained as the soft lens interacts with the eyelid. These lenses also provide excellent on-eye lens centration and can be purchased with add-on coating to enhance lens wettability and comfort. They generally require less lens vault than a scleral lens and, therefore, can provide enhanced oxygen transmissibility when fit properly with acceptable movement on blink. Hybrid lenses



A 32-year-old Hispanic male with pellucid marginal degeneration and an elevated pinguecula in each eye presented complaining of visual distortion with his spectacles. He had discontinued GP lens use due to discomfort issues and challenges that arose from using the lenses at his job. Despite achieving 20/25 acuity in a scleral lens with a toric periphery (to avoid compression on the pinguecula), the patient decided he would rather wear a specialty soft lens that gave him 20/30 acuity.

may even allow for more rapid tear exchange than scleral lenses.[13]

Modern scleral lenses have rapidly risen in popularity over the last decade, and their availability in high Dk GP materials has fueled their use in irregular and regular cornea applications.

These lenses are large enough to tuck under lids and range in size from approximately 13mm to 22mm, providing exceptional comfort for the patient. The addition of toric- or quadrant-specific peripheral curves can help ensure lens stability. Along with this stability comes the ability to include advanced applications, such as multifocal and front toric optics or edge lift options to vault conjunctival irregularities.

When fitting the highly irregular cornea with a scleral lens, limited tear exchange, asymmetric vault over a highly irregular surface and centration are still concerns. Additionally, vision can be compromised as the lens base curve becomes steeper and the underlying tear layer more convex. Switching to an oblate lens design can help reduce lens power and improve vision by reducing distortion. Other fitting challenges, such as conjunctival prolapse, epithelial bogging, midday fogging and limbal bearing, are unique to scleral lens wear and should also be addressed if they arise during the fitting process.[14]

In patients for whom even a highly customized scleral lens cannot achieve the best vision or physiology, a custom-molded, optically clear prosthetic scleral device may be indicated. Only once a practitioner completes the comprehensive certification process for these lenses are they able to fit patients in their office.[15]

Impression material is applied to the eye with a specialized tray device to create an impression mold of the cornea and sclera. This mold is then sent to the laboratory, which uses laser-imaging technology to create a contact lens that matches the impression. These lenses include highly customized options, such as prism, multifocal optics, decentered optics and higher-order aberration correction.[16]

Over the years, practitioners have found new ways to restore visual function to patients in need. As of 2019, there are more contact lens options for the irregular cornea than ever before.

As specialty lens fitting grows in popularity, we not only see life-changing improvements in visual function in our patients but we also see industry growth fueling further innovation and development.

When you're ready to take the plunge, just remember the variety of lenses you have at your disposal. While the first lens you try might not be the perfect fit, you can achieve success (and avoid complications) with persistence, motivation, trial and error and the guidance of expert laboratory consultants. RCCL

1. Schornack MM, Pyle J, Patel SV. Scleral lenses in the management of ocular surface disease. Ophthalmology. 2014;121(7):1398-405.

2. Shorter E, Harthan J, Nau CB, et al. Scleral lenses in the management of corneal irregularity and ocular surface disease. Eye Contact Lens. 2018;44(6):372-8.

3. Jackson AJ, Robinson FO, Frazer DG, et al. Corneal guttata: a comparative clinical and specular micrographic study. Eye (Lond). 1999;13(6):737-43.

4. Palay DA, Kangas TA, Stulting RD, et al. The effects of donor age on the outcome of penetrating keratoplasty in adults. Ophthalmology. 1997;104(10):1576-9.

5. Lass JH, Sugar A, Benetz BA, et al. Endothelial cell density to predict endothelial graft failure after penetrating keratoplasty. Arch Ophthalmol. 2010;128(1):63-9.

6. Melles G, Lander F, Rietveld F, et al. A new surgical technique for deep stromal, anterior lamellar keratoplasty. Br J Ophthalmol. 1999;83(3):327-33.

7. Sindt CW. Endothelial cell density: when it becomes a contraindication? AiLES Conference: scleral lens 2.0: from the past, the lens of the future. Rome. June 11, 2018.

8. Barnett M, Johns LK. Contemporary Scleral Lenses: Theory and Application. Vol. 4. Bentham Science Publishers, 2017.

9. Kerasoft Thin. www.kerasoftlens.com/professional/why-choose-thin/. Accessed March 11, 2019.

10. Saraç Ö, Kars ME, Temel B, et al. Clinical evaluation of different types of contact lenses in keratoconus management. Cont Lens Anterior Eye. February 23, 2019.

11. Woo M, Weissman BA. Effective optics of piggyback soft contact lenses. Cont Lens Spectrum. 2011.

12. Michaud L, Brazeau D, Corbeil ME, et al. Contribution of soft lenses of various powers to the optics of a piggy-back system on regular corneas. Cont Lens Anterior Eye. 2013;36(6):318-23.

13. Achenbach P, Bergmanson J, Miller W, et al. Tear exchange beneath a vaulted hybrid contact lens. Cont Lens Anterior Eye. 2018;41(1):S39-40.

14. Walker MK, Bergmanson JP, Miller WL, et al. Complications and fitting challenges associated with scleral contact lenses: a review. Cont Lens Anterior Eye. 2016;39(2):88-96.

15. Eyeprint Prosthetics. www.eyeprintpro.com/. Accessed March 11, 2019.

16. Eyeprint Prosthetics. Case reports. www.eyeprintpro.com/case-reports/. Accessed March 11, 2019.

11th Annual
OPTOMETRIC GLAUCOMA SYMPOSIUM

Join our faculty of renowned ODs and MDs for a highly interactive meeting covering the most up-to-date information in glaucoma care.

Earn up to 12 CE credits* for only $275.

EAST COAST

October 4, 2019 - October 5, 2019

Renaissance Baltimore Harborplace Hotel
202 East Pratt Street
Baltimore, MD 21202
Phone: 410-547-1200

Discounted room rate: $169
Please book with the hotel directly at 800-228-9290. Identify yourself as a participant of ECOGS for group rate. Rooms are limited.

THREE WAYS TO REGISTER

ONLINE: www.reviewsce.com/ECOGS2019
CALL: 877-451-6514
EMAIL: reviewmeetings@jhihealth.com

Administered by
REVIEW EDUCATION GROUP

Review Education Group partners with Salus University for those ODs who are licensed in states that require university credit.

Up to 12 CE Credits*

PROGRAM CO-CHAIRS

Murray Fingeret, OD, FAAO

Chief of the Optometry Section,
Brooklyn/St. Albans Campus,
Department of Veterans Administration
New York Harbor Health Care System

Clinical Professor,
SUNY, College of Optometry

Robert N. Weinreb, MD

Chairman & Distinguished Professor of Ophthalmology
Director of the Shiley Eye Institute
Director of the Hamilton Glaucoma Center
Morris Gleich, M.D. Chair in Glaucoma
University of California San Diego

WEST COAST

December 13, 2019 - December 14, 2019

Hyatt Regency Huntington Beach
21500 Pacific Coast Highway
Huntington Beach, CA 92648
Phone: 714-698-1234

Discounted room rate: $239
Please book with the hotel directly at 877-803-7534. Identify yourself as a participant of WCOGS for group rate. Rooms are limited.

THREE WAYS TO REGISTER

ONLINE: www.reviewsce.com/WCOGS2019
CALL: 877-451-6514
EMAIL: reviewmeetings@jhihealth.com

COPE® *Approval pending

SALUS UNIVERSITY
Pennsylvania College of Optometry

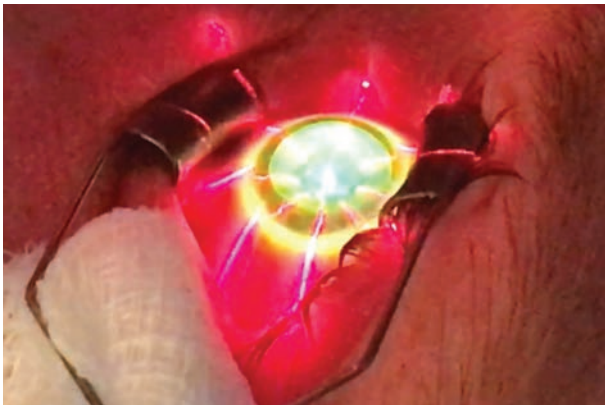
See event website for complete details.

DOES CXL for Keratoconus Improve Contact Lens Success?

A review of the literature shows scant evidence for this effect.

By Brian Chou, OD, and John Gelles, OD

Corneal cross-linking (CXL) has gained widespread clinical acceptance since April 2016 when the FDA approved the Avedro KXL system, which slows or halts progressive keratoconus. Today, CXL is the standard of care for progressive keratoconus, and many medical insurances cover the procedure.[1] However, most keratoconus patients still require specialty contact lenses for the best visual results post-CXL. Recently, there has been talk that CXL may make it easier to prescribe contact lenses for keratoconus.



This patient is undergoing CXL.

Although the primary goal of CXL is disease stability, the procedure can also reduce corneal curvature and surface irregularity. According to data submitted to the FDA, the maximum keratometry value in the CXL treatment group decreased by 1.6D from baseline to one year.[2] With a flatter cornea after the procedure, it seems intuitive that contact lens practitioners would find it easier to prescribe contact lenses. Is there peer-reviewed literature to support this claim, though? Here, we take a closer look.

CXL AND LENS TOLERANCE

General descriptions of contact lens prescribing after CXL underscore the importance of visual restoration following the surgery.[3,4] CXL temporarily reduces corneal sensitivity for about six months, after which point sensitivity levels return to their preoperative levels.[5] In a study using confocal microscopy, we can see that the sub-basal nerve plexus was not visible in 90% of patients at one month postoperative but that corneal innervation nearly restored to preoperative levels by six months.[5] These results corroborate the findings of an earlier study investigating accelerated CXL, which also found that the sub-basal nerve fiber density was reduced following CXL.[6] However, it notes that the density measurements did not reach preoperative values until 12 months post-op.[6]

From this literature, we can conclude that it is likely that the reduced corneal sensation after CXL enhances contact lens tolerance during the first six months after the procedure.

Researchers evaluated 20 eyes of 14 patients with keratoconus who underwent CXL and reported improved rigid gas permeable (RGP) fitting relationships and subjective patient comfort.[7] Among their findings, they note that all patients reported acceptable fits, with 20% experiencing an increase in near-ideal fit and 65% an improvement in subjective comfort with an eight-hour-longer duration of comfortable contact lens wear.[7] While subjectivity exists with what constitutes an improved RGP fitting relationship, the observed improvement in subjective patient comfort could be due to the relative hypoesthesia of the cornea following CXL.

A review paper on CXL recently mentioned an unpublished study reporting on contact lens tolerance

ABOUT THE AUTHORS

Dr. Chou owns ReVision Optometry, a referral center for treating keratoconus and prescribing scleral contact lenses in San Diego, CA.

Dr. Gelles is the director of the specialty contact lens division at the Cornea and Laser Eye Institute (CLEI) and the CLEI Center for Keratoconus in Teaneck, NJ.

in a small prospective randomized clinical trial of 10 subjects (eight keratoconus, two ectasia) who underwent CXL.[8] Participants were prescribed a hybrid contact lens three months post-op.[8] Prior to CXL, 62.5% of the keratoconus patients (5/8) claimed partial or good lens tolerance, whereas 90% of all patients (9/10) reported satisfactory lens tolerance at the conclusion of the study.[8] The authors state that, despite the limited sample size and the singular lens design, these findings might show early evidence of improved contact lens tolerance in post-CXL patients.[8]

Upon looking closer at the previous two studies, several things are evident. The practitioner's skill level may contribute to improved fitting relationships, patient comfort and lens tolerance. It is unclear in either study if the same practitioner prescribed contact lenses to the participants before and after CXL. If the patients' original lenses were prescribed by a less-experienced practitioner who handed the reins off to a more skilled practitioner after CXL, it would not be surprising to find better fitting relationships and lens satisfaction. In the latter study, there is no control for the lens design prior to CXL. These patients could have preoperatively worn a poorly fit RGP lens and postoperatively been prescribed a well fit hybrid lens and experienced improvement simply due to changes in the lens type or fitting relationship, not CXL. Overall, the sample sizes in both studies are too small to draw a reliable, accurate conclusion.

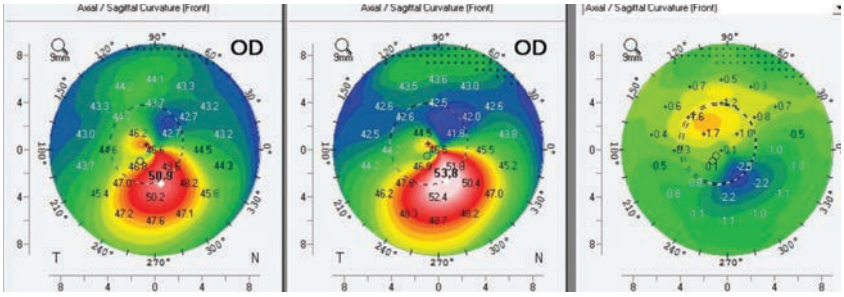
CXL AND LENS PRESCRIBING

To be clear, asking whether CXL makes it is easier to prescribe contact lenses is different from asking whether CXL increases patient contact lens tolerance. We are currently lacking published data assessing the ease of prescribing contact lenses after CXL. In future studies, contact lens practitioners could be surveyed on the average chair time and number of visits required to obtain a final contact lens Rx. Until then, however, we cannot definitively answer this question.

Despite scleral contact lenses—which completely vault the cornea surface—growing in popularity, it is unknown whether CXL enhances their tolerability. With more time and attention appointed to lens haptic to scleral alignment rather than corneal alignment, it seems unlikely that CXL would impact scleral lens prescribing. However, a recent case study used a profilometer—an ocular surface topographer—to show that CXL for keratoconus altered the scleral shape.[9] Keep in mind that this is simply one case that raises more questions about the global ocular shape effects of CXL.

LINKING IT TOGETHER

The claim that CXL makes it easier for a clinician to prescribe contact lenses appears unfounded, at least for the time being. This isn't to overshadow the fact that CXL may improve contact lens tolerance, possibly by causing short-term corneal hypoesthesia. Until compelling evidence comes forth to suggest otherwise, the primary rationale for undergoing CXL should be to stabilize disease progression. RCCL



The left map was taken six months post-op, the center map was taken pre-op and the right map is the difference or subtractive map showing 2.5D of Kmax flattening. Note the superior steepening and the inferior flattening over the cone, which represents normalization of the corneal shape. This patient had a robust response to CXL.

1. Avedro. Is cross-linking covered by insurance? www.livingwithkeratoconus.com/is-cross-linking-right-for-me/is-cross-linking-covered-by-insurance/. Accessed March 13, 2019.
2. Hersh PS, Stulting RD, Muller D, et al. United States multicenter clinical trial of corneal collagen cross-linking for keratoconus treatment. Ophthalmology. 2017;124(9):1259-70.
3. Severinsky B. Contact lens use after corneal cross-linking. RCCL. 2016;153(5):28-32.
4. Michaud L, Breton L. Contact lens fitting post-corneal cross-linking. Contact Lens Spectrum. 2018.
5. Ünlü M, Yüksel E, Bilgihan K. Effect of corneal cross-linking on contact lens tolerance in keratoconus. Clin Exp Optom. 2017;100(4):369-74.
6. Ozgurhan EB, Celik U, Bozhurt E, et al. Evaluation of subbasal nerve morphology and corneal sensation after accelerated corneal collagen cross-linking treatment on keratoconus. Curr Eye Res. 2015;40(5):484-9.
7. Singh K, Bhattacharyya M, Arora R, et al. Alterations in contact lens fitting parameters following cross-linking in keratoconus patients of Indian ethnicity. Int Ophthalmol. 2018;38(4):1521-30.
8. Chang CY, Hersh PS. Corneal collagen cross-linking: a review of 1-year outcomes. Eye Contact Lens. 2014;40(6):345-52.
9. DeNaeyer G, Sanders D. Collagen crosslinking for keratoconus can change scleral shape. J Cont Lens Res Sci. 2018;2(1):e15-21.

