ARVO 2015 REPORT:
Bridging Research & Practice

Our picks for 20 of this year’s most clinically relevant papers in the field of cornea and contact lenses.

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- Lens edge

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- Distance vision
  - Spherical zone
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IN BRIEF

• Multipurpose solutions have a limiting effect on contact lens biofilm formation, reports a study in May 2015 Eye and Contact Lens. Italian researchers evaluated the antibiotic activity of Regard (Vita Research), Biotrue (Alcon) on Serratia marcescens, Pseudomonas aeruginosa, Staphylococcus epidermidis and Staphylococcus aureus. Cultures were treated with two concentrations of the solutions (75% and 100%) and monitored for 24 hours. While all three were effective against the four bacterial species, bacterial growth was observed in the presence of a 75% concentration of Regard, while Biotrue and Opti-Free PureMoist were more effective, particularly against staphylococci. Biotrue was especially effective against Gram-negative bacteria. Regard was most effective in reducing Pseudomonas biofilm.


• A piggyback penetrating keratoplasty technique may be a safer alternative to conventional PKP when associated with an open-sky procedure, reports a case report in Cornea. During a combined cataract/PKP, the surgeon—note the possibility of imminent IOL prolapse—inverted the donor corneal graft into the anterior chamber beneath the recipient cornea, creating a temporary piggybacking effect before the recipient’s cornea was removed. The surgery was successful, but the authors note complexity is involved. “It is most difficult for a surgeon to suture between the lower peripheral donor corneal graft and the peripheral recipient cornea beneath the epithelium from the effects of ultraviolet radiation, direct exposure to air and chemical agents. In cases of oxidative stress, the levels of these compounds can be drastically reduced, leaving the epithelium open to the development of anterior eye disorders such as keratoconus, dry eye and Sjogren’s syndrome.”


• Acuvue has released its 1-Day Moist multifocal for presbyopia. The lens is the first on the market to match the aspheric center/near optical design to pupil size as it changes according to age and refractive power, the company says.

• Menicon has expanded its Minil daily disposable lens parameters to include powers of +0.50D to +4.00D in 0.25D steps, and introduced a rebate program that offers patients up to $10 back on an annual supply of lenses.

Treating Dry Eye with Lactoferrin-Loaded Lenses

Contact lenses loaded with lactoferrin (LF) could prevent the effects of oxidative stress on the tear fluid, reports a study in the June 2015 Cornea.1 Researchers from the University of Milano-Bicocca in Italy incubated three types of contact lenses—galyfilcon A, filcon V and falcon 1B—for one, three or five hours at room temperature in an apolactoferrin (iron-depleted form of lactoferrin; abbreviated as apoLF) 2mg/mL solution. Results indicated maximum loading at five hours was 61±19µg for falcon V, 39±4µg for filcon 1B and 42±14µg for galyfilcon A.

After incubation, the lenses were placed in a phosphate buffer and the quantity of released apoLF was evaluated at one, two, three and 24 hours. Data showed the release of adsorbed apoLF was 49±12% for filcon V, 66±20% for filcon 1B and 100% for galyfilcon A. This indicates the presence of accessible iron-binding sites is necessary for LF to protect against oxidative stress, the researchers say.

Using the same cellular model, researchers next evaluated the lactoferrin-loaded contact lenses for treatment purposes by incubating TsA cells with contact lenses loaded or unloaded with apoLF and evaluating the effect of induced oxidative stress. Results indicated the apoLF-loaded lenses had a mitigating effect on the number of dead cells compared with the control lenses; specifically, 10.5±1.2% vs. 36.2±4.7% for filcon V, 20.9±1.6% vs. 31.8±2.5% for filcon 1B and 19.4±2% vs. 37.3±2.7% for galyfilcon A. In fact, the researchers note, all of the contact lenses loaded with apoLF counteracted the H2O2 treatment for at least 24 hours.

Tear fluid contains antioxidative compounds that protect the corneal epithelium from the effects of ultraviolet radiation, direct exposure to air and chemical agents. In cases of oxidative stress, the levels of these compounds can be drastically reduced, leaving the epithelium open to the development of anterior eye disorders such as keratoconus, dry eye and Sjogren’s syndrome.1 Results from this study indicate, however, that “LF-loaded contact lenses may represent a new therapeutic approach to treating ocular surface pathologies characterized by high levels of oxidative stress,” the researchers conclude.1

**Growth Hormone Key to Corneal Wound Healing?**

Human growth hormone (HGH) activates epithelial cell movement in vivo, reports a new study published in the June 2015 *Cornea.* These findings could lead to topical compounds that promote more efficient corneal wound healing in patients with persistent corneal epithelial defects (PCEDs) by activating corneal epithelial cell proliferation and migration.

Researchers from Harvard Medical School and the University of Utah evaluated the effects of HGH cell signaling, proliferation and migration and whether insulin-like growth factor-1 (IGF-1) may mediate these effects using immortalized human corneal epithelial cells and primary human corneal fibroblasts. Five cultures were set up: corneal epithelial cells in keratinocyte serum-free medium (KSFM) supplemented with 5ng/mL epidermal growth factor (EGF) and 50µg/mL bovine pituitary extract (BPE) for two days; two cultures of corneal fibroblasts in 10% fetal bovine serum (FBS) for two days; and two cultures of corneal epithelial cells in 10% FBS for five to seven days. After culturing, researchers withdrew the respective serum or supplement. Culture one was treated with HGH of increasing doses for 15 minutes, followed by cell lysis and immunoblotting. Cultures two through five were treated with either HGH or IGF-1 for 15 minutes. Researchers observed a dose-dependent increase of p-STAT5, a protein responsible for cell signaling, in both cell types. IGF-1 did not play a differentiating role.

In the second part of the study, researchers performed an in vitro scratch test on confluent epithelial cells cultured alone and together with fibroblasts, finding that HGH significantly increased corneal epithelial cell migration only in the epithelial cell/fibroblast combination cultures. “This indicates the HGH does not act on corneal epithelial cells directly to stimulate migration, but rather acts through an intact epithelial/fibroblast communication system. This duplicates the situation in vivo, where epithelium and stromal keratocytes coexist,” the researchers explain. IGF-1 did not play a significant role in cell migration. A highly regulated process, corneal wound healing can be drastically impaired by ocular surface disease or trauma, systemic disease or surgical intervention. In some cases, this can lead to the development of PCEDs, which ultimately affect visual clarity. Treatment methods include patching, lubricants, ointments and even surgery, but currently no approved pharmacotherapy exists. Results from this study indicate, however, that HGH could be a potential topical therapeutic to promote corneal epithelial wound healing, suggesting further research is needed.

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Neuropathic Pain and Depression in Dry Eye Sufferers

The connection between ocular surface disease and certain negative stimuli may be greater than previously thought.

Each year at the annual meeting of the Association for Research in Vision and Ophthalmology (ARVO), renowned scientists share their valuable research on a range of topics. This year’s meeting in Denver was especially full of clinically relevant studies that can be applied to practice today, and I’m pleased to be able to share some of the most interesting abstracts from the cornea and contact lens areas in this issue (see pg. 12). In addition, however, I’d also like to take a closer look at two problems that plague the dry eye patient.

Under the heading of dry eye disease, the papers and posters that garnered the most attention were those about neuropathic pain and clinical depression in dry eye sufferers. Much has been written about the relationship between pain and depression in various diseases—for example, neurosensory dysfunction has been shown to be a component of dry eye and its symptoms.1

Neuropathic pain is often described as a burning, tingling or electric type of pain.1 In addition, spontaneous pain, pain as a response to normally non-noxious stimuli and exaggerated pain are hallmarks of neuropathic pain.1,2 Dry eye patients with neuropathic pain are more likely recalcitrant to conventional therapies directed at treating the ocular surface.1 Thus, in order to effectively treat these patients, this subset with neuropathic pain must first be identified and then educated on the chronic nature of their disease.2 One way to do this is through the use of questionnaires.7

Several risk factors for dry eye signal an underlying etiology that involves chronic pain or somatization and may account for why tear parameters seldom predict symptoms in dry eye patients.2 Essentially, looking at systemic connections is key. Depression is likely a problematic response to the disease process in many patients who suffer with this disease.

ARVO ABSTRACTS

Program 4445, “Incomplete Response to Artificial Tears in Associated with Self-Reported Features of Neuropathic Ocular Pain,” reported that an incomplete response to artificial tears more frequently endorsed symptoms of neuropathic pain and more severe ocular and non-ocular pain compared to those who reported complete response to therapy.3 This may help explain many of the responses we see clinically with a step-up approach to the necessary echelon therapy in treating dry eye patients.

Program 352, “Human Serotonin Levels and Neuropathic Ocular Pain in Dry Eye,” examined serotonin levels as a potential clinical descriptor for neuropathic pain. The researchers found patients with dry eye symptoms and normal tear production may have higher tear serotonin levels than those with dry eye symptoms and normal tear production, as patients with dry eye symptoms and normal tear production more frequently describe features of neuropathic pain. The results of their study suggest that this group may have central abnormalities in their ocular sensory apparatus driving their symptoms.

Program 312, “Depressive Symptoms in Dry Eye Patients: A Case-Control Study Using the Beck Depression Inventory,” looked at depressive symptoms in dry eye patients using the well-established Beck Depression Inventory. The researchers found that, overall, patients with dry eye exhibit more symptoms of depression compared to controls without dry eye. An important part of their conclusion section states that with the presence of depression in dry eye, patients may perceive their symptoms in an anomalous fashion that ultimately will likely affect their treatment decisions.

While just a snippet of the complete lineup, the above abstracts from ARVO 2015 highlight the value of the data presented at this fabulous meeting every year. They also show us that we have to be aware of the comorbidities in dry eye patients that are a direct or indirect result of their condition. As such, we must continue to develop clinical interventions to provide the best treatment possible for those afflicted with dry eye disease.8

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As Review of Cornea & Contact Lenses prepares to take its summer break, Lens Care Insights is shifting its focus this month to cover an important topic that impacts all of your patients, especially this time of year, regardless of age, gender and whether they wear contact lenses or spectacles.