1 CE Credit
(COPE APPROVED)

Pathologic Causes of Irregular Astigmatism

Thin is in—but not in the cornea. Here's a rundown of non-inflammatory corneal thinning disorders that lead to irregular astigmatism.

By Thomas Stokkermans, OD, PhD

When a refraction doesn't produce visual acuity of 20/20 or leaves the patient with glare and ghosting, and your subsequent slit-lamp exam doesn't indicate an overt cause, irregular astigmatism should be at the top of your differential diagnosis list.

In these cases, corneal topography, pachymetry, retinoscopy with careful observation of the reflex, a rigid gas permeable contact lens over-refraction, wavefront aberrometry or anterior segment optical coherence tomography (AS-OCT) can all help you identify irregular astigmatism as the culprit.

While the crystalline lens may be one source of the problem, irregular astigmatism is more often caused by the cornea. Of the corneal etiologies, keratoconus is the most common cause of primary irregular astigmatism (i.e., not caused by extraneous causes such as surgery or contact lens wear) (*Table 1*).[1]

To know when high amounts of astigmatism, myopia and anisometropia are likely caused by keratoconus or other non-inflammatory thinning disorders, you must have a working knowledge of the development and epidemiology of refractive error. This article can help you diagnose and manage patients with irregular astigmatism.

REFRACTIVE ERRORS

Refractive errors at birth are variable, decreasing until age six, when the highest degree of emmetropia is present.[2,3] This applies to astigmatism as well. The average amount of astigmatism at birth is 3D and is reduced to just 1D by age five.

However, not all children have a reduction in their refractive errors, as patients with high amounts of with-the-rule or low amounts of against-the-rule astigmatism will likely have significant residual astigmatism later in life.[2,3] This applies to anisometropia as well—while it is common to have some degree of anisometropia during the first few years of life, children with higher amounts of anisometropia at a young age are more likely to have it throughout their life.[2,3]

Non-pathologic myopic progression can be divided into four categories: congenital (present at birth, generally no emmetropization occurs), youth onset (occurs between six years and early teens), early-adult onset (occurs between the ages of 20 and 40) and late-adult onset (occurs after age 40).[2,3]

Family history strongly affects the risk for youth onset and early-adult onset myopia. For example, one parent with myopia increases the odds of their child developing myopia by threefold, while two myopic parents increases the odds almost eightfold.[4] As such, concern for corneal thinning is greatest in rapidly increasing youth onset myopia or early-adult onset myopia for children with parents with myopia.[5]

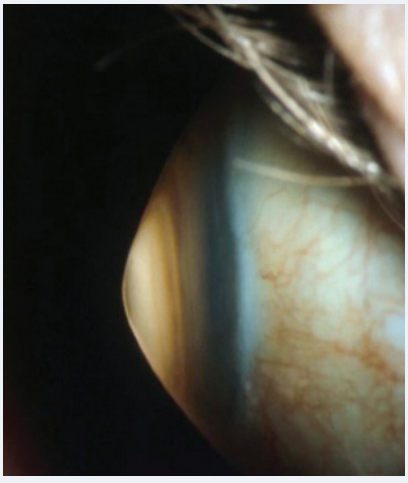


Photo: Jonathan Lass, MD

Keratoconus is associated with central corneal thinning resulting in corneal ectasia.

ABOUT THE AUTHOR

Dr. Stokkermans is an assistant professor at Case Western Reserve University's Department of Ophthalmology and Visual Sciences and director of the Optometry Service at the University Hospitals Eye Institute, Cleveland, Ohio. He has a busy medical and specialty contact lens practice and has participated in multiple clinical trials, including the Collaborative Longitudinal Evaluation of Keratoconus and the National Eye Institute Refractive Error Correction Questionnaire studies.

Regular astigmatism. Astigmatism of 0.5D and higher is found in 15% of children and 40% of adults worldwide and is the most prevalent refractive error compared with myopia and hyperopia.[6] Regular astigmatism of more than 3D makes up a small percentage of astigmatic patients, with one study finding one in 20 individuals affected.[7]

Unlike myopia, astigmatism in a teenager is much less dependent on family history, even though research suggests an autosomal dominant inheritance pattern.[8,9]

Asymmetry of astigmatism between the eyes is also uncommon (<20%) with asymmetry decreasing as astigmatism increases.[10] The axis of astigmatism follows mirror or direct symmetry in four out of five patients.[10] So, clinicians should have a high index of suspicion for ectasia in patients with asymmetrical high amounts of astigmatism.

Irregular astigmatism. This is a combination of higher-order aberrations such as coma, trefoil and quadrafoil, each of which can be quantified in terms of Zernike polynomials. Aberrometry allows us to quantify these different types of aberrations, and research shows the detection of higher amounts of vertical coma and overall amount of higher-order aberrations are good predictors of keratoconus.[11]

Once you've made the diagnosis of irregular astigmatism and have ruled out inflammatory corneal thinning, it's time to consider the causes of non-inflammatory corneal disorders and potential treatment strategies.

Table 1. Causes of Corneal Irregular Astigmatism

Category		Causes/examples
Thinning	Non-inflammatory: *corneal*	Keratoconus, posterior keratoconus
	Non-inflammatory: *peripheral*	Pellucid marginal degeneration Terrien's marginal degeneration, keratoglobus, dellen
	Iatrogenic	LASIK, PRK, pterygium removal
	Inflammatory: *peripheral*	Rheumatic thinning/ulcer, Mooren's ulcer, shield ulcer
	Infectious	Microbial keratitis, herpetic ulcer
Non-thinning	Deposits	Band keratopathy, vortex keratopathy
	Degenerative	Corneal edema
	Dystrophy: *epithelial*	Basement membrane dystrophy
	Dystrophy: *stromal*	Lattice dystrophy
	Mechanical	Rigid gas permeable lens warpage
	Mechanical: *adnexal*	Ptosis
	Iatrogenic: *corneal incisions*	Cataract incision wound, radial keratotomy
	Iatrogenic: *other surgical procedures*	Trabeculectomy, glaucoma shunt procedure, pterygium removal
	Traumatic	Penetrating injury, foreign body
	Neoplastic: *corneal*	Pterygium
	Neoplastic: *adnexal*	Chalazion, tumor

NON-INFLAMMATORY CORNEAL THINNING DISORDERS

Keratoconus is the most common non-inflammatory corneal thinning disorder, but it's certainly not the only one. Other thinning disorders—including pellucid marginal

Release Date: June 15, 2019
Expiration Date: June 15, 2022
Estimated time to complete activity: 1 hour

Jointly provided by Postgraduate Institute for Medicine and Review Education Group.

JOINTLY ACCREDITED PROVIDER™ INTERPROFESSIONAL CONTINUING EDUCATION

Educational Objectives: *After completing this activity, the participant should be better able to:*

- Discuss the prevalence of astigmatism in the population and how the changes that occur in astigmatism throughout life may provide some clues to the causes of astigmatism.
- Identify the involvement and interaction of genetic and environmental factors in the development of irregular astigmatism.
- Explain how corneal degenerations—non-inflammatory corneal thinning disorders—result in irregular astigmatism.
- Describe the presenting signs and features, as well as the natural progression of keratoconus and the non-inflammatory corneal thinning disorders.
- Review the most effective options—particularly surgical options (including corneal crosslinking)—for correcting keratoconus and other non-inflammatory thinning disorders.

Target Audience: This activity is intended for optometrists engaged in the care of patients with irregular astigmatism.

Accreditation Statement: In support of improving patient care, this activity has been planned and implemented by the Postgraduate Institute for Medicine and Review Education Group. Postgraduate Institute for Medicine is jointly accredited by the Accreditation Council for Continuing Medical Education, the Accreditation Council for Pharmacy Education, and the American Nurses Credentialing Center, to provide continuing education for the healthcare team. Postgraduate Institute for Medicine is accredited by COPE to provide continuing education to optometrists.

Faculty/Editorial Board: Thomas Stokkermans, OD, PhD, Case Western Reserve University.

Credit Statement: This course is COPE approved for 1 hour of CE credit. Course ID is **62683-AS**. Check with your local state licensing board to see if this counts toward your CE requirement for relicensure.

Disclosure Statements:
Dr. Stokkermans: Nothing to disclose.
Managers and Editorial Staff: The PIM planners and managers have nothing to disclose. The Review Education Group planners, managers and editorial staff have nothing to disclose.

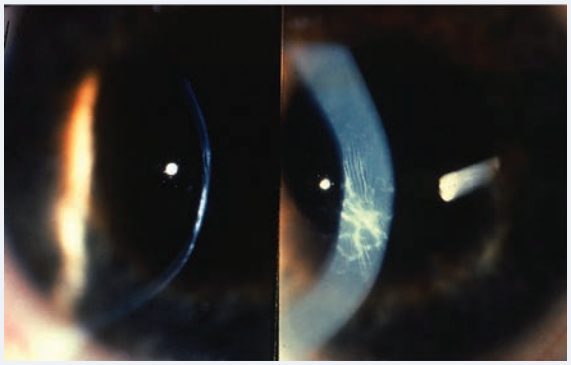


Photo: Jonathan Lass, MD

Apical scarring, together with Vogt striae, is a sign of moderate keratoconus.

Table 2. Amsler-Krumeich Classification to Determine Keratoconus Severity[17]

Stage I Eccentric steepening Myopia and astigmatism <5D Mean central K readings <48D
Stage II Myopia and astigmatism 5D to 8D Mean central K readings <53D Absence of scarring Minimal corneal thickness >400µm
Stage III Myopia and astigmatism 8D to 10D Mean central K readings >53D Absence of scarring Minimal corneal thickness of 300µm to 400µm
Stage IV Unable to refract Mean central K readings >55D Scarring is present Corneal thickness range of 200µm

degeneration (PMD), keratoglobus, posterior keratoconus and Terrien's marginal degeneration (TMD)—may closely resemble keratoconus, so a thorough examination is necessary in each case.

Keratoconus (KCN). This condition occurs in one in 500 to 2,000 people.[1,12,13] Men and women are equally likely to develop KCN, and it's also more common in Asians.[13] Research estimates genetics contribute the majority (60%) of the risk.[14] Patients with a first-degree relative with KCN have an increased risk of one in 30, and in turn, patients with diagnosed KCN have a one in six to one in 16 chance of having a family member with the diagnosis.[12,13]

Besides genetics, common risk factors determined in the Collaborative Longitudinal Evaluation of Keratoconus study include eye rubbing (50%) and atopy (53%).[15] Studies have also associated it with some systemic diseases, including Down syndrome and Leber's congenital amaurosis.[12]

Keratoconus generally develops in the second decade of life, along with myopia and regular astigmatism, and stabilizes in the fourth decade. It's associated with progressive high myopia, astigmatism, anisometropia and reduced visual acuity. It often develops asymmetrically—one in seven patients has KCN in strictly one eye.[12]

Clinical signs of KCN include a full or partial circle of corneal hemosiderin deposition that's best visualized with cobalt blue illumination (Fleischer ring), endothelial vertical lines (Vogt striae), increased visibility of corneal nerves, corneal thinning and scarring, a V-shaped distortion of the lower lid on downgaze (Munson's sign), a conical-shaped reflection on the nasal cornea when a light is shone from the temporal cornea (Rizzuti's sign), a round droplet-shaped reflection observed in retro-illumination of the pupil (Charleaux's "oil droplet" sign), a scissored reflex with retinoscopy and, rarely, a painful sudden onset of stromal edema and opacification that partially clears in weeks (hydrops).[12]

In the absence of overt signs, manual keratometry, topography, AS-OCT, pachymetry and aberrometry can help diagnose KCN while aiding in disease monitoring (*Table 2*).[16] These tests can detect "forme fruste" keratoconus in asymptomatic patients who are 20/20.

Two well established benchmarks of KCN are a central keratometry reading of more than 47.2D and a difference between the eyes of 0.92D or a 1.4 inferior minus superior (I-S) ratio.[18] The I-S ratio compares corneal curvature 3mm superior and inferior to the apex of the topographical map.

Another indication of KCN is when pachymetry deviates about 10% from the expected corneal thickness (550µm) and the thin-


Photo: Jonathan Lass, MD

The triangular deformation of the lower eyelid contour when looking down, or Munson's sign, is an indicator of advanced keratoconus.

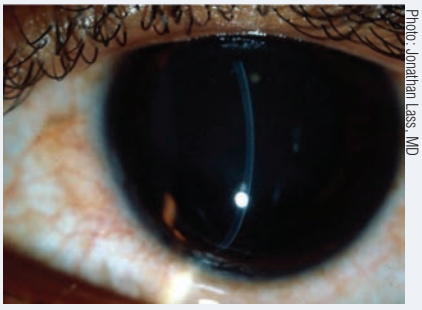
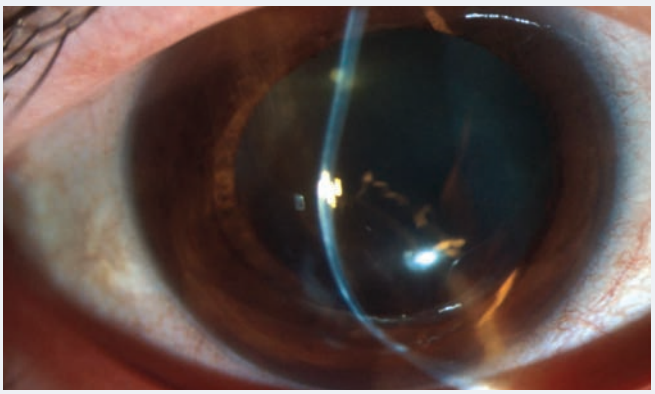
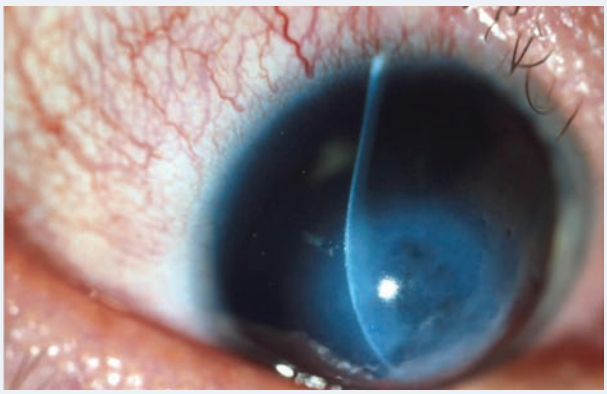


Photo: Jonathan Lass, MD

In keratoglobus, peripheral thinning of the cornea is associated with a large area of steepening.



Inferior steepening of the cornea associated with thinning at 2mm from the limbus is the hallmark of PMD.



Photos: Jonathan Lass, MD

Corneal hydrops in a patient with Down syndrome and advanced keratoconus.

nest point is not located within the central 1mm or there is asymmetry in corneal thickness between the two eyes.[19] The eyelid rubs on the corneal epithelium about 16,000 times a day, flattening the anterior surface in keratoconus. So, the posterior corneal curvature, and 10µm or more of elevation compared with the expected position, is a better indicator than anterior curvature in early KCN.[20]

Classification of the cone based on size of ectasia is standard practice; the three categories are "nipple cone" (less than 5mm), "oval cone" (greater than 5mm) and keratoglobus (three quarters of cornea affected).