Sun exposure is the number one cause of wrinkles and other signs of aging, and more serious conditions like basal cell carcinoma, squamous cell carcinoma and melanoma, particularly in the periorbital area.1 Yet some optometrists, who may be the first to notice these potentially deadly conditions, neglect to remind patients to use even the simplest form of skin protection available.

PUBLIC SERVICE ANNOUNCEMENT
The American Academy of Dermatology recommends use of a broad-spectrum sunscreen with a minimum sun protection factor (SPF) of 15 to protect against both ultraviolet A (UVA) and ultraviolet B (UVB) rays.2 These are available as both creams and powders, which can be easily applied over the skin and the eyelid region without a change in cosmetic appearance, and are regarded by many skin care specialists as having superior UV control. Regardless of which type of sun protection is used, however, dermatologists recommend making sure the product is approved for use around the eye and to use either balms or wax sticks when possible, as these are less apt to drip into the eye following application.

THE COSMETIC ANGLE
Many people who wear foundation in the periorbital area to even out skin tones or cover up blemishes may choose a particular brand based on the belief they are protecting their face from sun damage. Ironically, however, skin type and facial movement throughout the day can cause the foundation to pool in the fine lines of the face, called dermatoglyphs, leaving some parts of the skin open to sun exposure. Patients with oily skin and those using foundations in cream or powder form are more prone to rapid migration. As with sunscreen, any foundation being used for sun protection purposes should be reapplied every two hours.

Of course, ointments, lotions and creams don’t protect the eye itself from sun damage. It’s important to educate patients on the necessity of sunglasses. Beyond looking “cool,” sunglasses protect the eye from photokeratitis, cataracts and retinal damage. Even in the winter or in shady areas, eye protection is still recommended, as reflected light can be just as damaging.

Both cataracts and skin cancers are the result of years of accumulated sun exposure; thus, precautions should be taken early with small children, although sunscreen use is not FDA-recommended for children under six months of age.3 Early intervention can mean years of healthy living.

For more information on aesthetics and the eye, check out a special feature in the upcoming July issue of Review of Optometry!

If It Ain’t Broke, Don’t Fix It:
Changing habits and exceeding expectations with Bausch + Lomb ULTRA® contact lenses.

by John Womack, OD, Private Practice
Jacksonville, Florida

In the past I found myself approaching many of my contact lens patients with an “If it ain’t broke, don’t fix it” mentality. Often there wasn’t anything better to offer patients, so I simply hoped to keep them in the lenses they had, especially if they weren’t reporting any problems. Not that the patient was necessarily satisfied with what they were wearing, just that they weren’t complaining. Sound familiar?

For me, introduction of the Bausch + Lomb ULTRA® contact lens changed all that – revolutionized is perhaps a better word when I think about the impact this lens has had on me, my practice, and most importantly, my patients. It’s really the entire lens package that enables us to better serve our patients’ needs. Patients need a lens that’s comfortable and the Bausch + Lomb ULTRA® lens delivers with excellent comfort throughout the day. With many of my patients now spending large amounts of time on computers and other electronic devices – on the order of 10-12 hours per day – having a lens that stays comfortable is paramount. Equally important is clarity of vision; the design and aspheric optics of this lens deliver exceptional quality of vision.

With such an innovative option now available, I began to ask my contact lens patients much more probing questions about their lens wearing experience. How do your lenses feel when you insert them in your eye? How do they feel at the end of the day? Is there anything about your lenses that is not meeting your needs? To aid in the process of evaluation, we employed a grading scale, where we asked patients on a scale of 1 to 10 to rate the comfort and clarity of their vision. We began introducing the Bausch + Lomb ULTRA® contact lens to patients who were not completely satisfied with their present lenses -- with great success. Eventually though, we let patients who thought they had great vision and comfort experience the features of the Bausch + Lomb ULTRA® lens. What we found was that there were unmet needs even in patients who had rated their lenses a 10 out of 10; that it was possible to improve their lens wearing experience.

One patient who comes to mind was a 42-year-old woman, very myopic, who had worn Acuvue Oasys lenses for the past 8 years. When I asked about her vision and comfort she reported that everything was “fine,” but when I inquired more specifically about end-of-day comfort and vision – since she works on a computer 8 hours or more a day – she conceded that there was room for improvement. I took out a trial set of Bausch + Lomb ULTRA® lenses – same power as what she was wearing (-12 OU); she placed the lenses on her eye and before I could say anything else, she exclaimed that these were the most comfortable lenses she had ever worn. She walked over to the doorway where she could see her 10-year-old son across the waiting room and said to him, with a big smile on her face, that she could see him clearer than she’s ever seen him before. Funny, but other patients who were in the waiting room at the time all wanted to try the lens that this patient was wearing when they came into the exam room!

Another interesting patient was a 26-year-old man who came in with a request to have contacts just for use on weekends. He was mildly myopic and didn’t like wearing glasses all the time; when I asked “why only for weekends?” he explained that he spent 12 hours a day in front of a computer screen at work and that he had never worn a contact lens that didn’t dry out after 5 hours of use. I let him try the Bausch + Lomb ULTRA® lens and after putting them on he said how great they felt – “I can’t even tell that I have a contact lens on my eye.” He was still pretty skeptical and left intending to wear the lens just on weekends. When he returned a week later for follow-up, he reported not only being able to wear the lens through 14-hour days on the weekends as planned, but that he had also been able to wear the lens successfully through 12-hour days on the computer at his work.

Today, contact lens wearers are using digital technology more than ever before. Their satisfaction with contact lenses may diminish gradually and they may not complain. By changing my habits of the questions I ask contact lens wearers, I am able to improve the wearing experience of my patients. Whether it’s a patient who comes in and everything is not fine or even a so-called “happy” patient, I’m able to confidently offer a new technology that can provide a level of comfort and vision that the patient has not experienced before.
Patients wearing multifocals are just as apt to experience problems as those wearing single vision lenses. But the solutions they need are entirely different.

In our attempts to derail contact lens dropouts, we often focus on alleviating certain risk factors that may interfere with successful contact lens wear. These factors may present in different combinations in particular patient subpopulations—for example, in presbyopes we must not only address the decreased quality of the tear film, but also provide them with multiple points of focus.

While challenging, successfully integrating each factor into the approach is no less important. The following three cases demonstrate several non-traditional options to help presbyopic patients function better.

CASE 1: THE MULTIFOCAL GAS PERMEABLE WEARER
A 54-year-old patient came in to our office for the first time. He was wearing single vision rigid gas permeable (RGP) contact lenses and was using reading glasses over his RGPs to see things at near. He reported this method was cumbersome because he even had to put the reading glasses on to see his smartphone, which he looked at several times an hour. He said that he had tried monovision contacts in the past, but was unsuccessful, and was wondering if simply transitioning to glasses full time with a progressive addition lens would be a better, more convenient option for him.

We discussed vision correction options, including multifocal contact lenses, and the patient elected to proceed with the fitting.

He was fit with a front surface aspheric multifocal RGP with the distance optics located in the center of the lens progressing to the near optics towards the periphery. The initial lens fit well and gave the patient excellent distance and near vision; however, the patient complained that his distance vision in low light levels, specifically night driving, was significantly compromised compared to his previous single vision RGPs. This decrease in distance vision was attributed to pupil dilation: in scotopic conditions, the patient was asked to cover one eye and look at the 20/25 line with the other while wearing his multifocal lenses. The patient noted during this task that his visual acuity was worse, but with a light shone into his non-viewing eye, he reported an improvement in visual acuity.

We ordered new multifocal RGPs (Golden Eye AFM, Valley Contax) with a slightly larger central distance optic zone in the center of the lens in an attempt to reduce the effects of pupil dilation on his distance vision in the evening. The lenses were dispensed and the patient noted an immediate improvement in his night driving. However, because access to the near optics had been moved further out in the lens with the increased diameter of the distance optics in the center of the lens, the patient had a harder time with his near vision. So, while we had improved one problem, we had also created another one.

We discussed the advantages and limitations to both lens designs, and the patient said that he was still considering moving to glasses full time in either case. So, we came up with an additional option: the use of topical brimonidine in a non-FDA approved manner to help control pupil size in the evening. Topical brimonidine is available commercially in concentrations of 0.1%, 0.15% and 0.2%.

We provided the patient with a sample of 0.1% brimonidine to instill 15 minutes prior to night driving. Note, some studies show drops should be instilled 30 minutes prior to night driving for maximum effect. Because the RGP material doesn’t absorb the medication, the drops can be used while the lenses are being worn.

The patient reported experiencing a remarkable difference after the first night of use and affirmed that he wanted to proceed with the drops. He uses the drops more frequently in the winter due to the significantly shorter days and more rarely in the spring, summer and fall because of the increased daylight hours in northwest Ohio.

CASE 2: THE WEEKEND WARRIOR
A 49-year-old male who is a computer programmer wears a monthly disposable multifocal contact lens. He loves the comfort of the lens and understands the balance between his distance and near vision that is required when wearing multifocals. He particu-
larly enjoys the ability to work well at his computer screen while having functional distance vision. However, he recently started playing golf and while he loves his contacts for day-to-day work, he reported finding them difficult to wear while golfing because he has a hard time following the ball. For this reason, he has been wearing his glasses while playing golf.

We discussed single vision contact lens options and he conveyed that he didn’t like the idea of having difficulty seeing the scorecard with single vision lenses. We discussed other options, including sunglasses with a low set bifocal, but he expressed that he does not like to golf while wearing sunglasses. So, we fit this patient with a single vision lens set for his best corrected distance prescription for his dominant eye—in this case, the right eye—and we corrected his non-dominant eye with a multifocal lens in the lowest add power available.

The patient was fit into a daily disposable lens and reported he liked the flexibility of having this as an option for critical distance-dependent activities such as golf.

He ordered a 90-pack of daily disposable lenses for each eye.

**CASE 3: MONOVISION—DON’T RULE IT OUT**

A 53-year-old female is a +2.00D presbyope and has a distance refractive correction of -2.00D in both the right and left eye. She wears reading glasses over her distance vision contact lenses in order to see up close, and expressed interest in contact lens options that would reduce her dependence on reading glasses. Of note was a history of significant seasonal allergies that present in the spring and fall; she was also developing a mild case of contact lens-induced dry eye.

We decided to fit her with multifocal contact lenses; however, after trying two separate designs, she felt that her distance vision wasn’t acceptable in either case. We discussed monovision lenses as another option and the patient elected to try it. Because her right eye was dominant, the lens was removed from the left eye to leave her -2.00D myopic eye uncorrected. She reported that while her distance vision wasn’t as good as with two single vision lenses in her eyes, she felt her vision was clearer than with either of the other two multifocal lens designs she tried.

Initially, she wore a monthly disposable lens, but she experienced comfort issues during the first allergy season after she began wearing this lens, so she was refit into a daily disposable lens instead. She reported feeling much more comfortable throughout the day with the daily disposable lens than with monthly replacement, but even with proper topical anti-allergy therapy, she found it difficult to wear her lenses during allergy season.

We discussed orthokeratology as an alternative option and the patient was successfully fit with an ortho-k lens to be worn in her right eye overnight. She reported experiencing excellent distance vision during the day, without the comfort issues she had while wearing her contact lenses.

**“WE MUST NOT ONLY ADDRESS THE DECREASED QUALITY OF THE TEAR FILM, BUT ALSO PROVIDE PRESBYOPES WITH MULTIPLE POINTS OF FOCUS.”**

All three of these examples represent a challenging scenario in which a presbyope was prevented from dropping out of contact lens wear in a non-traditional manner. While not always the case, thinking outside the box to help this patient population function better in their contact lenses will prevent dissatisfaction and derail contact lens dropouts, thus ultimately helping your practice.

As with any field, innovation and change in eye care is happening constantly—and these days it’s occurring at breakneck speed. Ongoing studies, as well as plans for future research, are the cornerstone to advances in all areas of clinical care. Without novel ideas, stagnation and decline are inevitable.

While no single report can capture the scope of findings presented in the thousands of papers and posters offered during the recent Association for Research in Vision and Ophthalmology’s (ARVO) meeting in Denver, Colo., here we present 20 intriguing findings related to cornea and contact lens topics from the many abstracts presented. The research shared at this year’s meeting will undoubtedly help in developing new strategies for diagnosing ocular health and visual problems, directing new treatment plans and ultimately improving patient care.

1. **Photo-responsive contact lens may help patients suffering from iris damage or congenital defects.** Patients with diminished iris function often experience photophobia, glare and poor vision when exposed to excessive light. For those with congenital or trauma-induced iris damage, commercial artificial irises provide aesthetic improvement but don’t address iris function.

To solve this issue, researchers from the University of Chicago developed a photo-responsive contact lens that mimics the natural iris’s response to light using DEA, a photochromic material, within a biocompatible polymer matrix. Because DEA changes its opacity when exposed to blue light, the contact lens is able to control the amount of light entering the eye using rapid and reversible activation by blue light to alleviate the adverse symptoms of decreased iris function. Biocompatibility was demonstrated by cell culture experimentation and minimal DEA leaching was observed.

Program #6002. Designing a Photo-Responsive Contact Lens. ARVO 2015.

2. **Time between appointments impacts daily disposable overnight wear and reuse.** Researchers attempted to quantify predictors for wearing daily disposable lenses overnight and reusing them over time by evaluating data on silicone hydrogel daily disposable lenses from the 1-Day Acuvue or 1-Day Acuvue Moist Performance Overview (TEMPO) Registry. Factors included age, gender, compliance as rated by the wearer and eye care practitioner (ECP), and self-report of habitual overnight wear of contact lenses. Lens reuse was predicted both through self-reporting by the patient and based on ECP assessment of compliance and baseline measures. Both daily disposable lens overnight wear and reuse were found to increase significantly in correlation with longer time since refitting, suggesting that ECPs must retrain patients when refitting daily disposables in regards to proper wear and care.


3. **MMP-9 increase during early contact lens wear may signal oncoming dry eye disease.** This University of New South Wales team investigated how

**ABOUT THE AUTHOR**

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levels of a marker of inflammation in tears known as matrix metalloproteinase-9 (MMP-9) changed as a function of contact lens wear. In previous studies, altered morphology and poorer function of meibomian glands was identified in contact lens wearers and previous lens wearers. The mechanism for this remains unclear, but inflammation is thought to present as an etiological component of eyelid tissue change, as it is known to accompany dry eye disease and contribute to its propagation.

In the current study, total MMP-9 concentration was established using sandwich enzyme-linked immunosorbent assay. Researchers found that MMP-9 increases during the early years of contact lens wear, parallel to the onset of morphological change in the meibomian gland. This may be an indication of an inflammatory mechanism in meibomian gland dropout in contact lens wearers.

**4. Drug-delivering nanowafer could treat dry eye.** Scientists from the Baylor College of Medicine in Texas compared the effects of treatment with dexamethasone in a controlled-release nanowafer (DEX-NW) system or eye drops in a murine de dictifying stress model of dry eye, as the condition is believed to be a steroid-responsive ocular surface inflammatory disease. The DEX-NW system was placed on the bulbar conjunctiva on days one and three of the study and proved equally as effective in treating dry eye as topical dexamethasone drops instilled twice daily for five days. This suggests the DEX-NW system has potential for delivery of other drugs to the ocular surface.

**5. Androgens may play a more significant role in dry eye disease than previously thought.** Researchers from Croatia have discovered a statistical connection between dry skin and dry eyes as part of a study aimed at determining whether one is linked to the other. Patients were screened for dry eye symptoms and asked to describe their facial skin with regards to dryness or oiliness. A sebumeter was also used to objectively determine the amount of oil produced by each patient’s skin. Findings indicated that subjects without dry eye symptoms self-reported oilier skin than those with dry eye symptoms, and sebumometry scores were found to be higher in subjects without dry eye symptoms compared with those with dry eye symptoms.

The researchers surmised from the results that since both skin and eyes play a significant role in dehydration prevention, there may be a single regulator for this function. Additionally, since androgens play a role in sebum secretion, it’s likely that androgens play a much more significant role in dry eye that previously thought.

**6. Novel antibodies may aid in earlier diagnosis of Sjögren’s syndrome.** Traditionally, Sjögren’s syndrome (SS) is diagnosed based on the presence of certain autoantibodies including antinuclear antibodies, anti-Ro/SSA and anti-La/SSB antibodies, rheumatoid factor and thyroid antibodies. However, three new autoantibodies—secretory protein-1 (SP-1), carbonic anhydrase-6 (CA-6), and parotid secretory protein (PSP)—examined by researchers at the University of Pennsylvania may aid in earlier diagnosis of the immune system disorder. Researchers examined 68 dry eye patients using the Sjö kit: 22 tested positive for the novel SS autoantibodies (32.4%) while four tested positive for traditional autoantibodies (5.9%). Of the three novel autoantibodies, CA-6 was the most prevalent. There was no significant correlation...
between ocular surface exam signs and the presence of novel autoantibodies, however. The researchers concluded that further examination of patients who are positive for novel SS antibodies is needed to help determine the value of these antibodies in early detection of SS in dry eye patients.


7. **Back plate modification can reduce the glare effect experienced by patients with artificial corneas.** Patients frequently report significant glare following Boston Keratoprosthesis (Boston KPro) surgery, in which an artificial cornea is implanted as a last treatment option for patients with recalcitrant or endstage corneal disease. Use of an opaque contact lens is helpful but movement of the lens can limit its ability; thus, an alternative method is needed. Researchers at the Massachusetts Eye and Ear Infirmary and Case Western Reserve University found that use of a newer titanium back plate in the Boston KPro device provides better glare protection compared with the older PMMA counterpart. No difference in glare was noted between pseudophakic and aphakic KPros with this modification, suggesting it may be an effective way to reduce glare.

Program #549. Treatment Outcomes of Keratoprosthesis with Atopic Dermatitis. ARVO 2015.

8. **Graft rejection in atopic dermatitis patients undergoing keratoplasty reduced with corticosteroid use.** A retrospective study on outcomes and treatments for atopic patients undergoing keratoplasty suggests patients with atopic dermatitis have a higher potential for graft rejection, infection and post-keratoplasty atopic sclerokeratitis. Researchers at Fukouka University in Japan examined the medical records of 183 patients prescribed systemic immunosuppressants or corticosteroids during the preoperative period. Postoperative complications included four eyes with cornea graft rejection and two eyes with methicillin-resistant *Staphylococcus aureus* (MRSA) culture-positive from the graft and anterior chamber. No cases of post-keratoplasty atopic sclerokeratitis were observed, however. These results indicate that early treatment using immunosuppressants or corticosteroids could improve graft survival in high-risk atopic patients.

Program #565. Three-Year Follow-up of DSAEK Failure Rates and Endothelial Cell Loss in Eyes with Glaucoma Drainage Devices. ARVO 2015.

9. **Previous use of glaucoma drainage device may impact graft failure rate.** A small retrospective study from investigators at Wills Eye Hospital, Oxford Valley Laser Vision Center and Sidney Kimmel Medical Laser Vision Center at Thomas Jefferson Hospital in Philadelphia examined graft failure rates and endothelial cell loss after Descemet's stripping automated endothelial keratoplasty (DSAEK) in eyes with previous glaucoma drainage devices (GDD). Researchers reviewed 25 cases in 22 eyes with prior GDDs undergoing DSAEK, and found no cases of primary graft failure. However, secondary graft failure occurred in 48% of grafts, with average time to failure 33.3+/16.8 months over the mean follow-up period of 36.1 months. This suggests the procedure may be complicated by the presence of a prior GDD because of the frequent inability to raise the pressure in the eye adequately enough to achieve effective air tamponade. Additionally, compared to the endothelial cell count (ECC) at the time of transplantation, graft ECC decreased by 74.8+/-14% at 36 months, reaffirming the significant rate of intermediate term endothelial cell loss and secondary graft failure in eyes undergoing DSAEK with prior GDDs.