Most cases of keratoconus can be treated with glasses and contact lenses. But in some cases, scarring, excessive corneal distortion and steepening may make it impossible to correct vision with contact lenses. The risk for scarring is highest in patients younger than age 20, those with corneas steeper than 52D, with corneal staining and contact lens wearers.[21] The lifetime risk of patients with keratoconus requiring corneal transplantation is between one in five to one in 10.[22]

Pellucid marginal degeneration. Unlike keratoconus, this has a male predilection and causes thinning of the peripheral inferior cornea approximately 2mm from the limbus.[23] A Fleischer ring or Vogt striae are not common. Because both inferior KCN and PMD may reveal a "crab's claw" or "kissing doves" topographic pattern, and because many topography units don't measure beyond the central 9mm of the cornea, full-diameter pachymetry is required to differentiate these two related conditions.[24]

Optical densitometry using a Scheimpflug camera, while a technique not available in the average optometry office, can also be used to differentiate KCN from PMD. Both central and inferior KCN have elevated densitometry in the central cornea only, while PMD has elevation in the peripheral cornea as well. Correct diagnosis is important, as PMD tends to be diagnosed later than KCN, in the second to fifth decade of life, and is generally less severe.

Progressive, against-the-rule irregular astigmatism may result in the need for rigid contact lenses or surgery. Due to the peripheral nature, both contact lens and surgical options are often modified from those used for KCN. Corneal collagen crosslinking may be used to stabilize PMD.[25]

Keratoglobus. This condition presents with clear, diffuse, progressive bilateral corneal thinning, especially in the periphery.[26] It results in high myopia, irregular astigmatism, scarring in the case of hydrops and, rarely, globe rupture.[26] It can be congenital or acquired. Congenital cases can be associated with blue sclera and connective tissue disorders such as Ehlers-Danlos syndrome, Marfan syndrome and osteogenesis imperfecta.[26] Vision can often be corrected with spectacle wear. Advanced cases of keratoglobus with more thinning and irregular astigmatism can

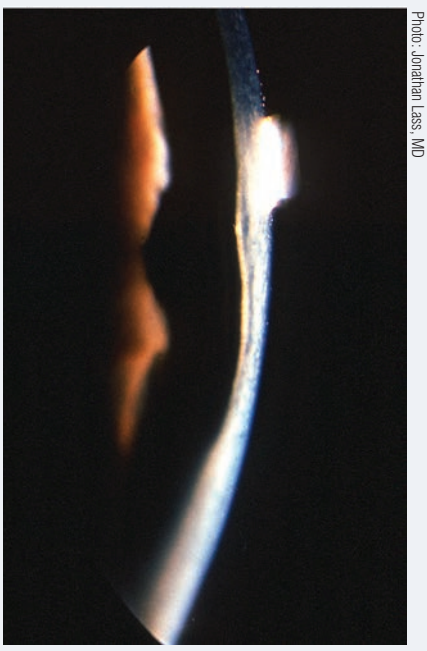


Photo: Jonathan Lass, MD

In posterior keratoconus, the posterior cornea is thin and the posterior float is significantly elevated without increased curvature of the corneal anterior surface.

be treated with contact lenses and specialized corneal transplantation techniques such as tuck-in lamellar keratoplasty.

Posterior keratoconus. This is generally congenital, non-progressive, often unilateral and presents with an abnormal posterior and normal anterior corneal curvature.[27,28] When congenital, a specific abnormality is present in a layer of Descemet's membrane that forms around six months gestation.[29] Researchers have identified two subtypes, one affecting a large area and the other affecting localized central or paracentral areas of the posterior cornea.[30] The latter form is more often associated with stromal scarring.

Because the anterior surface of the cornea does not change, irregular astigmatism is less extreme than in other types of keratoconus. When scarring is present, deprivation amblyopia is a concern and surgical intervention may be necessary. In rare cases, the condition can be acquired and associated with trauma and interstitial keratitis. Because it affects the posterior cornea, treatment with rigid gas permeable contact lenses is less likely to be successful.

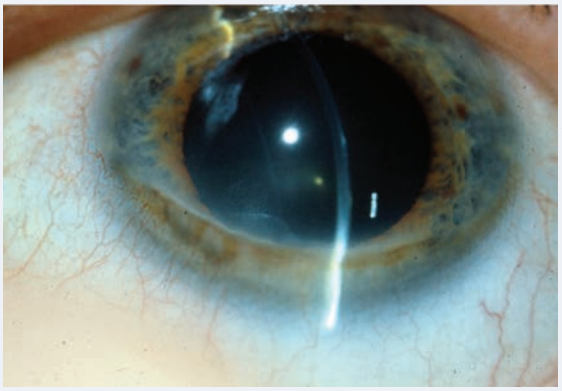


Photo: Jonathan Lass, MD

In Terrien's marginal degeneration, a clear zone of thinning with thin blood vessels crossing through is present. Opacification is associated with the steep, more central edge.

Terrien's marginal degeneration. Initially, this condition affects the superior peripheral cornea asymmetrically and causes progressive thinning.[31] It's associated with fine superficial neovascularization that crosses over the thin zone, subepithelial opacification and lipid deposition leaving a clear area between the affected cornea and the limbus.[31]

Thinning can slowly progress to affect the circumference of the cornea with a leading edge of lipid and a central steep edge and peripheral sloping edge as further hallmarks of the thin zone. Peripheral thinning in TMD can be differentiated from furrow degeneration by the absence of progression and vessels. It can be differentiated from Mooren's ulcer, which is characterized by pain, inflammation and an epithelial defect, as well as an absence of lipid.[31]

Like PMD, TMD is more common in men between the ages of 20 and 40 who present with increasing amounts of against-the-rule or oblique astigmatism.[31]

While no systemic diseases are known to be associated with TMD,

Is Keratoconus Truly a Non-inflammatory Disorder?

Keratoconus is considered a non-inflammatory corneal disorder because it develops in the absence of neovascularization and corneal infiltrates. But at the same time, a significant body of literature supports a role of inflammation in the development and progression of the disease.[1,2]

The association between atopy, elevated immunoglobulin E and keratoconus was made more than half a century ago.[2] More recently, studies have found that patients with keratoconus have more inflammatory mediators in their tears.[1]

Also, eye rubbing associated with eye irritation and other mechanical insult to the cornea such as rigid gas permeable contact lens wear, and the inflammation caused by this, may actually be the direct cause of keratoconus. In fact, in atopic patients keratoconus occurs more often on the side of the dominant hand.[2]

What other evidence do we have? It seems that much of it comes down to an inadequate balance of inflammatory mediators that may make some corneas more sensitive to mechanical insult.

For instance, proteolytic enzymes and prostaglandins are upregulated, which promotes collagen degradation and inhibits collagen synthesis—processes that may be responsible for thinning in keratoconic corneas. Meanwhile, upregulation of pro-inflammatory cytokines and other molecules can directly cause corneal cell death. And another group of mediators, including protease inhibitors and anti-inflammatory cytokines, are downregulated in keratoconus. Downregulation of this group results not only in upregulation of the other mediators, but also directly causes oxidative stress, collagen degradation, cell death and generalized reduction in immune functions.

Still, these results leave us with the question: Why do we find virtually no clinical and histological evidence of inflammation in patients with keratoconus? One possibility is that while both inflammation and keratoconus are present at the same time, there may be no causal relationship between the two.

1. Gatzioufas Z, Panos GD, Hamada S. Keratoconus: is it a non-inflammatory disease? Med Hypothesis Discov Innov Ophthalmol. 2017;6(1):1-2.
2. Galvis V, Sherwin T, Tello A, et al. Keratoconus: an inflammatory disorder? Eye (Lond). 2015;29(7):843-59.

the histopathological presence of large numbers of vacuoles in the affected corneal stroma may merit further study.

Most patients with TMD see well with glasses or rigid contact lenses. When corneal thickness is below 150µm and spontaneous perforation is possible, surgical options—such as tectonic grafting and lamellar keratoplasty—should be considered.[31]

TREATMENTS

A thorough review of treatment for non-inflammatory irregular astigmatism is beyond the scope of this article, but options include the use of rigid lenses (corneal gas permeables, sclerals and hybrids), as well as procedures such as corneal collagen crosslinking, conductive keratoplasty, intracorneal ring implants and corneal transplants.

Non-inflammatory corneal thinning resulting in irregular astigmatism demands swift diagnosis—preferably at a stage when no slit-lamp findings are present—and expedient intervention. Of the surgical treatments available, corneal crosslinking may have the most promise as it can be performed early in the disease to arrest progression to later stages, which are harder to treat. RCCL

1. Romero-Jiménez M, Santodomingo-Rubido J, Wolffsohn JS. Keratoconus: a review. Cont Lens Anterior Eye. 2010;33(4):157-66.

2. Yackle K, Fitzgerald DE. Emmetropization: An Overview. J Behav Optometry. 1999;10(2):38-42.

3. Gwiazda J, Thorn F, Bauer J, Held R. Emmetropization and the progression of manifest refraction in children followed from infancy to puberty. Clin Vision Sci. 1993;8:337-44.

4. Zadnik K, Sinnott LT, Cotter SA, et al; Collaborative Longitudinal Evaluation of Ethnicity and Refractive Error (CLEERE) Study Group. Prediction of juvenile-onset myopia. JAMA Ophthalmol. 2015;133(6):683-9.

5. Grosvenor T, Perrigin DM, Perrigin J, Maslovitz B. Houston Myopia Control Study: a randomized clinical trial. Part II. Final report by the patient care team. Am J Optom Physiol Opt. 1987;64(7):482-98.

6. Hashemi H, Fotouhi A, Yekta A, et al. Global and regional estimates of prevalence of refractive errors: Systematic review and meta-analysis. J Curr Ophthalmol. 2017;30(1):3-22.

7. Sharif-ul-Hasan K, Ansari MZH, Ali A, et al. Relative distribution and amount of different types of astigmatism in mixed ethnic population of Karachi. Pak J Ophthalmol. 2009;25(1):1-7.

8. McKendrick AM, Brennan NA. Distribution of astigmatism in the adult population. J Opt Soc Am A Opt Image Sci Vis. 1996;13(2):206-14.

9. Asharlous A, Khabazkhoob M, Yekta A, Hashemi H. Comprehensive profile of bilateral astigmatism: rule similarity and symmetry patterns of the axes in the fellow eyes. Ophthalmic Physiol Opt. 2017;37(1):33-41.

10. Read SA, Collins MJ, Carney LG. A review of astigmatism and its possible genesis. Clin Exp Optom. 2007;90(1):5-19.

11. Gordon-Shaag A, Millodot M, Ifrah R, Shneor E. Aberrations and topography in normal, keratoconus-suspect, and keratoconic eyes. Optom Vis Sci. 2012;89(4):411-8.

12. Rabinowitz YS. Keratoconus. Surv Ophthalmol. 1998;42(4):297-319.

13. Wheeler J, Hauser MA, Afshari NA, et al. The genetics of keratoconus: a review. Reprod Syst Sex Disord. 2012;Suppl 6. pii:001.

14. Szczotka-Flynn L, Slaughter M, McMahon T, et al; CLEK Study Group. Disease severity and family history in keratoconus. Br J Ophthalmol. 2008;92(8):1108-11.

15. Wagner H, Barr JT, Zadnik K. Collaborative Longitudinal Evaluation of Keratoconus (CLEK) Study: methods and findings to date. Cont Lens Anterior Eye. 2007;30(4):223-32.

16. Maeda N. Optical coherence tomography for corneal diseases. Eye Contact Lens. 2010;36(5):254-9.

17. Krumeich JH, Daniel J, Knülle A. Live-epikeratophakia for keratoconus. J Cataract Refract Surg. 1998;24(4):456-63.

18. Rabinowitz YS, McDonnell PJ. Computer-assisted corneal topography in keratoconus. Refract Corneal Surg. 1989;5(6):400-8.

19. Liu Z, Huang AJ, Pflugfelder SC. Evaluation of corneal thickness and topography in normal eyes using the Orbscan corneal topography system. Br J Ophthalmol. 1999;83(7):774-8.

20. Kent C. Catching keratoconus: Making the tough calls. Rev Ophthalmol. 2010 Jul;17(7).

21. Barr JT, Wilson BS, Gordon MO, et al; CLEK Study Group. Estimation of the incidence and factors predictive of corneal scarring in the Collaborative Longitudinal Evaluation of Keratoconus (CLEK) Study. Cornea. 2006;25(1):16-25.

22. Tuft SJ, Moodaley LC, Gregory WM. Prognostic factors of progression to keratoconus. Ophthalmology. 1994;101(3):439-47.

23. Martínez-Abad A, Piñero DP. Pellucid marginal degeneration: Detection, discrimination from other corneal ectatic disorders and progression. Cont Lens Anterior Eye. November 22, 2018 Nov 22. [Epub ahead of print].

24. Koc M, Tekin K, Inanc M, et al. Crab claw pattern on corneal topography: pellucid marginal degeneration or inferior keratoconus? Eye. 2018;32(1):11-18.

25. Mamoosa B, Razmjoo H, Peyman A, et al. Short-term result of collagen crosslinking in pellucid marginal degeneration. Adv Biomed Res. 2016 Dec;5:194.

26. Wallang BS, Das S. Keratoglobus. Eye (Lond). 2013;27(9):1004-12.

27. Silas MR, Hilkert SM, Reidy JJ, Farooq AV. Posterior keratoconus. Br J Ophthalmol. 2018;102(7):863-67.

28. Malik TG, Khalil M, Bhatti M. Topographic interpretation of posterior keratoconus. Pak J Ophthalmol. 2016;32(3):186-89.

29. Krachmer JH, Rodrigues MM. Posterior keratoconus. Arch Ophthalmol. 1978;96(10):1867-73.

30. Rao SK, Padmanabhan P. Posterior keratoconus. An expanded classification scheme based on corneal topography. Ophthalmology. 1998;105(7):1206-12.

31. Ding Y, Murri MS, Birdsong OC, et al. Terrien marginal degeneration. Surv Ophthalmol. 2019;64(2):162-74.

CE TEST ~ MAY/JUNE 2019

1. Each of the following is a good refractive predictor for keratoconus, *except*:
- a. Vertical coma.
- b. Scissored retinoscopy reflex.
- c. High amount of unilateral astigmatism.
- d. Bilateral progressive myopia.

2. Suspicion for keratoconus is not necessarily high in a teenager when:
- a. Retinoscopy reveals scissoring or a tear drop reflection.
- b. Rapid onset of anisometropia, myopic progression and large amount of astigmatism occur.
- c. Vision cannot be corrected to 20/20 in a patient with a longstanding high amount of astigmatism.
- d. Vision cannot be corrected to 20/20 in the absence of amblyogenic factors and slit-lamp findings.

3. The following clinical signs are associated with keratoconus, *except*:
- a. Rizzuti's sign.
- b. Munson's sign.
- c. Charleaux's sign.
- d. Hutchinson's sign.

4. A patient presents with 20/30 spectacle-corrected VA, 20/20 rigid gas permeable-corrected VA, topographical simulated Ks of 4D, central corneal thickness of 400µm, and Kmax of 54D. Fleischer ring and Vogt striae are present. According to the Amsler-Krumeich classification, what stage of keratoconus is this?
- a. Stage 1. Forme fruste (subclinical) keratoconus.
- b. Stage 2. Early keratoconus.
- c. Stage 3. Moderate keratoconus.
- d. Stage 4. Severe keratoconus.

5. A patient cannot be corrected to 20/20 and topography shows a "kissing doves" pattern. Which additional test and what result will lead to a conclusion that the patient has pellucid marginal degeneration (not inferior keratoconus)?
- a. Pachymetry reveals thinning within the central 9mm of the cornea.
- b. Optical densitometry reveals elevation in the central cornea but not in the peripheral cornea.
- c. Full-diameter pachymetry reveals thinning in the inferior peripheral cornea, 2mm from the limbus.
- d. The posterior corneal curvature is elevated over 10µm from expected, 4mm from the inferior limbus.

PATHOLOGIC CAUSES OF IRREGULAR ASTIGMATISM

6. A patient with Marfan syndrome can be corrected to 20/20, has high myopia and clear thinning of the peripheral cornea. The condition is most likely:
a. Posterior keratoconus.
b. Pellucid marginal degeneration.
c. Terrien's marginal degeneration.
d. Keratoglobus.