Program #1549. Three-Year Follow-up of DSAEK Failure Rates and Endothelial Cell Loss in Eyes with Glaucoma Drainage Devices. ARVO 2015.

10. **Significant link between ptosis and topical mitomycin C identified.** Topical mitomycin C (MMC) is a well-established primary or adjunctive therapy for ocular surface neoplasia. Adverse effects include allergic reactions, epiphora secondary to punctal stenosis and limbal stem...
cell deficiency. Ptosis, however, is rarely reported as a consequence (1%). Researchers from the University of Liverpool and the Oncology Service at University of California, San Francisco, suspected that the true incidence was underreported and studied the prevalence of this complication in their patients who had received topical MMC therapy. Fifty-four neoplasia patients were identified with a mean age of 62 at the time of treatment. Forty-two percent of patients receiving mitomycin application for neoplasia reported ptosis. Following retrospective chart review, researchers surmised that ptosis after topical MMC-therapy at a standard dose and regimen is vastly underreported, and that patients should be better warned of this potential adverse event.


11. Lid-debridement scaling could help treat Sjögren’s syndrome-related dry eye. A pilot study from investigators in Canada sought to determine the effect of lid-debridement scaling (LBS) of dry eye signs and symptoms in patients with Sjögren’s syndrome (SS). Subjects were divided into a control group and treatment group. The treatment group was evaluated pre-LBS and post-LBS with the Ocular Surface Disease Index (OSDI), ocular staining and Meibomian Gland Evaluator (MGE), and showed statistically significant improvements in OSDI along with ocular staining and meibomian gland function. Thus, this study indicates LBS may help with the management of Sjögren’s syndrome-related dry eye.

Program #2487. Effect of Lid Debridement-Scaling on Dry Eye Signs and Symptoms in Sjögren’s Syndrome. ARVO 2015.

12. Higher prevalence of meibomian gland dysfunction in Caucasians. Researchers in Boston evaluated the prevalence of meibomian gland dysfunction (MGD) among Caucasian patients (n=168) using a standardized metric for meibomian gland function to see whether various genetic factors (i.e., skin type, eye color and hair color) increase the likelihood of MGD in this population. The prevalence of MGD (characterized by 25% or fewer functional MGs) was 70.2%, while prevalence was 43% with a more conservative cutoff of four or fewer functional meibomian glands (17%). Skin type, eye color and hair color had no statistically significant impact on the likelihood of MGD in this population; nevertheless, overall prevalence of MGD in this population was substantial—70.2%—which is significantly higher than previous reports of the prevalence of MGD in Caucasian populations.


13. Blepharitis may cause corneal thinning. Alterations of the tear film and local inflammation, both hallmarks of blepharitis, may result in corneal thinning, reports a study from France. Researchers measured central corneal thickness of 40 eyes of 20 patients (11 men) with blepharitis; the mean age was 58.5. Forty eyes of 20 healthy patients were used as a control group; mean central thickness was 554.9µm. The researchers surmised that increased osmolarity and ocular surface inflammation are the cause of this decrease in corneal thickness.


14. Focal crosslinking is a better alternative to pan-corneal crosslinking. Traditionally, pan-corneal crosslinking (CXL) is used to stabilize and reduce corneal curvature in keratoconus (KC). However, theoretical finite
element models (FEM) of cross-linking in the keratoconic cornea have suggested focal treatment may lead to better postoperative central corneal symmetry, and the recent development of patterned UV systems offers an opportunity to provide focal treatment with the intention of improving vision.

This study retrospectively examined focally applied cross-linking in keratoconus patients to evaluate the potential of focal CXL to improve visual function. At six months, focal CLX subjects’ central topographies were more symmetric, exhibiting inferior flattening and superior steepening on sagittal and tangential maps as predicted by FEM models. On average, there was no significant progression of corneal steepening over the follow-up period, nor significant change in K max. For most subjects, however, the treatment area did not enclose the area of maximum corneal thinning and posterior elevation. Thus, preliminary results suggest that focal treatment may provide greater visual improvement and improved contact lens tolerance over pan-corneal crosslinking.


15. Subconjunctival injections for whiter eyes. Researchers from the Southwestern Eye Center, St. Bernard’s Medical Center and Ross University School of Medicine explored the possibility of an alternative method of whitening the eyes using subconjunctival injections to avoid complications associated with current, controversial techniques. Recent reports have detailed the dangers of certain eye whitening procedures that combine the removal of generous portions of the conjunctiva with cautery, laser and use of antimetabolites. In the new method, ink is injected into the subconjunctival space using a 25-gauge needle. Researchers noted the ink covered deeper scleral vessels but that superficial conjunctival vessels were still visible, suggesting the technique may be a viable, safer means of whitening the eyes.


16. Thermal pulsation for MGD and clinical merit of Sjö testing validated. Researchers from the Ohio State University investigated whether the LipiFlow (TearScience) device improves subjective and objective variables relating to dry eye and MGD, and if a correlation to Sjögren’s syndrome exists. Evaporative dry eye from MGD is the most common form of dry eye, and thermal pulsation therapy using the LipiFlow device is the only FDA-approved treatment.

Researchers retrospectively reviewed records of patients who received a single 12-minute session of thermal pulsation, paying particular attention to SPEED scores, preoperative lipid layer thickness, meibomian gland dropout, tear breakup time (TBUT) and meibomian gland evaluation scores (MGES). A test for Sjögren’s syndrome was also performed, and patients were retested six to eight weeks following treatment. Researchers noted a statistically significant difference between pre- and postoperative SPEED scores, TBUT and MGES, suggesting the effectiveness of a single treatment using LipiFlow. Additionally, 43% of the patients tested positive with the Sjö test compared with 26% of the controls, indicating there is a strong correlation between a positive Sjö test and MGD, indicating an autoimmune component contributing to symptoms experienced in this disease process.

17. **Dexamethasone formulation effective against blepharitis.** A joint team of researchers and clinicians from Minnesota Eye Consultants and InSite Vision evaluated the safety and efficacy of a fixed combination and single agents in DuraSite (dexamethasone and azithromycin) in combination with lid hygiene using lid scrubs to treat blepharitis. Clinical signs (i.e., eyelid redness, swelling and debris) were assessed along with patient-reported satisfaction results. Patients randomized to the dexamethasone-azithromycin arm and dexamethasone arm alone experienced a statistically significant greater reduction in blepharitis scores when compared with the AzaSite and/or vehicle alone groups. Few side effects were noted. These results suggest the anti-inflammatory properties of dexamethasone formulated in the long lasting DuraSite vehicle appear to be effective in treating signs and symptoms of blepharitis for up to six months.

Program #3058. A Phase 3 Clinical Study to Evaluate the Efficacy and Safety of Fixed Combination of Azithromycin and Dexamethasone in DuraSite and Dexamethasone Alone in DuraSite in the Treatment of Blepharitis. ARVO 2015.

18. **Contact lens discomfort mediated by leukotrione B4.** Elevated levels of tear film components may at least partially mediate the discomfort response during lens wear, according to a study from the University of New South Wales. Researchers measured prostaglandins, leukotriene B4 and cysteinyl leukptriene (C4, D4 and E4) using enzyme immunoassay kits in both symptomatic and asymptomatic contact lens wearers. An elevated LTB4 level was detected in symptomatic wearers compared with asymptomatic wearers, but the other markers remained essentially unchanged across the two comfort groups. Lysozyme levels were slightly reduced in symptomatic wearers at the end of the day. Further investigation is needed, however, to determine any significant findings that may aid in treating patients with contact lens comfort problems.

Program #3166. Tear Film in Symptomatic and Asymptomatic Lens Wearers. ARVO 2015.

19. **Is 200μm ideal clearance under scleral lens?** Investigators from the University of Montreal School of Optometry evaluated oxygen partial pressures under rigid gas permeable scleral lenses with different amounts of clearance in an effort to determine the ideal amount needed under a scleral lens. Researchers measured the thickness of the liquid layer beneath the contact lens using optical coherence tomography and pO2 levels at the corneal surface using a Clark electrode and an electrometer linked to a computer after five minutes of wear. As predicted, calculations of oxygen transmissibility of scleral lens systems demonstrated that an increased thickness in clearance reduces oxygen tension available to the cornea; ultimately, a clearance close to the 200μm level may help the adequate amount of oxygen reach the cornea.


20. **Mechanical mapping technology could assess corneal ectasia.** Scientists from the Massachusetts General Hospital and Harvard Medical School presented a non-contact in vivo mechanical mapping of keratoconus based on Brillouin scattering with axial scans at various lateral positions. The balance between the cornea’s mechanical strength and intraocular pressure is critical to maintain normal shape—when this is disrupted, the stress can lead to progressive compensatory thinning and bulging of the cornea, or keratoectasia. In normal patients, it was observed that corneal mechanical strength decreased with depth and increased toward the periphery. Additionally, the modulus also increases with age. Thus, the Brillouin modulus was positively correlated with corneal thickness and negatively with front surface sagittal curvature.

Striking differences could be observed between normal and keratoconic corneal biomechanics. In the normal cornea, the elastic modulus gradually increases from its center to the periphery. Strong focal weakening was observed in the keratoconic eyes. Corneal stiffness seems to increase with age and may explain the high prevalence of keratoconus in earlier years. Thus, this technology seems to hold potential in assessing corneal ectasia and measuring therapeutic benefits from procedures such as collagen crosslinking.

Program #1138. 3D Corneal Elasticity Mapping in Normal and Keratoconus Patients. ARVO 2015.