7. A five-year-old patient presents with unilateral corneal scarring and 20/60 vision in the affected eye. You manage to obtain pachymetry and topography in the eye with the scars, which show that the anterior corneal curvature is normal while the posterior curvature is abnormal. You diagnose posterior keratoconus. Which treatment should you consider?
a. Corneal surgery.
b. A rigid gas permeable contact lens.
c. Patching or atropine penalization.
d. Loteprednol ophthalmic gel BID for one month.

8. Which is correct about Terrien's marginal degeneration?
a. Thinning develops in the inferior cornea and causes with-the-rule astigmatism.
b. Thinning develops in the superior cornea and causes against-the-rule astigmatism.
c. Thinning progresses with a calcium deposit at the leading edge that causes a foreign body sensation.
d. Thinning occurs at the edge of the cornea with a clear area that may become vascularized and will commonly ulcerate.

9. A 35-year-old man presents for a routine eye exam due to blurred vision with his one-year-old glasses. He corrects to 20/25 with a large increase in against-the-rule astigmatism. Careful biomicroscopy reveals superior peripheral corneal thinning. You diagnose Terrien's marginal degeneration. You expect to see the following signs, *except*:
a. Fine superficial neovascularization crossing the thin zone.
b. Clear thinning with an epithelial defect.
c. Subepithelial opacification with a leading edge of lipid.
d. Thin zone has a central steep edge and peripheral sloping.

10. Levels of inflammatory mediators are altered in keratoconus, indicating a possible inflammatory cause. Which mediators are upregulated and which are downregulated?
a. Proteolytic enzymes and prostaglandins are upregulated; protease inhibitors and anti-inflammatory cytokines are downregulated.
b. Proteolytic enzymes and prostaglandins are downregulated; protease inhibitors and anti-inflammatory cytokines are upregulated.
c. Proteolytic enzymes and protease inhibitors are upregulated; prostaglandins and anti-inflammatory cytokines are downregulated.
d. Protease inhibitors and prostaglandins are upregulated; proteolytic enzymes and anti-inflammatory cytokines are downregulated.

EXAMINATION ANSWER SHEET

Pathologic Causes of Irregular Astigmatism
Valid for credit through June 15, 2022

Online: This exam can also be taken online at www.reviewsce.com. Upon passing the exam, you can view your results immediately and download a real-time CE ceriticate. You can also view your test history at any time from the website.

Directions: Select one answer for each question in the exam and completely darken the appropriate circle. A minimum score of 70% is required to earn credit.

Mail to: Jobson Healthcare Information, LLC, Attn.: CE Processing, 395 Hudson Street, 3rd Floor New York, New York 10014

Payment: Remit $20 with this exam. Make check payable to: Jobson Healthcare Information, LLC.

Credit: This lesson is approved for 1 hour of CE credit. Course ID is 62683-AS.

Jointly provided by Postgraduate Institute for Medicine and Review Education Group.

Salus University has sponsored the review and approval of this activity.

Processing: There is a four-week processing time for this exam.

Answers to CE exam:

1.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
2.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
3.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
4.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
5.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
6.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
7.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
8.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
9.	Ⓐ	Ⓑ	Ⓒ	Ⓓ
10.	Ⓐ	Ⓑ	Ⓒ	Ⓓ

Rate the quality of the material provided:
1=Strongly disagree
2=Somewhat disagree
3=Neutral
4=Somewhat Agree
5=Strongly agree

22. The content was evidence-based.
① ② ③ ④ ⑤

23. The content was balanced and free of bias.
① ② ③ ④ ⑤

24. The presentation was clear and effective.
① ② ③ ④ ⑤

Post-activity evaluation questions:
Rate how well the activity supported your achievement of these learning objectives:
1=Poor, 2=Fair, 3=Neutral, 4=Good, 5=Excellent

11. Discuss the prevalence of astigmatism in the population, and how the changes that occur in astigmatism throughout life may provide some clues to the causes of astigmatism. ① ② ③ ④ ⑤
12. Identify the involvement and interaction of genetic and environmental factors in the development of irregular astigmatism. ① ② ③ ④ ⑤
13. Explain how corneal degenerations—non-inflammatory corneal thinning disorders—result in irregular astigmatism. ① ② ③ ④ ⑤
14. Describe the presenting signs and features, as well as the natural progression of keratoconus and the non-inflammatory corneal thinning disorders. ① ② ③ ④ ⑤
15. Review the most effective options—particularly surgical options (including corneal crosslinking)—for correcting keratoconus and other non-inflammatory thinning disorders. ① ② ③ ④ ⑤
16. Based upon your participation in this activity, do you intend to change your practice behavior? (choose only one of the following options)
Ⓐ I do plan to implement changes in my practice based on the information presented.
Ⓑ My current practice has been reinforced by the information presented.
Ⓒ I need more information before I will change my practice.
17. Thinking about how your participation in this activity will influence your patient care, how many of your patients are likely to benefit? (please use a number) _____
18. If you plan to change your practice behavior, what type of changes do you plan to implement? (check all that apply)
Ⓐ Apply latest guidelines Ⓑ Change in pharmaceutical therapy Ⓒ Choice of treatment/management approach
Ⓓ Change in current practice referral Ⓔ Change in non-pharmaceutical therapy Ⓕ Change in differential diagnostics
Ⓖ Change in diagnostic testing Ⓗ Other, please specify: _____
19. How confident are you that you will be able to make your intended changes?
Ⓐ very confident Ⓑ somewhat confident
Ⓒ unsure Ⓓ not confident
20. Which of the following do you anticipate will be the primary barrier to implementing these changes?
Ⓐ Formulary restrictions
Ⓑ Time constraints
Ⓒ System constraints
Ⓓ Insurance/financial issues
Ⓔ Lack of interprofessional team support
Ⓕ Treatment related adverse events
Ⓖ Patient adherence/compliance
Ⓗ Other, please specify: _____
21. Additional comments on this course: _____

Identifying information (please print clearly):
First Name _____
Last Name _____
Email _____
The following is your: ☐ Home Address ☐ Business Address
Business Name _____
Address _____
City _____ State _____
ZIP _____
Telephone # ___-___-____
Fax # ___-___-____

By submitting this answer sheet, I certify that I have read the lesson in its entirety and completed the self-assessment exam personally based on the material presented. I have not obtained the answers to this exam by fraudulent or improper means.

Signature: _____ Date: _____

Please retain a copy for your records. LESSON 118375, RO-RCCL-0619

Earn up to 19 CE Credits*

NEW TECHNOLOGIES & TREATMENTS IN 2019 EYE CARE REVIEW
EDUCATION GROUP

CHARLESTON, SOUTH CAROLINA

Date:
November 1-3, 2019

Location:
Charleston Marriott
170 Lockwood Blvd., Charleston, SC 29403
Reservations: 1-800-228-9290

A limited number of rooms have been reserved at the rate of **$229/night**. Please book with the hotel directly by calling the number above. Mention "*Review*'s New Technologies & Treatments" for group rate.

Program Chair:
Paul Karpecki, OD, FAAO

Early Bird Special: $420
Register before September 9, 2019 for early bird pricing.

Three Ways to Register
Online: www.reviewsce.com/Charleston2019
Call: 1-866-658-1772
E-mail: reviewmeetings@jhihealth.com

REGISTER ONLINE: WWW.REVIEWSCE.COM/CHARLESTON2019

Administered by: REVIEW EDUCATION GROUP

COPE® *Approval pending

SALUS UNIVERSITY Pennsylvania College of Optometry

Partially supported by unrestricted educational grants from:
Sun Pharmaceuticals
Bausch & Lomb
Carl Zeiss Meditec
Alcon

Review Education Group partners with Salus University for those ODs who are licensed in states that require university credit. See www.reviewsce.com/events for any meeting schedule changes or updates.

Contact Lens Wear and Its Disruption of the Tear Film

A better understanding of the intricacies of this relationship can help put patients' discomfort and other issues into better context.

By Karen Walsh, BSc(Hons), PGDip, Jaya Dantam, PhD, and Doerte Luensmann, PhD

The tear film is crucial for maintaining a healthy and comfortable ocular surface. When contact lens wearers experience dryness and discomfort, it is often from lens use. Experiencing recurrent contact lens discomfort leads to a reduction in both the number of hours, and eventually days, of wear for patients, to the point of dropping out of contact lens wear entirely.[1] This article reviews the components of the tear film, its overall functions, the interactions that occur during lens wear and the actions most relevant for practitioners.

COMPOSITION AND FUNCTION

The tear film is an extraordinarily complex, exquisite fluid, with many different components working together to deliver several important functions of vision, health and comfort related to the anterior eye. The appropriate balance of these components is crucial, as loss of homeostasis contributes to dry eye disease.[2]

The tear film over the ocular surface has a volume of approximately 7µL, a thickness of approximately 3µm to 5µm and is a highly complex biological fluid that comprises of over 1,500 unique proteins, more than 600 individual lipid species from 17 distinct lipid classes and up to 20 distinct mucin genes classified into two different types.[3-9] Additional constituents include multiple small molecule metabolites, peptides, antioxidants, electrolytes and inflammatory mediators. The homeostasis of these components is crucial to the maintenance of several vital functions of the ocular surface, including hydration, lubrication, nutrition, protection and modulation of optical properties.

The initially proposed three-layer tear film structure—mucin, aqueous and lipid (*Figure 1*)—has been superseded by more contemporary theories of a multiple blended-phase tear film. Accordingly, a superficial lipid layer adjacent to an aqueous-mucin gel with an anchoring glycocalyx layer has been suggested to best describe the structure of the tear film over the ocular surface (*Figure 2*).[10]

The common proteins found in the tear film include lysozyme, lactoferrin, secretory immunoglobulin A (IgA) and lipocalin.[7] Of these, lysozyme is the most abundant in tears and is capable of killing bacteria by breaking their outer cell walls.[11] Lactoferrin provides antimicrobial efficacy in tears by binding free iron to reduce the availability of iron necessary for microbial growth and survival.[12] Lactoferrin also plays an important role against inflammation by directly interacting with antigen-presenting cells, such as monocytes or macrophages, and modulating cytokine production.[13] An essential component of the immune system, secretory IgA prevents the adhesion of microorganisms to the ocular surface by stimulating their ingestion.[14,15] Lipocalin is a predominant lipid carrier in human tears and, due to its lipid binding properties, may integrate into meibomian lipids, leading to improved tear film stability and retardation of evaporation.[16,17]

Lipids in tears are broadly classified as polar and non-polar lipids. The non-polar lipids consist of fatty acids, cholesterol esters, diesters, free sterols, triglycerides and hydrocar-

ABOUT THE AUTHORS

Ms. Walsh is a clinical scientist at the Centre for Ocular Research & Education at the University of Waterloo in Canada and is a Fellow of the International Association of Contact Lens Educators.

Dr. Dantam is a laboratory scientist at the Centre for Ocular Research & Education and is a Fellow of the American Academy of Optometry.

Dr. Luensmann is a clinical scientist at the Centre for Ocular Research & Education and is a Fellow of the American Academy of Optometry.

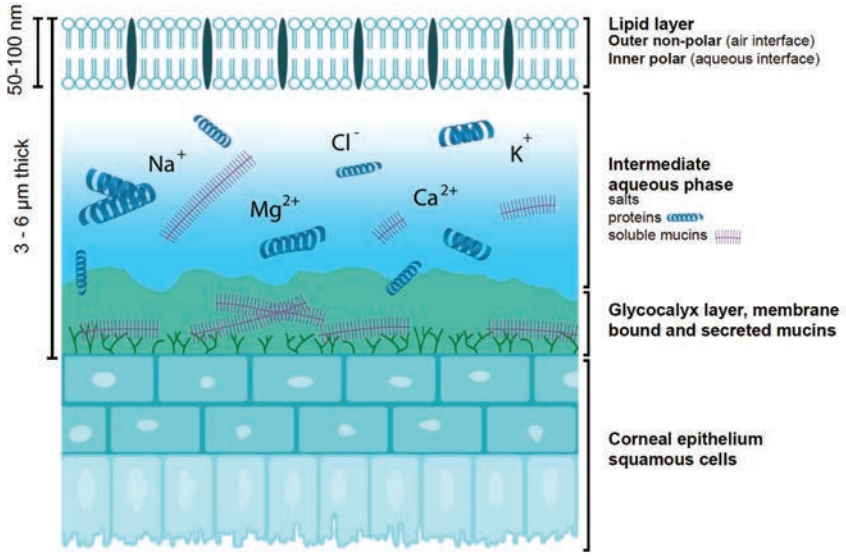


Fig. 1. Graphic representation of the tear film.
Adapted from Butovich IA, Millar TJ, Ham BM. Curr Eye Res. 2008;33(5):405-20.

bons, while the polar lipids primarily consist of phospholipids and omega hydroxy fatty acids.[18] Many believe the non-polar lipids prevent tear evaporation, provide a clear optical surface and present an external barrier against foreign bodies.[19,20]

In contrast, polar tear lipids, via their amphiphilic properties, provide an intermediary between the outer non-polar lipid layer and inner aqueous layers of the tear film. This structure creates stability by lowering surface tension and increasing the viscoelasticity of aqueous tears. This promotes proper segregation of the tear film molecules, enables normal spreading of the tears and prevents dehydration of the ocular surface.[18,21,22]

Most of the mucins found in the tear film belong to two different sub-classes: membrane-spanning mucins and secretory gel-forming mucins. Membrane-spanning mucins are found close to the epithelial surface and play critical roles in protecting the cornea and conjunctiva by maintaining the hydration of the ocular surface and providing lubrication and anti-adhesive properties between the cells of the ocular surface and conjunctiva during blinking.[23,24] Additionally, these mucins contribute to the epithelial barrier by restricting bacterial and viral access to the epithelium and participating in cell interactions.[25] Furthermore, researchers hypothesize that gel-forming mucins are capable of trapping foreign bodies and pathogens and clearing them from the ocular surface into the nasolacrimal duct with the help of blinking.[26]

Although tear metabolites have not been studied extensively, about 60 small molecule metabolites have been identified, providing valuable insight into the dynamic biochemical processes occurring within the tear film.[27] Among the antioxidants present in the tears, uric acid and ascorbic acid account for about 50%, with other examples including glutathione, cysteine, tyrosine and vitamin D.[28,29] Antioxidants in tears help scavenge reactive oxygen species, which occur from UV exposure, radiation and pollutants, thereby protecting the eye from oxidative damage.[30]

More than over 200 different peptides have been detected in tears. These peptides, along with the inhibition of proteases and peptidases, are involved in antimicrobial response that may have potential therapeutic applications for some ocular diseases.[31,32] Some electrolytes found in tears include sodium, potassium, calcium, magnesium, chloride and bicarbonate. Measurement of tear electrolytes may help identify and differentiate dry eye severity.[33] Several other tear components that require further investigation. These include inflammatory mediators, such as IL-1 beta, increased concentrations of which have been reported with contact lens wear.[34]

CONTACT LENS INTERACTIONS

Because the tear film consists primarily of water and contains different components, it is not surprising that the concentrations of some of these components may be impacted by the presence of a contact lens (*Table 1*). Contact lenses interact with the tear film as soon as the two are exposed to each other.

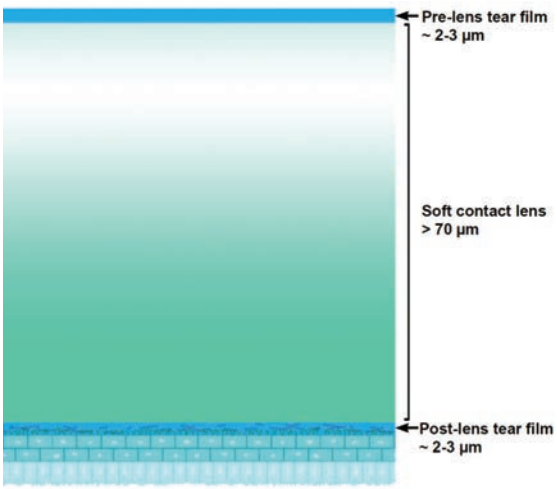


Fig. 2. Graphic representation of a contact lens sitting with the pre- and post-lens tear film.
Adapted from Butovich IA, Millar TJ, Ham BM. Curr Eye Res. 2008;33(5):405-20.

CONTACT LENS WEAR AND ITS DISRUPTION OF THE TEAR FILM

When the lens is applied to the eye, the additional fluid from either the packaging solution or the care regimen dilutes the tears initially. Once in position, the contact lens splits the tear film into two distinct layers called the pre-lens and post-lens tear film.[35] At the same time, tear film components start to deposit on the lens surface, with proteins being detectable on soft lens materials within seconds.[36,37]

In a healthy eye, tear film thickness is about 7µm; however, once a contact lens (which has a typical center thickness of at least 70µm) has settled on the eye, the pre-lens tear film is only about 1µm to 2µm.[35] The tear film over the front surface of a soft lens has a thinner lipid layer, increased evaporation rate and reduced tear volume compared with the normal tear film.[38,39] These changes destabilize the tear film, which may result in patients reporting dry eye symptoms during lens wear.[40]

Possibly related to increased tear evaporation, another change reported in contact lens wear is an increase in osmolarity from about 284mOsmol prior to lens wear to about 313mOsmol after three months of hydrogel lens wear.[41] When soft contacts are worn, the noninvasive tear break-up time (NTBUT) typically reduces from 15 to 30 seconds prior to insertion to fewer than 10 seconds, irrespective of the material or wear regimen.[42,43] NTBUT has been reported to be significantly different between "tolerant" (20 seconds) and "intolerant" (13 seconds) lens wearers when they are segregated based on their ability to tolerate lens wear for at least six hours.[44]

Whether the baseline protein, lipid or mucin profile of an individual's tear film can be indicative of their potential for successful contact lens wear requires further investigation. However, research shows that the tear protein profile in lapsed lens wearers is different compared with that in non-lens wearers.[45] One study found that the amount of total protein, lysozyme and lactoferrin were lower in previous lens wearers, while albumin levels and IgA-heavy chain were significantly higher, indicating the presence of enhanced immune activity weeks after lens wear was discontinued.[45] The authors reported that ocular surface changes in intolerant contact lens wearers did not recover after a discontinuation period of three months, causing the recurrence of ocular discomfort symptoms during the refit attempt.[45]

Table 1. Changes in Tear Composition During Lens Wear

Lipids[52,53,61,65]	• Reduced lipid layer thickness • Lower concentration of phospholipids • A higher concentration of cholesterol and an increase in degraded lipids in tears in symptomatic lens wearers
Proteins[40,66,67]	• Lysozme concentration unaffected • No association between either lysozyme, lactoferrin or lipocalin-1 levels, and contact lens comfort • Higher concentration of prolactin-induced protein in dry eye patients (concentration increases over the day and correlates with an increase in contact lens discomfort)
Inflammatory mediators[68]	• Higher concentration of IL-8 in individuals with dry eye and also in contact lens wearers
Mucin layer[69]	• Thinner with contact lens wear • Lower concentration of certain tear film mucins in symptomatic wearers

The amount of protein and lipid that deposits on contact lenses is dependent on the material composition and other factors, such as overall charge, hydrophobicity and lens wear duration.[36,46] Significant differences are seen between hydrogel and silicone hydrogel materials; however, few studies have found a link between tear film deposition and contact lens comfort or discomfort.[47] It is desirable that deposited lysozyme remains in its active state to keep its antimicrobial properties, but studies often report a significant loss of activity once lysozyme binds to certain contact lens materials, which could impact comfort.[48,49]

The level of bacterial adhesion to contact lenses is increased in the presence of some proteins, although research shows that viable counts were reduced in the presence of lactoferrin deposits.[50] If the ocular defense mechanism is compromised, the chance of developing an ocular inflammation or infection may increase.

A focus of current, ongoing contact lens material development is to optimize the way materials can work with the tear film rather than against it—integrating with the tear film rather than trying to resist its deposition.[51] Further, new work is examining different surface modifications using components such as silver or melimine to resist the attachment of microorganisms to the lens surface and inhibit its activity. The ultimate goal is to produce contact lens materials that can maintain a healthy ocular surface and tear film homeostasis, keeping deposited components in their natural state while optimizing comfort for the wearer.

CLINICAL APPLICATION

The application of a contact lens onto the ocular surface splits the tear film in two, disrupting its structure and stability and altering the com-

position and concentration of some of its components.[35, 40,42,43,52,53] Given this knowledge, what are the most relevant considerations and clinical findings for the eye care professional to keep in mind when reviewing their contact lens patients?

Clinicians should include a thorough assessment of the tear film in every examination of a contact lens wearer. While we currently lack evidence to be able to use the results of that assessment to inform choice of contact lens material or replacement frequency, evidence suggests that a combination of measures can indicate the likelihood a new patient will become a successful wearer.[54-56] The combined results of baseline ocular symptoms, tear stability and tear volume can indicate whether the patient will be able to wear contact lenses comfortably.[44,57,58]

A simple approach for symptom assessment is asking the patient to describe how their eyes feel. Three or more descriptors such as dry or stinging eyes indicate an increased chance of being intolerant with contact lens wear.[44] Quantify baseline symptoms by using a questionnaire, such as the Ocular Surface and Disease Index (OSDI), with the advantage of being able to monitor any change in scores over time.

While fluorescein break-up time has traditionally been and still is routinely used to assess tear stability, it is an invasive technique, with the instilled drop of fluorescein being around two to four times larger than the volume of the tear film it is trying to assess.[59] The ability to use TBUT to distinguish asymptomatic and symptomatic wearers is improved when a practitioner uses a non-invasive technique. A Placido disc, keratometer mires or corneal topographer all enable NTBUT. Average NTBUT measures ranging between 12 to 15 seconds indicate the potential for less successful contact lens wear compared with successful or asymptomatic wearers who have an average NTBUTs ranging between 17 and 23 seconds.[44,57,58]

Table 2. Information Related to Baseline Symptoms and the Tear Film Combined

Factor	Likely tolerant, asymptomatic, successful wearer	Likely intolerant, symptomatic, unsuccessful wearer
Baseline symptoms (verbal, number of reported symptoms[44])	1	3
Baseline symptoms (OSDI score[57,58])	3.97 to 7.60	12.20 to 14.48
Tear stability (Fluorescein TBUT, secs[58])	10.7±6.4	7.5±4.7
Tear stability (NITBUT, secs[44,57,58])	17.0–22.7	12.0–14.9
Tear volume (Phenol red thread, mm[44])	16.4±3.2	11.9±4.2
Tear volume (Tear meniscus height, mm[44])	0.43±0.1	0.31±0.1

Tear volume can be estimated by invasive techniques such as the Schirmer test or phenol red thread test. These have particular application for the assessment of dry eye disease. Recording tear volume is also beneficial in contact lens wearers. It can be estimated through measuring the tear meniscus height along the lower lid margin. While this value is not particularly helpful in isolation, when combined with NTBUT and baseline ocular symptoms, it becomes a useful predictor of future contact lens intolerance (*Table 2*).[44]

The lipid layer of the tear film plays a crucial role in reducing tear evaporation. A severely compromised or absent lipid layer leads to evaporative dry eye.[60] As contact lens wear disrupts the lipid layer, assessment of this particular tear film component is imperative.[40,61] Even in the absence of having specialized equipment designed to estimate lipid layer thickness, check tear film lipids by paying close attention to the eyelids—specifically the lid margins and, the producers of the majority of tear film lipids, the meibomian glands.[62] All contact lens wearers should have their meibomian glands examined. Check if the gland orifices are open or blocked. Can meibum be expressed, and what is the consistency of the meibum that is released? This information helps to build a image of how well these glands are functioning. Wherever suboptimal performance is found, appropriate management is necessary, including hot compresses, lid massage and hygiene, or in-practice treatments of lid debridement, exfoliation, heat and massage therapy.[63,64]

The tear film is incredibly complex, with a number of crucial roles in maintaining ocular health, comfort and vision. Components of the tear film interact with contact lens materials as soon as they come into contact, and the addition of a contact lens inevitably disrupts tears, resulting in changes at a molecular level and to its overall physical properties. Disruption of tear film homeostasis in contact lens wearers can lead to reduced comfort and

wearing times, which may ultimately result in drop out from lens wear.

When reviewing contact lens wearers, it is worth paying close attention to the quality and quantity of the tear film, with specific focus on the function of the meibomian glands. For some clinical presentations, it can be helpful to introduce appropriate management as soon as possible to help improve tear quality. For new wearers, collect the results of symptoms and tear film measures together. These preliminary findings can help inform a useful discussion with the patient about their expectations related to the comfort and wearing hours they may be able to achieve with their lenses. RCCL

1. Craig JP, Nichols KK, Akpek EK, et al. TFOS DEWS II Definition and Classification Report. Ocul Surf. 2017;15(3):276-83.

2. Nichols KK, Redfern RL, Jacob JT, et al. The TFOS International Workshop on Contact Lens Discomfort: report of the definition and classification subcommittee. Invest Ophthalmol Vis Sci. 2013;54(11):TFOS14-19.

3. Mishima S, Gasset A, Klyce SD, Jr., Baum JL. Determination of tear volume and tear flow. Invest Ophthalmol Vis Sci. 1966;5(3):264-76.

4. Wang JH, Fonn D, Simpson TL, Jones L. Precorneal and pre- and postlens tear film thickness measured indirectly with optical coherence tomography. Invest Ophthalmol Vis Sci. 2003;44(6):2524-28.

5. King-Smith PE, Fink BA, Hill RM, et al. The thickness of the tear film. Curr Eye Res. 2004;29(4-5):357-68.

6. King-Smith PE, Fink BA, Fogt N, et al. The thickness of the human precorneal tear film: evidence from reflection spectra. Invest Ophthalmol Vis Sci. 2000;41(11):3348-59.

7. Zhou L, Zhao SZ, Koh SK, et al. In-depth analysis of the human tear proteome. J Proteomics. 2012;75(13):3877-85.

8. Lam SM, Tong L, Duan X, et al. Extensive characterization of human tear fluid collected using different techniques unravels the presence of novel lipid amphiphiles. J Lipid Res. 2014;55(2):289-98.

9. Hodges RR, Dartt DA. Tear film mucins: front line defenders of the ocular surface; comparison with airway and gastrointestinal tract mucins. Exp Eye Res. 2013;117:62-78.

10. Pflugfelder SC, Solomon A, Stern ME. The diagnosis and management of dry eye: a twenty-five-year review. Cornea. 2000;19(5):644-9.

11. Fullard RJ, Snyder C. Protein levels in nonstimulated and stimulated tears of normal human subjects. Invest Ophthalmol Vis Sci. 1990;31(6):1119-26.

12. Flanagan JL, Willcox MD. Role of lactoferrin in the tear film. Biochimie. 2009;91(1):35-43.

13. Puddu P, Valenti P, Gessani S. Immunomodulatory effects of lactoferrin on antigen presenting cells. Biochimie. 2009;91(1):11-8.

14. Williams RC, Gibbons RJ. Inhibition of bacterial adherence by secretory immunoglobulin A: a mechanism of antigen disposal. Science. 1972;177(4050):697-9.

15. Willcox MD, Lan J. Secretory immunoglobulin A in tears:functions and changes during contact lens wear. Clin Exp Optom. 1999;82(1):1-3.

16. Glasgow BJ, Gasymov OK. Focus on molecules: tear lipocalin. Exp Eye Res. 2011;92(4):242-3.

17. Millar TJ, Mudgil P, Butovich IA, Palaniappan CK. Adsorption of human tear lipocalin to human meibomian lipid films. Invest Ophthalmol Vis Sci. 2009;50(1):140-51.

18. McCulley JP, Shine W. A compositional based model for the tear film lipid layer. Trans Am Ophthalmol Soc. 1997;95:79-93.

19. Craig JP, Tomlinson A. Importance of the lipid layer in human tear film stability and evaporation. Optom Vis Sci. 1997;74(1):8-13.

20. Nichols KK, Foulks GN, Bron AJ, et al. The international workshop on meibomian gland dysfunction: executive summary. Invest Ophthalmol Vis Sci. 2011;52(4):1922-9.

21. Rosenfeld L, Fuller GG. Consequences of interfacial viscoelasticity on thin film stability. Langmuir. 2012;28(40):14238-44.

22. Shine WE, McCulley JP. Polar lipids in human meibomian gland secretions. Curr Eye Res. 2003;26(2):89-94.

23. Argueso P. Glycobiology of the ocular surface: mucins and lectins. Jpn J Ophthalmol. 2013;57(2):150-5.

24. Gipson IK. Distribution of mucins at the ocular surface. Exp Eye Res. 2004;78(3):379-88.

25. Mantelli F, Argueso P. Functions of ocular surface mucins in health and disease. Curr Opin Allergy Cl. 2008;8(5):477-83.

26. Gipson IK, Argüeso P. Role of mucins in the function of the corneal and conjunctival epithelia. Int Rev Cytol. 2003;231:1-49.

27. Chen LY, Zhou L, Chan ECY, et al. Characterization of the human tear metabolome by LC-MS/MS. J Proteome Res. 2011;10(10):4876-82.

28. Choy CKM, Benzie IFF, Cho P. Ascorbic acid concentration and total antioxidant activity of human tear fluid measured using the FRASC assay. Invest Ophthalmol Vis Sci. 2000;41(11):3293-8.

29. Gogia R, Richer SP, Rose RC. Tear fluid content of electrochemically active components including water soluble antioxidants. Curr Eye Res. 1998;17(3):257-63.

30. Chen Y, Mehta G, Vasiliou V. Antioxidant defenses in the ocular surface. Ocul Surf. 2009;7(4):176-85.

31. Azkargorta M, Soria J, Ojeda C, et al. Human basal tear peptidome characterization by CID, HCD, and ETD followed by in silico and in vitro analyses for antimicrobial peptide identification. J Proteome Res. 2015;14(6):2649-58.

32. Pescosolido N, Barbato A, Pascarella A, et al. Role of protease-inhibitors in ocular diseases. Molecules. 2014;19(12):20557-69.

33. Yetisen AK, Jiang N, Tamayol A, et al. Paper-based microfluidic system for tear electrolyte analysis. Lab Chip. 2017;17(6):1137-48.

34. Yüksel Elgin C, İskeleli G, Talaz S, Akyol S. Comparative analysis of tear film levels of inflammatory mediators in contact lens users. Curr Eye Res. 2016;41(4):441-7.

35. Nichols JJ, King-Smith PE. Thickness of the pre- and post-contact lens tear film measured in vivo by interferometry. Invest Ophthalmol Vis Sci. 2003;44(1):68-77.

36. Luensmann D, Jones L. Protein deposition on contact lenses: the past, the present, and the future. Cont Lens Anterior Eye. 2012;35(2):53-64.

37. Hall B, Jones L, Forrest JA. Measuring the kinetics and activity of adsorbed proteins: in vitro lysozyme deposited onto hydrogel contact lenses over short time periods. J Biomed Mater REs A. 2013;101(3):755-64.

38. Lloyd AW, Mahalingham N, Guillon M. Tear evaporation in contact lens wear. ARVO 2004. Invest Ophthalmol Vis Sci. 2004;45:3890.

39. Chen Q, Wang J, Shen M, et al. Tear menisci and ocular discomfort during daily contact lens wear in symptomatic wearers. Invest Ophthalmol Vis Sci. 2011;52(5):2175-80.

40. Craig JP, Willcox MD, Argueso P, et al. The TFOS international workshop on contact lens discomfort: report of the contact lens interactions with the tear film subcommittee. Invest Ophthalmol Vis Sci. 2013;54(11):TFOS123-56.

41. Iskeleli G, Karakoc Y, Aydin O, et al. Comparison of tear-film osmolarity in different types of contact lenses. CLAO J. 2002;28(4):174-6.

42. Keir N, Jones L. Wettability and silicone hydrogel lenses: a review. Eye Contact Lens. 2013;39(1):100-8.

43. Morris CA, Holden BA, Papas E, et al. The ocular surface, the tear film, and the wettability of contact lenses. Adv Exp Med Biol. 1998;438:717-22.