While the 20 abstracts highlighted here were selected specifically for this Review of Cornea & Contact Lenses report, you are encouraged to review the many other abstracts available from this year’s ARVO conference (Available at www.arvo.org/Annual_Meeting/2015/Abstracts2015_Session_Abstracts_PDFs/). I’m sure you’ll find them fascinating. And as always, we look forward to another round of clinically relevant research to be presented next year!
Soft contact lenses are big business: in 2010, the soft lens market in the United States was estimated at $2.1 billion, with an approximate growth of 5% per year since, despite a contact lens dropout rate of 15% to 25%, depending on which study is considered.1-3,18

One of the primary reasons for discontinuing wear is contact lens discomfort (CLD), with estimates of greater than 50% of patients having symptoms of discomfort or dryness while wearing contact lenses.3 With much at stake and a clear culprit in the form of discomfort, naturally much of the innovation coming out of contact lens R&D labs focuses on ameliorating CLD.

This article will review how different contact lens properties can impact comfort, and how recent innovations are reshaping the daily disposable soft lens market.

THE DK DILEMMA

The physical properties of a specific soft contact lens are largely manipulated by the monomers that make up each polymer in the lens. Dating back to the first soft contact lens, most hydrogels contain poly-2-hydroxyethyl methacrylate (HEMA), which has a low oxygen permeability (DK). Increasing the water content results in a logarithmic increase in DK; however, to maintain stability and reduce lens dehydration, the center thickness must be increased, effectively reducing oxygen transmissibility (DK/t).5

Adding silicone to soft hydrogel lens polymers increases the level of oxygen that flows to the cornea. Oxygen is highly transmissible in silicone, with an inverse relationship to water content.3 First generation silicone hydrogel lenses (SiHys) contained high levels of

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New lens materials and technologies are making their way into the market. Here’s a refresher on the latest available for your patients.

By Robert Ensley, OD
silicone with a lower water content, allowing for a highly oxygen permeable, but higher modulus lens. Although SiHys reduce the risk of hypoxic complications, they are not without their own challenges. Silicone is inherently hydrophobic, which can lead to increased lipid deposition and wettability concerns. Higher modulus lenses can also induce complications from mechanical interaction with conjunctival tissue. However, newer generation SiHys are able to increase the water content to decrease modulus, while still maintaining a higher DK/t.6

CONTACT LENS PROPERTIES
A number of lens characteristics exist with varying influences on patient comfort.

• Oxygen Transmission. Clinical experience may suggest some early resistance when moving long-time lower DK/t hydrogel lens wearers to higher DK/t SiHy lenses, as increased corneal sensitivity can lead to initial discomfort. In general, most studies indicate a higher subjective level of comfort in SiHys vs. hydrogels; research shows evidence to the contrary. Additionally, when comparing different SiHys, no evidence shows that comfort is dependent on DK.9,10

• Water Content and Dehydration. In vitro studies indicate lower water content lenses exhibit less dehydration.11 While it is reasonable then to conclude that CLD with higher water content lenses is due to dehydration, there has been no definitive correlation.12 This in part may be attributable to other factors influencing in vivo dehydration, including the tear film and environment.

• Lens Deposition. In addition to water content, HEMA lenses are classified by ionic charge. Lenses with a negatively charged surface will attract more positively charged tear film proteins, which if denatured can lead to a decreased tear break up time and decreased comfort.13 SiHys tend to bind lipids more than proteins, which may contribute to contact lens-induced inflammation. Surprisingly, there is no evidence of significant correlation between protein or lipid deposition to decreased comfort.14

• Friction or Lubricity. The friction force between a contact lens and palpebral conjunctiva is commonly described in the context of lubricity. As the reciprocal of friction, when lubricity is high, friction is low. Correlating in vitro measurements of friction to comfort can be difficult, and studies are limited; however, current data available suggests a direct relationship. Lower levels of friction is highly predictive of higher comfort levels.15,16

• Surface Wettability. Wettability is used to describe how the tear film spreads out over the surface of the contact lens. This often correlates to lubricity, as a better wetting lens reduces the friction forces on the contact lens surface. Researchers suggest that thinning of the pre-lens tear film is highly indicative of CLD; however, they are less clear on whether that is a result of a previously unstable tear film or an interaction between the lens surface and tear film.12

• Wetting Agents. Wetting agents are commonly used to aid in providing superior end-of-day comfort. These may include polyvinyl alcohol (PVA), polyvinylpyrrolidone (PVP) and hyaluronic acid (HA). The additives can be incorporated into the lens matrix to retain moisture and improve surface wettability. No evidence shows that wetting agents directly improve comfort.17

RECENT INNOVATIONS AND TRENDS
Although daily disposable lenses were initially introduced in the
1990s, the last few years have witnessed the most rapid growth of this modality. In 2014, nearly 30% of all soft contact lenses prescribed were daily disposables. A large part of this growth is due to recent innovations in contact lens technology.

**Hydrogels.** Several of the newest daily disposable hydrogel lenses on the market incorporate unique properties to achieve comfortable wear. While most wetting agents are bound within the contact lens to help retain internal moisture, Dailies Aqua Comfort Plus (Alcon) lenses use “blink activated” moisture technology. The nelafilon A polymer contains several moisturizing agents, including hydroxypropyl methylcellulose (HPMC), polyethylene glycol (PEG) and PVA. Additional HPMC is also added to the saline contained within the packaging to improve initial comfort. When wearing the lenses, the blinking mechanism releases these wetting agents on the lens surface over a 20-hour period, allowing for continuous tear film stability.

A different approach to retaining moisture is to mimic the lipid layer of the tear film. Although higher water content lenses typically dehydrate more, this combination forms a dehydration barrier retaining moisture within the lens. One of the latest hydrogel daily disposables to reach the market is the Miru (Menicon), made with the well-known polymer hioxifilon A. This pHEMA and glycercal methacrylate copolymer (HEMA-GMA) binds tightly to water, resisting dehydration more than a typical pHEMA high water content lens. Its smooth edge design also reduces eyelid friction while blinking. The contact lens is packaged with the outside surface facing up in a one-millimeter thin flat pack to help prevent contact with the inner surface before insertion on the eye, thus improving lens hygiene.

**Silicone Hydrogels.** In 2014, silicone hydrogels accounted for nearly 70% of the soft lens market. Although silicone hydrogel lenses make up the majority of the monthly and two-week modalities, they have only recently become an option as daily disposables.

The first silicone hydrogel daily disposable to reach the United States market was the 1-Day Acuvue TruEye (J&J Vision Care). First released using the nelafilon B polymer, it later became available as nelafilon A, which increased the DK/t from 63 to 118. To counter the hydrophobic nature of silicone, PVP is added to the lens as an internal wetting agent.

The Dailies Total1 (Alcon) features an interesting type of water gradient polymer. While technically a silicone hydrogel, the delafilon A core is 33% water, which transitions to greater than 80% water at the lens surface. This allows for not only the highest oxygen transmission of any daily disposable with a DK/t of 156, but its hydrophilic

### Beyond Dailies

While most of the recent additions to the soft contact lens marketplace have been in the daily disposable modality, there were also two new monthly replacement lenses released nationwide in the last year.

- **Air Optix Colors (Alcon)** is the first silicone hydrogel color contact lens available on the market. The color is embedded within the lotrafilcon B matrix, rather than imprinted on the lens surface. This technology allows for a higher oxygen transmissibility than other colored lenses available.

- **The Ultra lens (Bausch + Lomb)** was designed with end-of-day comfort in mind. The samifilon A silicone hydrogel polymer incorporates “moisture seal” technology, which incorporates higher levels of PVP on the lens surface than other monthly lenses. The Ultra lens also balances a DK/t of 163, low modulus and water content of 46%.
The Academy meeting is traveling to the culturally and historically rich city of New Orleans for four days of exceptional education. Join us for another year of research-based and clinically relevant CE, top-notch speakers, captivating papers and posters, and memorable social events. We hope to see you there!

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Better soft contact lenses may also help prevent the development of corneal infiltrates.

surface makes it a highly wettable and lubricious lens.

In addition to spherical lenses, the Clariti 1-Day (Cooper Vision) family of lenses offers both toric and multifocal options. Using the somofilcon A polymer, these lenses balance many of the desired attributes for a contact lens. With a 56% water content and a proprietary hydrophilic surface, these lenses have both a lower modulus and coefficient of friction.

• Multifocals. While there is little evidence to support the notion that CLD is directly associated with age, many practitioners would acknowledge that CLD and dry eye are a common concern with presbyopic patients. With the increasing demands on near vision, there is more need than ever for daily disposable multifocal lenses.

There are four center-near daily multifocal options: Dailies Aqua Comfort Plus Multifocal (Alcon), Clariti 1-Day Multifocal (Cooper Vision), BioTrue OneDay for Presbyopia (Bausch + Lomb) and the Proclear 1-Day Multifocal (Cooper Vision). These lenses use the same technologies as their spherical counterparts. The Proclear 1-Day multifocal, for example, uses the omafilcon A material with a 62% water content. The polymer structure resembles phospholipids, which can attract and bond with water and reduce dehydration.

Interestingly, while most recent strides have been made with comfort in mind, two new daily disposable lenses set to roll out this year showcase multifocal optics not available in the more commonly used monthly modality. The 1-Day Acuvue Moist Multifocal (J+J Vision Care) is a center-distance design with a pupil diameter optimization that changes with add power. The NaturalVue 1-Day Multifocal (Visioneering Technologies) is inspired by a camera aperture and is designed to provide an enhanced depth of focus.

• Enhancers. Long available in Asian markets, the 1-Day Acuvue Define (J+J Vision Care) contact lenses are rolling out in the United States market this year. Designed to enhance natural beauty of the eye, these lenses increase the contrast between iris color and the sclera. Rather than the color pixels being imprinted on the surface, however, the design pigments are encapsulated within the etafilcon A polymer.