44. Glasson MJ, Stapleton F, Keay L, et al. Differences in clinical parameters and tear film of tolerant and intolerant contact lens wearers. Invest Ophthalmol Vis Sci. 2003;44(12):5116-24.

45. Giannaccare G, Blalock W, Fresina M, et al. Intolerant contact lens wearers exhibit ocular surface impairment despite three months wear discontinuation. Graefes Arch Clin Exp Ophthalmol. 2016;254(9):1825-31.

46. Jones L, Brennan NA, Gonzalez-Meijome J, et al. The TFOS International Workshop on Contact Lens Discomfort: report of the contact lens materials, design, and care subcommittee. Invest Ophthalmol Vis Sci. 2013;54(11):TFOS37-70.

47. Subbaraman LN, Omali NB, Heynen M, et al. Could lipid deposition on contact lenses be beneficial?. Presentation at: BCLA Clinical Conference and Exhibition. June, 2014; Birmingham, UK.

48. Jones L, Senchyna M, Glasier MA, et al. Lysozyme and lipid deposition on silicone hydrogel contact lens materials. Eye Contact Lens. 2003;29(1 Suppl):75-9.

49. Subbaraman LN, Glasier MA, Varikooty J, et al. Protein deposition and clinical symptoms in daily wear of etafilcon lenses. Optom Vis Sci. 2012;89(10):1450-9.

50. Subbaraman LN, Borazjani R, Zhu H, et al. Influence of protein deposition on bacterial adhesion to contact lenses. Optom Vis Sci. 2011;88(8):959-66.

51. Buch J, Canavan K, Fadli Z, Scales C. The tear film and contact lens wear. Contact Lens Spectrum. 2016;31(2):34-7.

52. Yamada M, Mochizuki H, Kawashima M, Hata S. Phospholipids and their degrading enzyme in the tears of soft contact lens wearers. Cornea. 2006;25(10 Suppl 1):S68-72.

53. Glasson M, Stapleton F, Willcox M. Lipid, lipase and lipocalin differences between tolerant and intolerant contact lens wearers. Curr Eye Res. 2002;25(4):227-35.

54. Wolffsohn JS, Arita R, Chalmers R, et al. TFOS DEWS II Diagnostic Methodology report. Ocul Surf. 2017;15(3):539-74.

55. Mousavi M, Jesus DA, Garaszczuk IK, et al. The utility of measuring tear film break-up time for prescribing contact lenses. Cont Lens Anterior Eye. 2018;41(1):105-9.

56. Ruiz-Alcocer J, Monsalvez-Romin D, Garcia-Lazaro S, et al. Impact of contact lens material and design on the ocular surface. Clin Exp Optom. 2018;101(2):188-92.

57. Pult H, Murphy PJ, Purslow C. A novel method to predict the dry eye symptoms in new contact lens wearers. Optom Vis Sci. 2009;86(9):E1042-50.

58. Best N, Drury L, Wolffsohn JS. Predicting success with silicone-hydrogel contact lenses in new wearers. Cont Lens Anterior Eye. 2013;36(5):232-7.

59. Mooi JK, Wang MTM, Lim J, et al. Minimizing instilled volume reduces the impact of fluorescein on clinical measurements of tear film stability. Contact Lens Anterior Eye. 2017;40(3):170-4.

60. Craig J, Tomlinson A. Importance of the lipid layer in human tear film stability and evaporation. Optom Vision Sci. 1997;74(1):8-13.

61. Young G, Efron N. Characteristics of the pre-lens tear film during hydrogel contact lens wear. Ophthalmic Physiol Opt. 1991;11(1):53-58.

62. Butovich IA. Tear film lipids. Exp Eye Research. 2013;117:4-27.

63. Arita R, Fukuoka S, Morishige N. Meibomian gland dysfunction and contact lens discomfort. Eye Contact Lens. 2017;43(1):17-22.

64. Geerling G, Tauber J, Baudouin C, et al. The international workshop on meibomian gland dysfunction: report of the subcommittee on management and treatment of meibomian gland dysfunction. Invest Ophthalmol Vis Sci. 2011;52(4):2050-64.

65. Young WH, Hill RM. Tear cholesterol levels and contact lens adaptation. Am J Optom Arch Am Acad Optom. 1973;50(1):12-6.

66. Masoudi S, Stapleton FJ, Willcox MD. Contact lens-induced discomfort and protein changes in tears. Optom Vis Sci. 2016;93(8):955-62.

67. Zhou L, Beuerman RW, Chan CM, et al. Identification of tear fluid biomarkers in dry eye syndrome using iTRAQ quantitative proteomics. J Proteome Res. 2009;8(11):4889-905.

68. Poyraz C, Irkec M, Mocan MC. Elevated tear interleukin-6 and interleukin-8 levels associated with silicone hydrogel and conventional hydrogel contact lens wear. Eye Contact Lens. 2012;38(3):146-9.

69. Berry M, Pult H, Purslow C, Murphy PJ. Mucins and ocular signs in symptomatic and asymptomatic contact lens wear. Optom Vis Sci. 2008;85(10):E930-8.

SAVE THE DATE

October 23-27, 2019 Orlando, FL Orange County Convention Center

Over **450** hours of optometry CE

28 CE hours dedicated to contact lenses

CONTACT LENS LECTURE & SYMPOSIA SCHEDULE

Wednesday, Oct. 23

Prescribing Pediatric GP Lenses: From Corneal to Scleral
Melanie J. Frogozo, Vivian P. Shibayama, Alexandra K. Williamson

The Science of Soft Contact Lenses Fitting
Beth T. Kinoshita, Matthew Lampa, Mark P. Andre

Micro Vault, Macro Impact: Scleral Lenses
Jason G. Jedlicka, Andrea Lasby, Greg DeNaeyer

Acknowledging and Eliminating Contact Lens Visual Discomfort
Erin M. Rueff

Invisible Pain Syndromes: Why Scleral Lenses Do Not Always Work
Lynette K. Johns

Thursday, Oct. 24

Corneal GP Contact Lenses for Post-Surgical Patients
Annie Chang, Dawn Y. Lam

Hot Topics in Scleral Lens Research
Andrew D. Pucker

Beyond Keratoconus: Scleral Lenses Following Ocular Trauma
Ryan O. McKinnis

Multifocal Contact Lens Fitting: The Importance of Communication
Shalu Pal, Melissa Barnett

Rapid Fire: Myopia Control in the Astigmatic Patient
Beth T. Kinoshita, Patrick J. Caroline, Matthew Lampa, Roxanne Achong-Coan

Friday, Oct. 25

Section on Cornea, Contact Lenses and Refractive Technologies Symposium: New Game and New Rules: Interpreting the ISO Guidelines to Safeguard Our Contact Lens Practice and OSD Patients
Louise Sclafani, Ed Bennett, Christine Sindt, Jennifer Harthan, Carole Lakkis, Laura Periman

Nuts & Bolts of Fitting the Irregular Cornea
Tiffany Andrzejewski, Lindsay Sicks

A Case for Specialty Contact Lenses
Chad Rosen, Joshua Lotoczky

Advances in Contact Lens Care for the New Contact Lens Technologies
Susan J. Gromacki

Rapid Fire: Success with Multifocal Lenses
Julie DeKinder, Dawn Y. Lam, Beth Kinoshita, Vinita Henry

Contact Lenses for Visual Rehabilitation in Keratoconus
John D. Gelles

Saturday, Oct. 26

Rapid Fire: The Next Generation in Scleral Lens Fitting
Brooke M. Messer, Sheila Morrison, Maria K. Walker, John Gelles

Evolving Orthok Lens Construction to Optimize Myopia Control
Randy Kojima, Patrick Caroline

Corneal Toric GPs- Concepts to Clinical Application
Thomas Quinn

Technology and the Scleral Lens Practice
Thomas Arnold

Ocular Prosthetic Devices for the Optometrist
Jamie Kuhn, Suzanne Sherman

Wavefront Guided Contact Lenses
Jason Marsack, Matthew Kauffman

Sunday, Oct. 27

Proactively Prescribing and Fitting Soft Contact Lenses in Commercial Setup
Luigina Sorbara, Lakshmi Shinde

Demystifying Scleral Lenses
Karen Carrasquillo, Muriel Schornack, Lynette Johns, Gloria Chiu, Alan Kwok

Stuck in a Rut: Corneal Ulcers and Contact Lenses
Justin Schweitzer, Melissa Barnett

Contact Lenses for the Presbyope
Janice Jurkus

Contact Lens Options for Irregular Corneas
Lakshmi Shinde, Luigina Sorbara

Schedule subject to change. Visit www.aaopt.org/2019 for updated information.

AMERICAN ACADEMY of OPTOMETRY

WORLD COUNCIL OF OPTOMETRY

ACADEMY 2019 ORLANDO
3rd World Congress of Optometry

www.aaopt.org/2019 **worldcongressofoptometry.org**

Trust the Process

Double-digit cylinder in a post-transplant eye can be daunting, but surgery can bring the number back down to earth and contact lenses can handle the rest.

A 47-year-old male presented with poor vision. He had a corneal transplant 2.5 years ago to his right eye and a penetrating keratoplasty (PK) 10 years ago to his left eye for keratoconus. His right eye declined to the point where he could not wear contact lenses, so he had a deep anterior lamellar keratoplasty (DALK). He reported healing uneventfully from the recent transplant but said his vision was not satisfactory and he had not been able to correct it with contact lenses.

PRELIMINARY TESTING

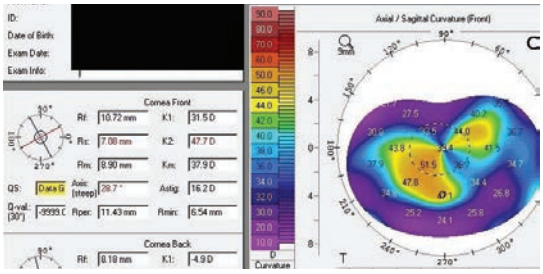
The patient had an uncorrected visual acuity (VA) of 20/400 OD and a well-corrected VA of 20/25 OS with a hard lens. His entrance test results were normal, and he had intraocular pressures of 18mm Hg OU. I was unable to perform autorefraction on his right eye. After removing the rigid gas permeable (RGP) lens in his left eye, he was -1.50 -2.25x096 to 20/30. Manifest refraction yielded no measureable improvement in VA.

The slit lamp exam showed a DALK graft on the right eye, which was secured by a running suture around the circumference of the graft. It was healthy, clear and compact, as was the PK with no sutures. Deeper ocular structures were normal in both eyes.

Based on topography, the patient had 18.8D of astigmatism in his right eye, which was relatively regular centrally but became progressively more irregular the further from the central cornea.

THE PROBLEM

I diagnosed the patient with pathologic irregular astigmatism. The magnitude of this case deemed vision correction with an optical device unfeasible. If left untreated, the transplant would constitute an optical failure.



The patient's topography upon presentation.

SOLUTIONS

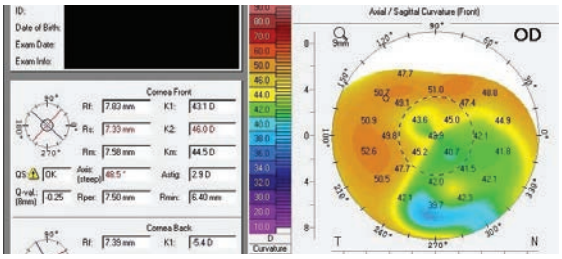
Postoperative care for corneal transplants aims to achieve graft preservation and visual rehabilitation. We need to diagnose and treat allograft rejection to prevent the need for subsequent transplant. Visual rehabilitation beyond being fit with a hard lens is often an afterthought. However, high levels of astigmatism commonly follow these transplants, limiting uncorrected vision and, in extreme cases, correctable vision.

High astigmatism after PK and DALK is usually explained by the unequal tension placed on the sutures that secure the transplant, resulting in irregular corneal curvature. Discussed less frequently is host and donor graft trephination. The process of trephinating the donor and host tissues necessitates some pressure on the cornea, causing it to deform slightly as the blade passes through. This deformation occurs with both cuts (opening the host central cornea and creating the donor button) and is not uniform between them. Attempts are then made to join the two slightly different, imperfect circles, resulting in varying amounts of astigmatism.

Astigmatism could also be caused by "shaving" the anterior portion of a DALK graft or transplant to roughly match the thickness of the host cornea at the interface, which could be very thin in cases of keratoconus, to prevent an anterior overhanging ledge of the graft at the interface. In full-thickness grafts, this ledge can be placed in the anterior chamber where it doesn't cause any issues. If left anterior in a DALK where it cannot be pushed posteriorly by the presence of the patient's own Descemet's membrane, this ledge can result in problems with epithelization. Manually "shaving" the donor tissue can result in scar tissue, producing irregular astigmatism.

Combining these elements causes varying degrees of astigmatism. In cases of worse-than-average astigmatism, surgical remediation may be required before using an RGP or scleral lens. In extreme cases, a single intervention effort may not be able to treat the magnitude of cylinder, so it is important to understand the surgical steps to take and the order in which to take them.

Our facility approaches extreme levels of post-transplant astigmatism in a stepwise fashion, moving from less precise to more precise options, that begins with removing all remaining sutures.



The patient's topography after total suture removal, subsequent corneal relaxing incisions at eight weeks post-suture removal and subsequent PRK.

Your options include:

- Suture adjustment or removal to create long-term corneal stability.
- Corneal relaxing incisions to induce flattening. Because corneal relaxing incisions are more central (just central to the graft host interface), they tend to be more impactful than limbal relaxing incisions.
- Compression sutures to induce steepening.
- Wedge resections to induce marked steepening. Removing a thin (0.1mm to 0.2mm) wedge of donor tissue from near the graft host interface with subsequent suturing causes steepening.
- Excimer laser ablations, or phototherapeutic keratectomy, to treat transplant eyes that have pathologic refractive with LASIK or photorefractive keratectomy (PRK).

Though suture adjustment with running sutures or selective suture removal with interrupted sutures may fine-tune astigmatism early on, the magnitude of the effect of these interventions is usually smaller later in the postoperative course. Further, if surgical intervention is pursued to treat pathologic astigmatism prior to suture removal and a suture breaks, the effect of surgery will be diminished. Removing all sutures creates long-term stability for the cornea, which is important if a subsequent refractive surgery is performed. Though sutures with DALK grafts can often be removed safely one year postoperative and those with PK grafts by 36 months, a corneal specialist should determine when and if sutures can be removed to avoid creating graft dehiscence if they are removed prematurely.

The impact of suture removal on astigmatism is unpredictable, so we must inform patients that removal may result in their astigmatism worsening but is performed to create a stable cornea for subsequent treatments. After sutures are removed, the patient should not undergo further treatment for several months as the cornea stabilizes. Repeat the process of manipulating the cornea and waiting for stability after each subsequent procedure.

In my opinion, these efforts should conclude with excimer laser ablation, which is the most precise technique. Post-transplant excimer laser ablation limitations, however, do exist. First, treatment accuracy with excimer laser ablation is far from the level achieved with conventional treatments in normal eyes, with one study reporting an average cylinder reduction of less than 50%.[1] Second, the ability to treat high amounts of astigmatism is limited by the treatment zone of all excimer laser applications. As the magnitude of cylinder increases, the treatment zone becomes more oval-shaped. At significantly high levels of treatment, the size of this oval becomes thin enough to create diminishing returns in treatment. Thus, the amount of cylinder you treat with excimer laser-based treatments should be no greater than 6.0D to 7.0D. Due to the limited magnitude of treatment offered by laser vision correction, we begin with incisions, compression sutures and/or wedges and move to PRK as needed.

AFTERMATH

We followed these steps to treat this patient. All sutures were removed, and relaxing incisions were placed four months later. Six months later, PRK was performed. At the conclusion of this process, the patient's uncorrected vision was 20/60, and he had 2.9D of moderately irregular cylinder and could correct to 20/40 with glasses and 20/20 with contact lenses.