When patients present with CLD, careful evaluation of both contact lens fit and the ocular surface is warranted. In mild cases, refitting the patient with a different lens may resolve this discomfort. Most of the recent innovation involves contact lens surface technology, which impacts dehydration, lubricity, wettability and deposition rates. Although it can be difficult to ascertain which lens attribute will improve contact lens comfort for each individual, there is no shortage of daily disposable lenses at our disposal.

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Invented in 1911 by Swedish ophthalmologist Allvar Gullstrand, the first slit lamp biomicroscope was a bright rectangular beam of light used to examine the cornea and crystalline lens. While the slit lamp was a cutting-edge device at the time, technology for corneal analysis has since evolved tremendously. Not only are the newest devices capable of examining the cornea at its cellular level, they also use sophisticated software to detect the earliest signs of corneal issues. As with all technology, however, each device has its advantages and limitations. This article will discuss the latest diagnostic imaging technology for corneal analysis, including corneal topography, corneal tomography, Scheimpflug-based noncontact tonometry, anterior segment optical coherence tomography, ultrasound biomicroscopy and confocal microscopy.

**CORNEAL TOPOGRAPHY**

This mainstay of most eye care practices analyzes the anterior surface of the eye by reflecting a series of concentric circles, known as Placido rings, off of the cornea. A digital camera captures the reflected pattern and any deviations from the original image are processed by software to calculate the shape of the cornea. Placido-based corneal topography is considered advantageous for its ability to quickly capture a clear image without contact; however, its scope is limited to the anterior cornea and its premise is based upon the assumption that the cornea is prolate. Non-prolate corneas or irregular corneal surfaces are often misdiagnosed or broadly categorized as “irregular” with no further data given. Additionally, the patient must have an intact epithelial surface and tear film for the instrument to obtain a clear image. Poor tear films disrupt the smooth surface of the cornea and reduce corneal topography’s image quality.

Interestingly, the necessity of an intact tear film has led to the use of corneal topography in dry eye evaluations. Because tear film stability is needed to produce clear images, any irregularity caused by a poor tear film is captured in a series of corneal topography images over a period of 10 seconds. The images are then analyzed and quantified with a tear stability analysis software program to objectively measure the stability of the tear film on the eye.

While many corneal topographers exist, one of the newest devices available on the market, a color LED corneal topographer, is considered particularly novel. Similar to the VU (Vrije Universiteit) topographer, which projects a color-coded checkerboard on the cornea instead of Placido rings, the Cassini (i-Optics) shines up to 700 red, yellow and green spots from hundreds of LEDs on up to 8.5mm of the corneal diameter. Reflections of the spots are captured from seven different angles with a number of cameras, and ray tracing is calculated to determine the corneal curvature and refraction.

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done for every three spots, allowing for multiple elevations to be defined across the cornea without the assumption that the cornea is prolate. This allows for higher predictability in central irregular corneas as compared to Placido-based topographers. Its reliability in measuring keratometry on normal corneas was repeatable and comparable to the Pentacam (Oculus), though it provided higher keratometry values than both the Pentacam and EyeSys (EyeSys Vision). In irregular corneas, it showed high specificity in estimating corneal keratometry as compared to the manual keratometer and the Pentacam, Orbscan II (Bausch + Lomb), Galilei (Ziemer Ophthalmic Systems) and Sirius (Schwind) corneal topographers.

CORNEAL TOMOGRAPHY

Whereas corneal topographers are limited to evaluating the anterior surface of the cornea, corneal tomographers can measure the elevation maps of both the anterior and posterior cornea to create three-dimensional images. Corneal tomographers can be used to evaluate corneal thickness, anterior chamber depth, lens thickness and lens opacification, as well as create cross-sectional images of the cornea and topographies of the anterior surface of the lens and iris. Because corneal tomographers can easily detect the higher and lower aberrations of irregular corneas, they are now being used to guide combination collagen crosslinking and photorefractive keratectomy surgical procedures in keratoconic eyes for improved visual outcomes.

Three types of corneal tomographers exist: those that use slit scanning (i.e., Orbscan II), those with Scheimpflug imaging (i.e., Pentacam) and those that combine Scheimpflug cameras and Placido topography (i.e., Galilei, Sirius and TMS-5/Tomey). All are limited, however, by longer procedure times, which necessitates longer steady eye fixation as compared to Placido-based corneal topographers.

• Slit Scanning. Similar to a slit lamp’s light slits, optical slits are projected along multiple points across the cornea at a fixed 45 degree angle. The reflections of the slits of light are captured by a digital video camera and analyzed to reconstruct the anterior and posterior cornea. However, these tomographers are limited by their accuracy in measuring corneal thickness in irregular corneas and those with corneal opacities.

• Scheimpflug Imaging. A rotating Scheimpflug camera captures 25 to 50 cross-sectional slits in a two-second scan across the corneal surface. A second stationary camera centered at the pupil aligns the images and monitors ocular fixation. Both sets of images are then analyzed to reconstruct the corneal topographies and produce a high-resolution three-dimensional image of the anterior segment, from the anterior cornea to the posterior crystalline lens. Some tomographers equipped with Scheimpflug imaging (e.g., Pentacam) also provide corneal wavefront analysis, densitometry and information about the anterior chamber.

• Scheimpflug-based Noncontact Tonometry. The biomechanics of the cornea can be better understood by measuring its deformation during noncontact applanation, such as during air puff tonometry. The measurement of corneal deformation induced by refractive surgery
DIAGNOSTIC IMAGING TECHNOLOGY FOR CORNEAL ANALYSIS

procedures may help predict the development of ectasias. The first device to record this effect, the Ocular Response Analyzer (Reichert), measures the reflected infrared light from the deformed corneal surface. Studies using the ORA have shown statistically different biomechanical strengths between normal and keratoconic eyes and post-LASIK.13,14

The new Corvis ST (Oculus) noncontact tonometer integrates a high-speed Scheimpflug camera that takes approximately 4,300 frames per second to measure the corneal deformation. Thinner and hence less rigid corneas would have a longer application time. The Corvis ST tonometer’s corneal thickness measurements were similar to those measured with ultrasound pachymetry.15

OPTICAL COHERENCE TOMOGRAPHY (OCT)

Similar to an ultrasound—albeit reflecting light instead of sound—anteri or segment OCT noninvasively captures high-resolution cross-sections of the eye by reflecting near-infrared light waves, which are scattered on the ocular structures. Low coherence interferometry analyzes the delay and intensity of the reflected light beams and compares it to light that has traveled along a referenced path. The axial scans (A-scans) are then combined to create a three-dimensional image, allowing for cross-sectional views of the cornea and anterior chamber.

These cellular level images provide more in-depth evaluations of the cornea, anterior chamber and corneal thickness, allowing for the study of tear film dynamics and the diagnosis of corneal abnormalities. OCTs are as efficient as ultrasound biomicroscopy for measuring pachymetry with the advantage of being noncontact, allowing them to be used to view ocular structures in their natural state.16 Additionally, because corneal opacities reflect and scatter the reflected light beams, OCTs are also useful in measuring opacity depths and sizes.

Several categories of OCT instruments exist. The most common distinction is time-domain vs. spectral-domain (also called Fourier-domain).

• **Time-Domain (TD).** TD-OCTs are older generation tomographers that create serial A-scans as a mechanical arm with a reference mirror moves across the cornea. These devices are particularly sensitive to motion errors, so the A-scans must be well aligned to produce clear images. Additionally, due to the mechanical limitation of the reference mirror, there is a lag in scanning time of 2,000 axial scans per second. However, while TD-OCTs are slower than spectral-domain OCTs, their lower wavelength can penetrate deeper into the eye—as much as 18µm through tissues such as the sclera, iris and opacified corneas—making them valuable instruments for anterior segment care. Examples include Visante and Stratus (both from Carl Zeiss Meditec).

• **Spectral-Domain (SD)/Fourier-Domain (FD).** SD-OCTs are newer tomographers capable of producing higher-resolution images than their TD-OCT predecessors. Instead of the mechanical sweeping arm of the TD-OCT, reflections from a reference light generate spectral interference fringes that are captured through an FD spectrometer and a high-resolution charge-coupled device camera. The signals are captured in parallel rather than serially and calculated electronically instead of mechanically, allowing for faster imaging speeds (up to 26,000 axial scans per second). The speed of image acquisition is somewhat limited to the camera’s frame capture rate and the computer speed of the Fourier calculation; however, the high imaging speed combined with the SD-OCT’s ability to track eye movement minimizes motion artifacts and hence improves repeatability of results.

Both SD-OCT and TD-OCT instruments can be used for similar evaluations of a high-resolution image of the cornea and other anterior segment structures, as well as recording pachymetry.17,18 The higher resolution imaging capabilities of SD-OCTs, however, improves sensitivity and repeatability of measured results. A custom-built, ultrahigh-resolution SD-OCT can evaluate epithelial, Bowman’s layer or endothelial conditions up to 2µm.19 OCTs can also measure corneal pachymetry over contact lenses, allowing for the creation of corneal thickness measurements caused by contact lens wear.20 Studies have found that SD-OCT has good correlation to confocal microscopy when evaluating the cornea demarcation line during corneal collagen crosslinking.21 SD-OCTs are also used to assess the location of Descemet’s membrane to guide manual dissection during deep anterior lamellar keratoplasty.22

The primary limitation of SD-OCT is the need for clear corneas to achieve accurate imaging. One study found that SD-OCT could not image corneas obscured by vascularized, densely inflamed or thick lesions such as pterygia. Similarly, underlying sclera could not be imaged in detail beneath conjunctival lesions.23 Newer platforms being developed—largely for posterior segment imaging—use concepts such as swept-source (i.e., multi-frequency) OCT or enhanced depth imaging (a modification of conventional SD-
OCT) to capture the choroid and improve image resolution.

**ULTRASOUND BIOMICROSCOPY (UBM)**
UBM noninvasively examines the anterior cornea through the use of ultra-high frequency acoustic waves (as opposed to light waves in OCT). An eyecup filled with a coupling medium (generally saline or methylcellulose) is applied on an anesthetized cornea when a patient is in a supine position. The transducer immersed in the coupling medium emits the sound waves. Each A-scan is mapped and the real-time image is displayed on a video monitor.