As ODs, we put a lot of pressure on ourselves to fit post-transplant eyes with contact lenses; but, sometimes, the magnitude of cylinder precludes the ability to fit a hard lens. Unless a surgery center is able to mitigate the astigmatism, the graft will fail. Knowing your options and being aware that astigmatism improvement, but not always cylinder elimination, is attainable will allow you to educate patients appropriately and refer them in a timely fashion. RCCL

1. Bilgihan K, Ozdek SC, Akata F, et al. Photorefractive keratectomy for post-penetrating keratoplasty myopia and astigmatism. J Cataract Refract Surg. 2000;26(11):1590-5.

By Vivian P. Shibayama, OD

The More the Merrier

When an out-of-the-ordinary case presents, make sure you have options to fall back on.

When I started as a contact lens specialist, the best advice I received was to understand and perfect a lens in each category. After gaining more experience, I realized having several lenses in your repertoire has its advantages. While I have a few go-to lens designs that I use most of the time, I am also able to defer to other options. In the following case, I ended up choosing a scleral lens design that I don't use as often but was well suited for my patient.

THE CASE

A 21-year-old female presented with complaints of blurred and fluctuating vision that was giving her headaches and making it difficult to concentrate in school. She was using reading glasses on top of her contact lenses. She had tried a handful of different lenses, including rigid gas permeable (RGP) lenses that she could not tolerate and hybrid lenses that gave her the most consistent and clear vision but were very dry, and finally settled on Cooper Biofinity toric lenses that gave her good comfort but fluctuating and unclear vision.

A month ago, she was screened by a pediatric ophthalmologist to rule out accommodative disorders and strabismus. The exam findings were unremarkable, and she was cleared.

Her contact lens prescription was +5.25 -0.75x170 OD and +5.50-0.75x180 OS. Her presenting visual acuities (VAs) were 20/30+ OD and 20/25- OS. Over-refraction yielded -0.50 20/25+ OD and plano OS.

The patient's cover test revealed ortho at distance and at near. Her accommodative amplitudes were to the nose OU. Her positive and negative relative accommodations were within normal limits. Her pupils were round, equal and reactive to light. Her confrontation fields were full-to-finger counting.

Topographical imaging revealed irregular asymmetric bowties OU with simulated keratometry readings of 43.32@092/40.86@002 OD and 42.94@086/40.52@176 OS and horizontal visible iris diameters (HVIDs) of 12.0mm OU (*Figure 1*).

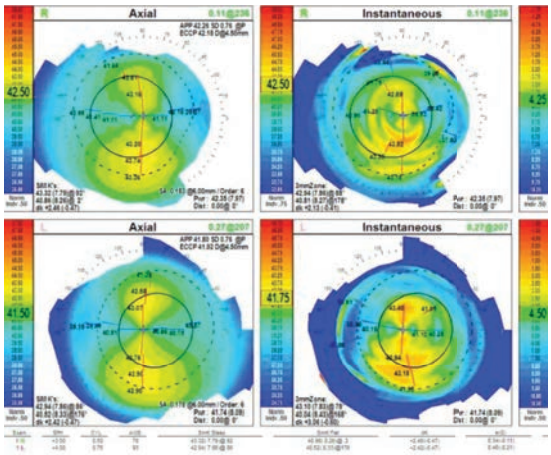


Fig. 1. Topography showed asymmetrical bowties and slightly irregular astigmatism OU.

Her slit lamp exam revealed clear lids and lashes and clear conjunctiva with deep and quiet anterior chambers OU. Her corneas, irises and lenses were normal. Her intraocular pressures were 15mm Hg OD and 14mm Hg OS.

CONTACT LENS EVALUATION

Manifest refraction revealed:

+4.00+1.00x078 (VA of 20/25+) OD

+4.25+1.00x087 (VA of 20/30) OS

After reviewing the patient's results, I discussed contact lens options with her. Given her previous success with hybrid lenses and her dryness issues and irregular astigmatism, we decided on scleral RGP lenses. I placed diagnostic lenses with a base curve (BC) of 8.04/-2.00/sag 4.6 and a diameter of 16.9mm on both eyes.

Both of her eyes exhibited an excessive sagittal clearance of 400 and dropped low. The chamber size was small for the HVIDs even after pushing the lenses up. Over-refraction yielded +5.25 OD and +5.00 OS and brought the patient's VAs to 20/20- OU. The patient was thrilled with the comfort and vision these lenses provided, so we decided to move forward with them.

The BC of the lenses was flattened to address the increase in vault from increasing the diameter to accommodate the patient's larger-than-normal HVIDs. Changing the BC increased the power of the lens. The sag was also lowered to achieve a vault of 200µm. I ordered scleral lenses from Advanced Vision Technology with a BC of 9.08 OU, a diameter of 17.1mm OU and powers of +9.50 OD and +10.00 OS.

After the diagnostic contact lens fitting, I dilated the patient with Cyclogyl to complete her exam. The cycloplegic exam revealed +4.50+1.25x085 OD and +4.75+1.25x087 OS with VAs of 20/25+ OD and 20/30 OS.

Cycloplegic refraction did not show a significant amount of latent

hyperopia compared with the dry manifest refraction. The dilated view of the posterior segment revealed a cup-to-disc ratio of 0.25 OU. Everything else was within normal limits. I concluded that the patient had hyperopia with irregular astigmatism OU.

ORIGINAL DISPENSING

The patient returned for a dispensing visit the following week. I placed the lenses and evaluated the lens fit and her vision. Her VAs were 20/40- OD and 20/60 OS. The central vault was 200µm OU, but the lenses were dropping low. When the lenses were pushed up, the patient's vision improved. Autorefraction showed an optic that was decentered inferiorly (*Figure 2*). I did not perform over-refraction due to the decentered lens optics.

I ordered scleral lenses with the original BC, diameter and powers in addition to a 2D toric haptic OU to raise them up and a thinner center thickness to reduce their weight.

DISPENSING REDO

The lenses were placed on the patient's eyes a week later. They exhibited some improvement in centration but were still decentered. Her VAs were 20/30- OD and 20/40- OS.

After returning to school, the patient would not be able to come back for follow-up visits, so I decided to refit her in a different design to see if I could achieve a better fit.

I chose the Europa lens from Visionary Optics with a 16.0mm diameter to reduce the mass of the lens and achieve a lighter center of gravity and BCs of 40.00 OD and 42.00 OS. The central vault of the right lens was 200µm with good limbal clearance, and the central fit of the left lens was slightly excessive at about 300µm. Over-refraction brought the patient's vision to 20/20- OU. Even though this lens diameter was smaller than the previous, the limbal vault was slightly excessive. The following lenses were ordered: 40/+5.50/15.7 standard periphery BXO clear OD and 41/+4.50/15.7 standard periphery BXO blue OS.

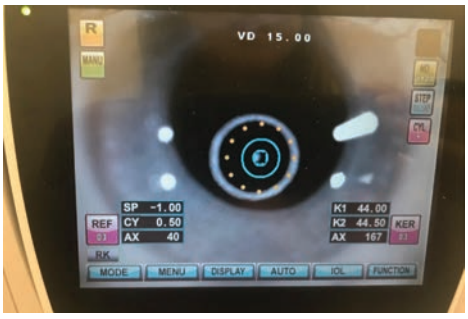


Fig. 2. Autorefraction of the lens over the eye exhibited inferiorly decentered optics.

Since we did not need to adjust the sag or diameter much, the power of these lenses was roughly half of the original scleral lens order. I anticipated that this would produce good centration and a better fit.

DISPENSING TAKE THREE

The patient returned a week later, and the Europa lenses were placed on her eyes. Her VAs were 20/25+ OD and 20/25- OS. An over-refraction of +0.50 OU brought the patient's vision to 20/20- OU. The central vault of 200µm and the limbal vault were adequate OU. The patient was thrilled with the vision and comfort the lenses offered, so I ordered them.

FOLLOW-UP

The patient returned a month later and had no complaints. For the first time in years, her vision was consistently clear, she no longer needed reading glasses and her eyes were comfortable. Her prescription was finalized.

DISCUSSION

In this modern age of scleral lenses, we have many designs to choose from. Some don't use BC to dictate sagittal height, which is advantageous for high minus keratoconus patients. For example, some sclerals have a standard flat BC that doesn't change with changes in sagittal height.[1] Instead, BC is used to address limbal fit in these lenses. A -23.00D keratoconus patient wearing RGP lenses may be a -8.00D in a scleral lens because of the difference in BC when it is not dependent on the curvature of the cornea. Lower powers can improve optics, lens mass and patient comfort. However, if a patient is already a high plus, transitioning between designs like this can be disadvantageous and cause lens decentration in a scleral lens, which results in induced astigmatism and poor vision.

Choosing a design that is closest to what the patient needs on diagnostic fitting is something I learned how to do quickly to reduce chair time and increase patient satisfaction. HVID, diagnosis, scleral shape, material availability and refractive error are all factors that need to be assessed immediately for the best lens fit and lasting patient success.[2] RCCL

1. Hellem A. SynergEyes. A lens designed to fit true scleral shape. blog.synergeyes.com/blog/a-lens-designed-to-fit-true-scleral-shape. Accessed March 27, 2019.
2. Johns LK, Barnett M. Contemporary scleral lenses: theory and application. Bentham Science. 2017.

By Mile Brujic, OD, and David Kading, OD

Special Considerations for Specialty Lenses

Follow these four strategies for the best shot at success.

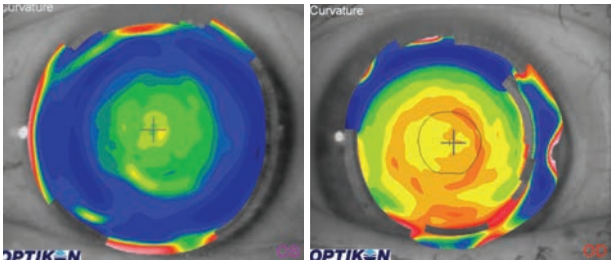
Specialty lenses give many patients a clear and functional window to the world. At times, fitting these lenses is straightforward and follows a predictable process. At other times, we need to be more creative to make sure these lens fits are ideal for patients. This column discusses four strategies to improve specialty lens success.

TAKING TOPOGRAPHY

Multifocal lenses provide patients an opportunity to see at distance and at near with minimal to no need for supplementary glasses. Unfortunately, some patients have a difficult time with them. Soft multifocals are based on the premise that we look through the center of the lens and the distance and near optics focus on the retina. Neuroadaptation allows patients to adjust to distance and near vision when these lenses are fit and worn successfully.

The optical centers of multifocal lenses don't always line up with a patient's line of sight. Most patients look through a point that is nasal to the geometric center of the pupil. Many of the optical properties of soft multifocals are located on the anterior surface of the lens. If a topography measurement is taken over the surface of a multifocal lens, because of the differences in optical properties, steeper zones associated with more plus power will be evident. For example, when a topography measurement is taken over the surface of a near-center lens, it will be steeper centrally (*Figure 1a*). If a patient is wearing a distance-center, near periphery lens, there will be steeper regions in the peripheral portion of the lens and flatter zones in the central portion (*Figure 1b*).

Most topographers can identify a patient's line of sight to help you see where it is with respect to the optical center of the lens on the eye. In our experience, the closer a patient's line of sight is to the optical center of the lens, the higher the likelihood of success with the multifocal lens design. A patient is usually less successful when their line of sight diverges from the optical center of the lens (*Figure 2*). Specialty lens designs in soft and scleral lenses can now alter the position of the optics in the center of the lens to more appropriately align with a patient's line of sight.



Figs. 1a and 1b. The topography of a near-center multifocal lens (left) shows a steeper region centrally that corresponds to near optics. The topography of a distance-center multifocal lens (right) shows a flatter region centrally that corresponds to distance optics.

Topography can be taken over the surface of most lenses, including gas permeable (GP) multifocals. These lenses are typically designed with their distance optics in the center of the lens and their near optics located more peripherally. Topography taken over the GP lens demonstrates a flatter profile centrally and a steeper profile peripherally. When the lens and line of sight are aligned appropriately, patients tend to do very well. If the lens is decentered from a patient's line of sight, however, it can alter the optical zones and degrade the patient's visual quality at distance and at near (*Figure 3*).

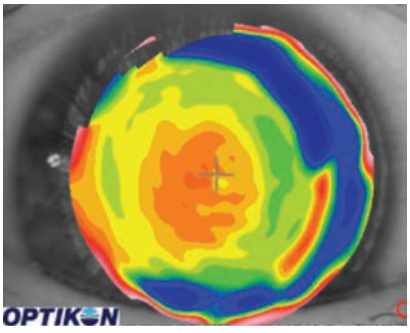


Fig. 2. The near zone of this lens is decentered inferior temporally.

CONQUERING COMFORT

There are certain cases in which patients may be able to see remarkably well out of their specialty lenses but experience poor comfort that precludes them from being able to wear them. Several strategies—including modifying lenses, switching solutions and prescribing drops—may improve comfort. If patients have comfort issues but do not have dry eye, they may benefit from a Lacrisert placed in the lower fornix.

A Lacrisert is a prescription ophthalmic insert comprised of hydroxypropyl cellulose. After the insert is placed, it slowly dissolves over 24 hours, releasing demulcents into the tear film and providing more comfort.[1] Teach users to place the insert in the lower fornix only after they have placed the lens on their eye so it does not fall out.

An additional option for increasing comfort is a coating called Hydra-PEG (Tangible Science) that adds hydrophilicity to provide a more moisture-rich surface that resists lipid deposition.[2] This coating is applied to the lens surface at the time it is manufactured. Lenses with this coating cannot be rinsed with water and should not be stored dry.

ORDERING ORTHO-K

Ortho-K helps manage and correct myopia. Strategies for fitting the lens appropriately include optimizing the lens fit, dispensing the right lens and following up with topographies and refractions after the patient has worn the lens overnight.

New technologies provide us with greater insights to help guide our ortho-K fits. AS-OCT gives us the ability to measure epithelial thickness before and after treatment, which shows us the effects of ortho-K on the cornea. Visualizing the area of thinned epithelium helps guide lens positioning on the cornea and treatment zone placement (*Figure 4*).

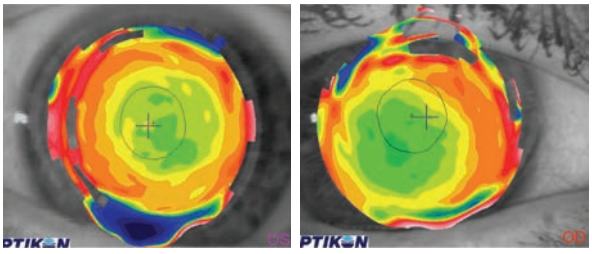


Fig. 3. At left is the topography over a well-centered GP multifocal. At right is the topography over a GP multifocal lens that is decentered inferior temporally.

PINPOINTING PUPILS

There are times when pupil dilation degrades the quality of vision that some patients experience with specialty lenses. GP multifocals are designed so that the distance optics are centrally located and the near optics are in the periphery. When the pupil dilates, it may encroach into the near optics, reducing the quality of distance vision. Patients undergoing ortho-K can have issues with night vision if the pupil enlarges into the reverse curve created in the cornea. Patients wearing small diameter lenses, specifically those fit for an inferiorly decentered cone in cases of keratoconus, may notice reduced vision if their pupils dilate in low light levels past the optical zone of the lens or, in extreme cases, the outer edge of the lens.