Recent advances in UBM have contributed to its rise in popularity amongst clinicians, as higher quality images are being produced, correlating to diagnoses that previous imaging technologies could not assess. UBM may offer better imaging quality of corneal wounds than traditional technologies. A study evaluating the results of a standard slit lamp exam compared to an UBM examination on a full-thickness corneal laceration found that while a slit lamp examination could not accurately discern the architecture of the corneal laceration due to the severe irregularity and localized corneal edema, the UBM examination defined the edges of the wound and identified the overlapping cornea.24 UBM also has better imaging quality posterior to the iris pigment epithelium compared to AS-OCT. UBM allows for an in-depth assessment of anatomical and pathophysiological changes of the cornea, iris, sclera, ciliary body and zonules. Because the acoustic waves only penetrate 4mm to 5mm, however, visualization of the eye is restricted to the anterior structures. UBM is useful in measuring corneal pachymetry, especially prior to refractive surgery or in cases of corneal edema or ectasia. Since frequency is too low for the tissues to absorb, there is no tissue damage and the transmissions are instead reflected.25

While UBM technology is typically affordable and portable, the high level of technical skills needed

<table>
<thead>
<tr>
<th>Imaging Device</th>
<th>Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>Corneal Topography</td>
<td>Placido disc</td>
<td>• Quick image capture.</td>
<td>• Not as accurate when evaluating irregular corneas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Noncontact imaging.</td>
<td>• Requires an intact corneal surface.</td>
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<tr>
<td></td>
<td></td>
<td>• Allows for tear film analysis.</td>
<td>• Measures only the anterior corneal surface.</td>
</tr>
<tr>
<td>Corneal Topography</td>
<td>Color LED</td>
<td>• Quick image capture.</td>
<td>• Limited studies on Cassini because of its recent release.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Noncontact imaging.</td>
<td>• Requires a clear cornea.</td>
</tr>
<tr>
<td>Corneal Tomography</td>
<td>Slit scanning</td>
<td>• Creates three-dimensional image of cornea.</td>
<td>• Slower image capture compared to corneal topography devices.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Silt scanning can be combined with Placido disc technology.</td>
<td>• Requires a clear cornea.</td>
</tr>
<tr>
<td>Corneal Tomography</td>
<td>Scheimpflug imaging</td>
<td>• Produces high resolution 3D imaging.</td>
<td>• Slower image capture so a steady eye fixation is required.</td>
</tr>
<tr>
<td>Schiempflug Based</td>
<td></td>
<td>• Produces high resolution 3D imaging.</td>
<td>• Measures corneal biomechanical strength.</td>
</tr>
<tr>
<td>Noncontact Tonometry</td>
<td></td>
<td>• Images penetrate deeper into the eye (such as the sclera, iris and opacified corneas).</td>
<td>• Limited studies on Corvis ST due to its recent release.</td>
</tr>
<tr>
<td>Anterior Segment OCT</td>
<td>Time Domain</td>
<td>• Noncontact imaging system.</td>
<td>• Requires a steady eye fixation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Large scan width (16x6mm).</td>
<td>• Slower exam time than SD-OCT.</td>
</tr>
<tr>
<td>Anterior Segment OCT</td>
<td>Spectral Domain</td>
<td>• Higher resolution images than TD-OCT.</td>
<td>• More expensive than TD-OCT.</td>
</tr>
<tr>
<td>Ultrasound Biomicroscopy</td>
<td></td>
<td>• Provides accurate pachymetry and images anterior to the iris.</td>
<td>• Requires contact with the patient’s eye.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Requires high technical skills to operate.</td>
<td>• Can only precisely analyze a small area during each scan.</td>
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<tr>
<td></td>
<td></td>
<td>• Can only penetrates 4mm to 5mm deep (low penetration because of high frequency).</td>
<td>• Can only precisely analyze a small area during each scan.</td>
</tr>
</tbody>
</table>

Table 1. Advantages and Disadvantages of Corneal Imaging Devices
to operate it limits its use. Additionally, the patient needs to be supine and the device must be in contact with the eye. Environmental factors like room illumination and lighting also affect the anterior segment, so these factors must be held constant when analyzing the image.25

IN VIVO CONFOCAL MICROSCOPY (IVCM)
IVCM is a noninvasive procedure that provides a high-resolution real-time analysis of living corneal tissues at the cellular level. Whereas with a conventional light microscope the entire specimen is evenly illuminated from a light source and the depth seen is limited to that at which light penetrates into the tissue, IVCM only uses one pinpoint source of light and images the one point of the specimen, allowing for high-resolution imaging even through opaque objects. Multiple images are then acquired through rapid scanning and then reconstructed digitally for three-dimensional images of the specimen's interior structures.

There are several different types of IVCM technology, including tandem-scanning, scanning-slit and laser scanning confocal microscopes. Tandem-scanning IVCM provides high corneal endothelium images, but isn’t as effective for imaging specific structures like the organelle within cells of the cornea.26 Scanning-slit confocal microscopes can provide high-resolution images at the cellular level, but the photos are limited to transparent tissue. Laser scanning confocal microscopy allows for high-resolution images at the cellular level including that of opaque tissue.

In vivo confocal microscopy has been able to identify and visualize epithelial cells and endothelial cells in a variety of depths of the cornea.26 Pathological abnormalities of the cornea at a microstructural level have been examined in patients with ocular rosacea, Sjögren’s syndrome, dry eyes, Stevens-Johnson syndrome and keratitis.27 IVCM is currently considered the most optimal modality at the moment that can evaluate and capture corneal nerves in vivo with high resolution.26

SO, HOW DO YOU CHOOSE?
There have been many studies that compare accuracy and repeatability of various diagnostic imaging devices. Though all of the above devices individually are very reliable and repeatable, reciprocity of results may not always be the same when interchanging between devices in comparison studies because each manufacturer uses its own algorithms to produce their results.28-35 One study comparing Scheimpflug imaging devices found that while they all worked adequately, the measurements of anterior keratometry and posterior keratometry achieved with the Pentacam were significantly better than those of Galilei and Sirius in keratoconic eyes.36 A second study also comparing three Scheimpflug devices (the Galilei G2 Dual Scheimpflug Analyzer, Pentacam HR and Sirius)
determined inter-device repeatability and reproducibility, but noted that maximum anterior and posterior corneal elevation and total high order aberrations from the Strus 3D and Galilei G2 were not interchangeable with the Pentacam HR’s results.29

Meanwhile, another study comparing an AS-OCT instrument (Casia) and a rotating Scheimpflug camera with Placido topography system (TMS-5) found measurements of keratoconic patients using the former were more repeatable.27 Also, a comparison of a corneal topographer (Orbscan) and a rotating Scheimpflug imaging system (Pentacam) found that the topographer is capable of evaluating thinner corneas in keratoconic eyes and those with corneal opacities.12

Overall however, it is difficult to compare different comparison studies since each study uses unique methodologies to evaluate repeatability.28 Each imaging device has its own unique advantages and limitations, and instrument selection depends upon the clinical needs of the practice. Because many of the devices are not interchangeable, accurate clinical interpretation is required to augment the plethora of information from each of these devices. Nevertheless, the imaging devices can provide a wealth of information to supplement traditional slit lamp examinations.

References

21. Kymionis GD, Grentzelos MA, Plaka AD, et al. Comparison of three Scheimpflug topographer (Orbscan) and a rotat- ing Scheimpflug imaging system (Pentacam) found that the topographer is capable of evaluating thinner corneas in keratoconic eyes and those with corneal opacities.12

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The EVOLUTION of Keratoconus Care

Researchers and practitioners alike continue to make advances toward better treatment of this progressive disease. Here’s a look at the current state of affairs.

By Jeffrey Sonsino, OD, Nathan Rock, OD, and Ming Wang, MD

In the past few years, the standard of care for keratoconus has transitioned to more effective use of contact lenses and earlier surgical treatment to arrest or delay the progression of the disease as well as improve visual acuity. Minimally invasive surgical treatments including collagen crosslinking (CXL) and intrastromal corneal ring segments (ICRS) are aimed at replacing or delaying the need for corneal grafting. These procedures represent the culmination of centuries of research—so how do they measure up against current and preceding treatments? What innovations are we and our patients now enjoying, and what’s on the horizon for the near future? This article will trace the path of evolution in one of eye care’s most persistent challenges.

HISTORICAL STANDARDS OF KERATOCONUS CARE

Burchard Mauchart, a professor at the University of Tübingen, Germany, first described keratoconus in a doctoral dissertation in 1748 as *staphyloma diaphanum.*1,2 Previously, there was scant mention of this condition in the literature and many physicians simply called it *ochlodes,* which translates from Greek to mean “annoying.”3 However, it wasn’t until 1854 that British physician John Nottingham, in a 270-page treatise, clarified this condition as a corneal ectasia. Naming it “conical cornea,” Nottingham described several hallmark features of the disease, including the distinct cone shape and thinness of the cornea, which became the modern definition we use today.3 In 1859, British surgeon William Bowman was the first to use an ophthalmoscope to observe the condition, and many of his clinical insights are still used to diagnose the disease today.4 The condition was finally given its modern name, *keratoconus,* meaning “horn-shaped cornea” in a thesis by Swiss physician Johann Horner in 1869.4 At that time, keratoconus was commonly treated with chemical cauterization with silver nitrate.5 Results were less than optimal, and in 1888 a blown glass contact lens by Fick was introduced for the purpose of compressing the cone—one of the earliest uses of contact lens technology. Polymethylmethacrylate (PMMA) scleral lenses were subsequently introduced as another method by American optometrist William Feinbloom in 1936.4 In 1936, Spanish-American ophthalmologist Ramon Castoviejo Briones successfully performed the first corneal transplant.4 Then in the late 1970s, American chemist

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Dr. Rock is a consultative optometrist at Wang Vision Institute who advises keratoconus patients on nonsurgical and surgical treatment options, including corneal crosslinking, Intacs, and corneal transplantation. He is also the clinical study coordinator for an FDA Phase III corneal crosslinking clinical trial.