Fortunately, there is a pharmacological way to prevent a patient's eyes from dilating. Alpha-2 receptors are located on the presynaptic nerve endings that innervate the dilator muscle. They bind excessive quantities of norepinephrine in the synaptic cleft to down-regulate the release of further norepinephrine. Brimonidine, an alpha-2 adrenergic agonist, binds directly to alpha-2 receptors to prevent pupil dilation by preventing norepinephrine release into the synaptic cleft.[3]

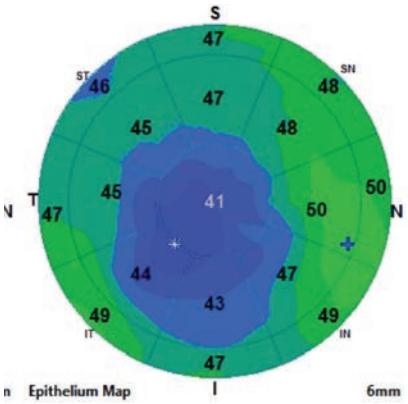


Fig. 4. This epithelial thickness map taken after ortho-k shows an inferior temporally displaced treatment zone.

Brimonidine is available in these concentrations: 0.2%, 0.15%, 0.1% and 0.025%. We typically recommend patients use the drops 30 minutes prior to performing critical viewing tasks in low light levels, such as driving at night. We reserve this strategy for patients whose vision cannot be improved with refractive correction or lens alteration.

There are a handful of strategies that can help our specialty lens users successfully wear their lenses. Any one technique, however, doesn't always work for all patients. Knowing alternative options gives you the best chance at achieving a good, comfortable fit for the best results in these patients. RCCL

1. Bausch + Lomb. Lacrisert. www.bausch.com/ecp/our-products/rx-pharmaceuticals/rx-pharmaceuticals/lacrisert. Accessed March 29, 2019.
2. Tangible Science. tangiblescience.com/professionals/. Accessed March 29, 2019.
3. Kato COS, Shimizu K, Kamiya K, et al. Effects of brimonidine tartrate 0.1% ophthalmic solution on the pupil, refraction and light reflex. Sci Rep. 2018;8:9003.

By Christine W. Sindt, OD

Spread Too Thin

Patients with Terrien's marginal degeneration should keep their safety glasses handy.

A 53-year-old white male presented with a long history of slowly increasing astigmatism in both eyes. He denied pain or redness but stated his glasses were no longer working for him.

His exam revealed 360 degrees of peripheral stromal thinning with corneal neovascularization and lipid at the leading edge. The conjunctiva/sclera was white and quiet.

He had a manifest refraction of -2.00 +5.50 x 180 OD and -3.00 +6.00 x 180 OS, yielding 20/20 vision in each eye.

Based on these findings, he was diagnosed with Terrien's marginal degeneration (TMD), given a new prescription, counseled on the progressive nature of the disease and cautioned to wear glasses or eye protection at all times to avoid the risk of accidental perforation.

DISEASE BASICS

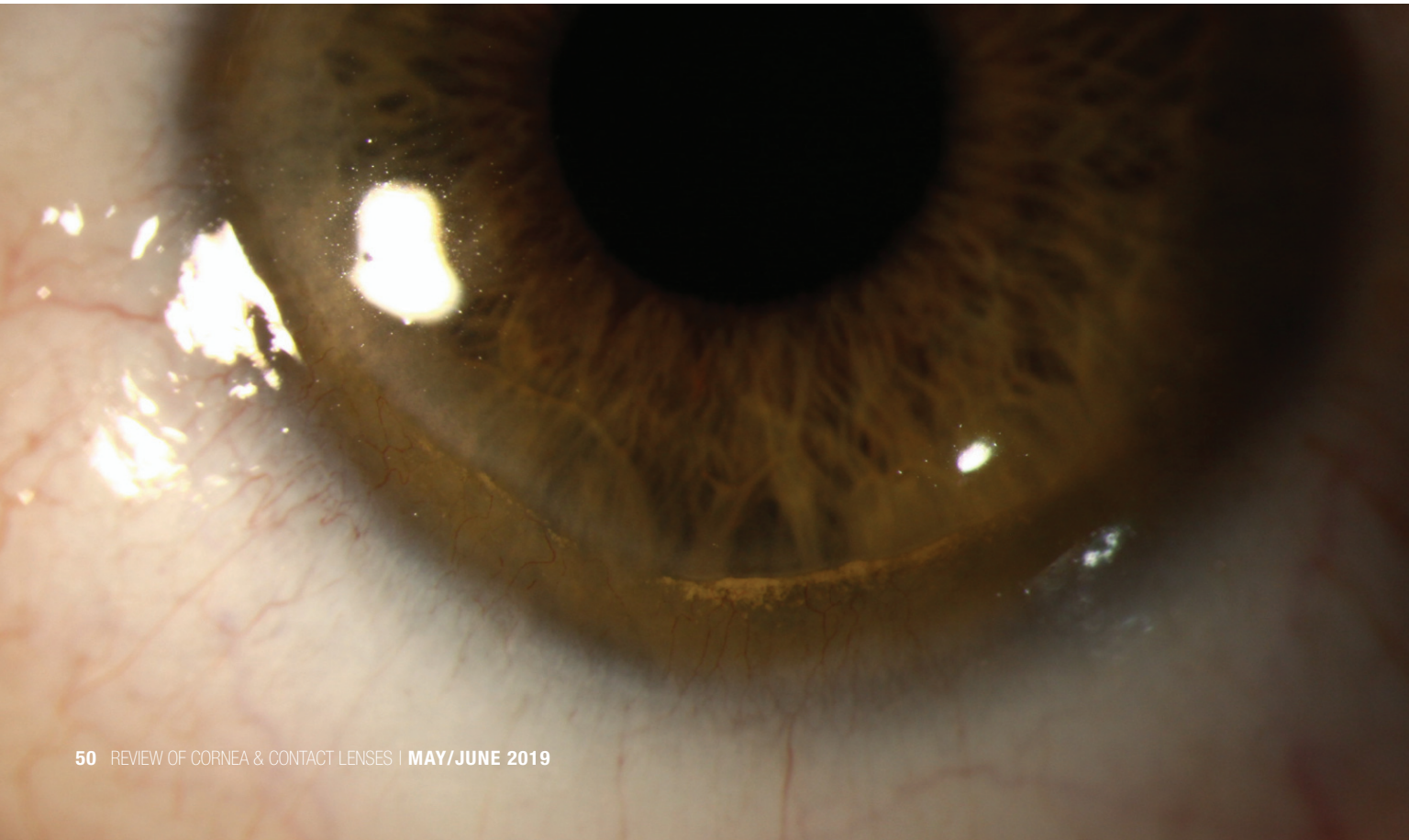
TMD is a non-inflammatory condition that causes thinning of the peripheral/limbal cornea. It typically begins on the superior cornea and advances circumferentially. Opacification and lipid deposits form at the edge of the thinned area, and lacy pannus vessels form throughout it. While punctate epithelial erosion is possible, the epithelium generally appears intact. Spontaneous perforations are rare; however, Descemet's membrane may rupture and cause intracorneal swelling. Progressive, high against-the-rule astigmatism is a classic refractive finding in TMD.

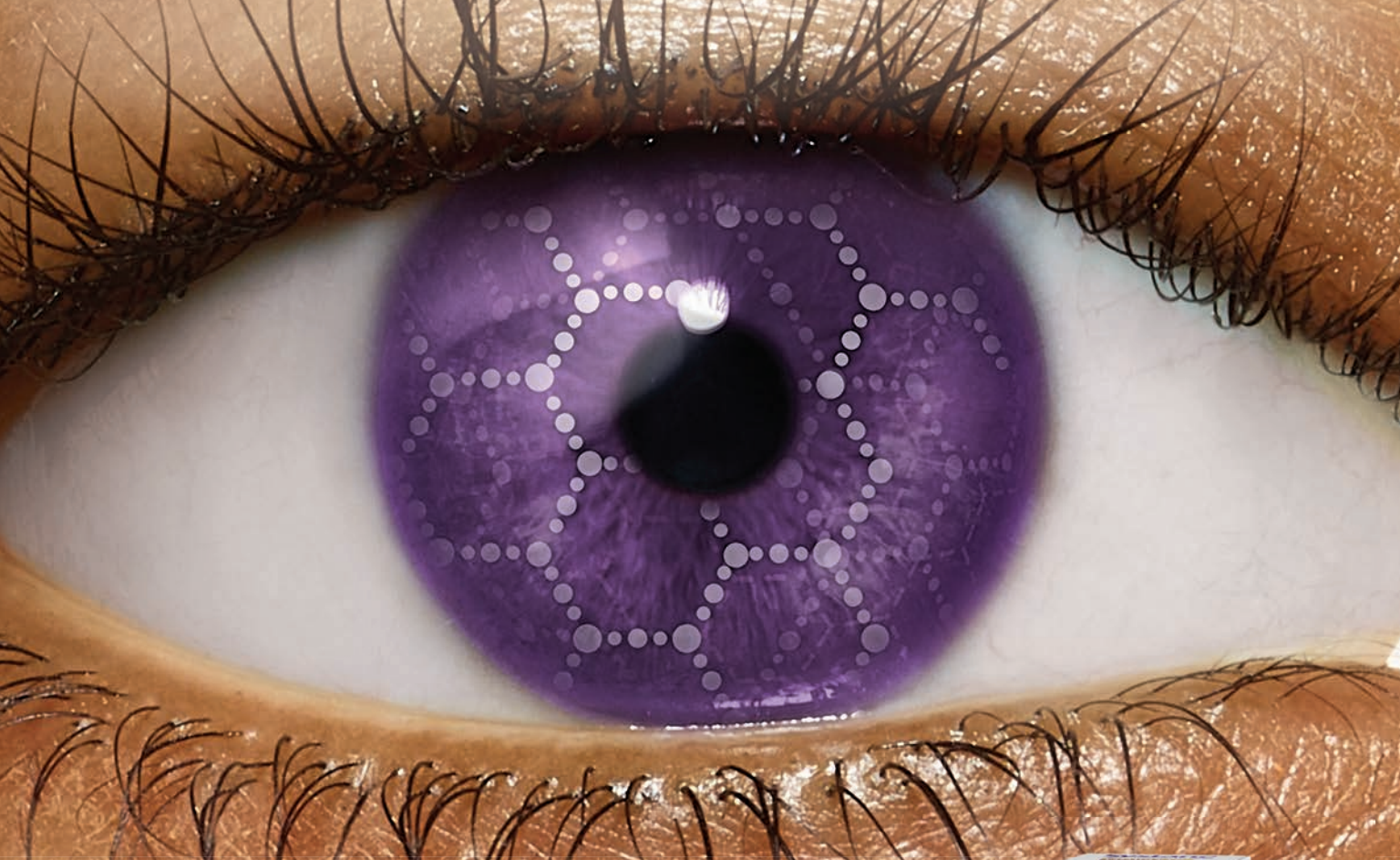
The condition can be differentiated from other corneal thinning disorders such as pellucid marginal degeneration (PMD) based on the location of the thinning. For TMD, thinning starts superiorly and rarely involves the inferior limbus. PMD thinning, however, starts inferiorly and only involves the cornea within 1mm to 2mm of the inferior limbus.

A complete differential diagnosis includes: dellen, collagen vascular disease, sclerokeratitis, dry eye, staphylococcal marginal keratitis and infectious corneal ulcer.

MAINTAINING VISION

Patients should be cautioned about the risk of traumatic perforation and given protective eyewear. Scleral lenses may be indicated if vision does not improve with glasses. RCCL





SYSTANE® COMPLETE:

OUR MOST ADVANCED SOLUTION.
ONE SIMPLE CHOICE.

Our most innovative drop supports all layers of the tear film and is designed to provide symptom relief for **every major type of dry eye**:[1-9]

- ☑ **Evaporative Dry Eye**
- ☑ **Aqueous-deficient Dry Eye**
- ☑ **Mixed Dry Eye**

The Relief is Real™

Advanced, lipid nano-droplet technology rapidly delivers the lubricant across the ocular surface — resulting in **better coverage* to provide fast-acting hydration, tear evaporation protection, and long-lasting relief**[1,5-6,8-10]

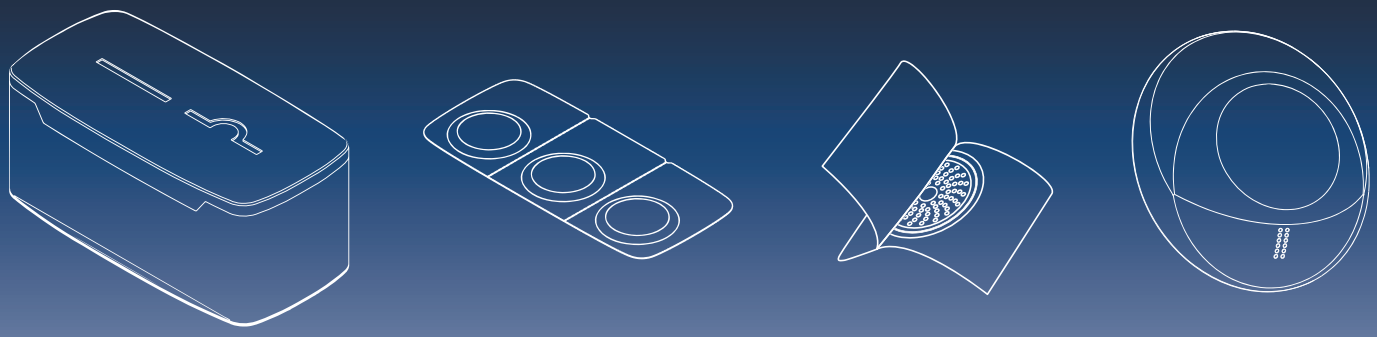
VISIT SYSTANE.COM TO LEARN MORE!

*Compared to SYSTANE® BALANCE Lubricant Eye Drops.

References: 1. Korb D, Blackie C, Meadows D, Christensen M, Tudor M. Evaluation of extended tear stability by two emulsion based artificial tears. Poster presented at: 6th International Conference of the Tear Film and Ocular Surface: Basic Science and Clinical Relevance; September 22-25, 2010; Florence, Italy. **2.** Moon SW, Hwang JH, Chung SH, Nam KH. The impact of artificial tears containing hydroxypropyl guar on mucous layer. *Cornea*. 2010;29(12):1430-1435. **3.** Davitt WF, Bloomenstein M, Christensen M, Martin AE. Efficacy in patients with dry eye after treatment with a new lubricant eye drop formulation. *J Ocul Pharmacol Ther*. 2010;26(4):347-353. **4.** Willcox MDP, Argueso P, Georgiev GA, et al. TFOS DEWS II tear film report. *Ocul Surf*. 2017;15:366-403. **5.** Ketelson H, Rangarajan R. Pre-clinical evaluation of a novel phospholipid nanoemulsion based lubricant eye drop. Invest Ophthalmol Vis Sci. 2017;58:3929. **6.** Ogundele A, Ketelson H, et al. Preclinical evaluation of a novel hydroxypropyl-guar phospholipid nanoemulsion lubricant eye drop for dry eye disease. Poster presented at: The 36th World Ophthalmology Congress (WOC); June 16-19, 2018; Barcelona, Spain. **7.** Craig J, Nichols K, Akpek E, et al. TFOS DEWS II definition and classification report. *Ocul Surf*. 2017;15:276-283. **8.** Lane S, Paugh J, et al. An Evaluation of the in vivo Retention Time of a Novel Artificial Tear as Compared to a Placebo Control. Invest Ophthalmol Vis Sci. 2009;50(13):4679. **9.** Benelli U. Systane® lubricant eye drops in the management of ocular dryness. *Clin Ophthalmol*. 2011;5:783-790. **10.** Torkildsen G. The effects of lubricant eye drops on visual function as measured by the Inter-blink interval Visual Acuity Decay test. *Clin Ophthalmol*. 2009;3:501-506.

Alcon A Novartis Division

Now Available!



EASY, CLEAN, PORTABLE.

A Unique Approach to Daily Disposable Soft Toric Lenses

The 1day Miru Toric flat pack is designed using SmartTouch™ Technology which minimizes lens handling and contamination concerns so contact lenses can be worn more comfortably and hygienically.

1day Miru toric employs a unique Smart Fit™ design that naturally orients the lens correctly no matter which way it is inserted.

For a trial pair, please email information@menicon.com

Menicon

Miru 1day Menicon Flat Pack