Dr. Wang is the director of Wang Vision Institute, where he performs Intacs, corneal crosslinking and corneal transplantation procedures for patients with keratoconus and corneal ectasia. He is also the principal investigator for an FDA Phase III corneal crosslinking clinical trial.
Norman Gaylord was credited with a key role in developing gas permeable (GP) contact lens materials. Corneal GP lenses remained the medical treatment of choice for keratoconus for over 40 years.

**CHALLENGES WITH THE CURRENT STANDARD**

When well fit and tolerated, corneal GP lenses correct visual acuity far better than spectacles. However, they do come with downsides: first and foremost, the number one challenge with corneal GP lenses is comfort. Even long-term wearers who adapt to the feeling rarely describe their lenses as truly comfortable. If environmental debris becomes trapped under the lenses, it must be removed immediately to avoid piercing pain.

Most corneal GPs are designed to translate upon blink in the lid-attachment style of fitting. This lens movement annoys many patients both sensorially and in the momentary fluctuation of vision, yet it is rarely addressed by practitioners. The interpalpebral style of fitting, in which the lens does not tuck under the lid at all and resides between the open eyelids in the interpalpebral space, is harder to achieve and is potentially problematic with keratoconus since the apex of the cone is rarely located in geometric center of the cornea and the lens will seek the apex of the cone. This lens fit is typically reserved for special circumstances, such as in the case of Graves disease or the presence of a bleb.

In addition to fitting style, practitioners have also debated which type of fitting against the apex of the cone is best. The Collaborative Longitudinal Evaluation of Keratoconus (CLEK) studies show an association between flat fitting lenses or compression of the apex of the cone and corneal scarring. Because CLEK was not a prospective multicentered randomized trial, causality could not be established; however, it is generally agreed upon that an apical clearance type fit reduces the risk of scarring in keratoconus. The problem with apical clearance fitting is that practitioners report compromised comfort and visual acuity. And with either fitting philosophy, as soon as the patient blinks and there is translation of the lens, the peripheral curve system contacts the corneal apex.

**VAULTING LENSES**

With the decrease in emphasis on corneal transplantation and the shift toward less invasive surgical procedures in the era of partial-thickness lamellar keratoplasties, surgeons have renewed their interest in ensuring keratoconic patients are fit optimally in contact lenses. Contact lenses complement these less invasive procedures and are almost universally necessary to achieve optimal vision. Based on the growth rate in industry data, prescribers are increasingly choosing vaulting strategies over traditional corneal GP lenses for patients with keratoconus.

Vaulting contact lenses include both hybrid and scleral lenses. When properly designed, vaulting lenses never touch the apex of the cornea and move very little, if at all. Vaulting the apex of the cone is the best way that we know to avoid corneal scarring based on the CLEK criteria. With hybrid lenses, there is a tear pump under the lens, as evidenced by the loss of sodium fluorescein under the lens with time. When properly fit, hybrid lenses provide adequate oxygen supply to the cornea. Similarly,
with properly fit scleral lenses, dissolved oxygen in the fluid of the significant post-lens tear reservoir and diffusion from the atmosphere maintains adequate corneal physiology. Scleral lenses are accommodating corneas that have been far too steep to fit with corneal GP lenses or may have failed with other modalities.

CORNEAL CROSSLINKING

Practitioners the world over—minus the United States—have in recent years been able to treat keratoconic patients with one of the biggest advances in modern times: corneal collagen crosslinking using a combination of topical riboflavin and ultraviolet light to strengthen the cornea and arrest progression of the condition. The traditional procedure, or Dresden protocol, is completed after removal of the corneal epithelium. Trans-epithelial CXL is performed with an intact epithelium and has a mildly reduced risk of complications; however, studies have not confirmed that it has equal efficacy with regards to corneal stabilization. For this reason, many surgeons still prefer epithelium-off CXL.

In late 2014, a project aimed at reaching a global consensus on the treatment of keratoconus and other ectatic diseases brought together 36 experts from the Asian Cornea Society, Cornea Society, EuCornea and PanCornea corneal societies. With regards to surgical management of keratoconus, the representatives reached a consensus that surgery should be considered for contact lens patients who are not able to obtain satisfactory best-corrected vision, meaning either those who could not achieve good corrected vision with contact lenses or those who are unable to tolerate or wear them comfortably. The panel determined that corneal collagen crosslinking in particular was important for the treatment of keratoconus with documented progression and recommended that it should be considered for this group of patients of any age. The panelists also indicated that CXL was important for treatment of keratoconus with a perceived risk of progression, but where progression has not yet been confirmed. The panel indicates that for eyes with contact lens intolerance or poor visual acuity with contact lenses, ICRS may be considered.

CXL has been used safely in Europe for over 15 years but remains unapproved by the FDA in the United States. In February 2015, the FDA Dermatologic and Ophthalmic Drugs Advisory Committee and Ophthalmic Devices Panel of the Medical Devices Advisory Committee voted in support of approval of Avedro’s crosslinking system for the treatment of progressive keratoconus or corneal ectasia following refractive surgery. Despite the FDA advisory committee decision, however, the FDA ultimately decided in March 2015 to hold approval for the procedure and device. At this time, the exact timeline for approval and on-label treatment remains uncertain, but many clinics throughout the US are already performing the procedure on an off-label basis at an out-of-pocket expense to the patient or as part of clinical trials.

INTRASTROMAL CORNEAL RING SEGMENTS (ICRS)

The most common ICRS are Intacs, which are semicircular inserts made of PMMA. During this procedure, small channels are created in the corneal stroma using a femtosecond laser (though a manual instrument can also be used) and the rings are inserted into these channels to reinforce and remodel the corneal structure. A single segment or two segments can be implanted based on topographic parameters and refractive state. ICRS implantation results in moderate corneal flattening, with studies citing a range of 1.5D to 7.8D of flattening effect. Returning to contact lens wear is often an important goal of implantation, and studies indicate a variable rate of success at achieving this goal ranging from 33% to 100%. By redistributing corneal stress, ICRS are considered by many to be a therapeutic option to delay the progression of corneal ectasia. This thought is supported by some literature, but is not yet a clear consensus among practitioners. More research regarding this topic is indicated.

Intacs segments were first FDA-approved for treatment of low myopia in 1999. In 2004, the FDA approved Intacs for treatment of keratoconus under a Humanitarian Device Exemption. Because the
procedure is FDA approved, it is covered by many medical insurance panels. Complications of ICRS, though rare, include microbial keratitis, cornea thinning in the area over the segment, extrusion, reduced corneal sensation, neovascularization, persistent epithelial defects, corneal haze, corneal melting and uveitis.14

CXL and Intacs implantation can be used together and have been suggested to have a synergistic effect, with the ICRS achieving primarily corneal flattening and CXL achieving primarily corneal stabilization. CXL can be performed before, during or after ICRS implantation, but the ideal sequence is currently unknown.18

**TRANSPLANTATION**

Whereas full-thickness penetrating keratoplasty (PKP) historically has been the mainstay of treatment for keratoconus, corneal transplantation is now generally reserved for eyes that are unable to achieve functional vision with other surgical or nonsurgical modalities due to scarring or contact lens intolerance. PKP has become increasingly successful due to advances in microsurgical techniques, including the use of the femtosecond laser. Advances in eye banking, corneal preservation and treatment of postoperative complications have also improved success rates. Nevertheless, risk of rejection is always possible: data from the Australian Corneal Graft registry indicates a 91% successful PPK graft rate at one year postoperatively and a 74% success rate at five years. Even when the graft is anatomically successful and clear, irregular astigmatism, contact lens intolerance and other complications can cause poor visual function.19

Deep anterior lamellar keratoplasty (DALK) is now preferred over PKP for conditions anterior to Descemet’s membrane, including keratoconus. In DALK, the pathological corneal stroma is removed to the level of Descemet’s membrane and then a donor graft is placed. It has several advantages over PKP including preservation of the endothelium, reduced use of postoperative steroids and faster visual rehabilitation. An intact host endothelium reduces the risk of graft rejection and keeps the procedure safer as it remains extracocular.18

Over history, we have come a long way in the treatment of keratoconus. New options for treating both medically with contact lenses and surgically have changed the standard of care for this condition. Vaulting contact lenses will potentially significantly reduce the risk of central corneal scarring and accommodate much more severe conea, further relegating full-thickness corneal transplantation to a relic of the past.10 And when CXL is eventually approved in the US, we will again see the standard of care shift.20

As optometrists, we wear two hats—that of an eye care provider and that of a detective. After all, a diagnosis is essentially a conclusion based on the combination of the clinical picture we see and the patient’s history as it is reported to us. These conclusions can sometimes be easy to make, such as in the case of a patient with a history of a gradual vision reduction and the presence of cataracts on exam. Other times, we are forced to think a little more critically to arrive at a diagnosis. Take, for example, an obese patient who presents with concerns of unilateral eye irritation and a clinical exam showing lash ptosis. These signs and symptoms likely prompt us to test lid laxity for a possible diagnosis of floppy eyelid syndrome that may be associated with obstructive sleep apnea.

In some cases, the clinical picture is unhelpful, or even entirely misleading. How do you make sense of a patient with relatively normal ocular health—but reduced vision? Or, how do you attribute relative contributions to vision loss from two different pathologies? Successfully handling these situations is all part of the art of eye care.

In my experience, one of the most confounding clinical considerations we can encounter is how diseases of the cornea impact vision, particularly in conditions that we don’t typically associate with vision loss. Such a scenario, in fact, isn’t all that rare. The purpose of this review is to look at some of the frequently encountered sources of subtle corneal vision loss and investigate the basic tools we have at our disposal to aid in our diagnosis.

**PATHOLOGY**
The two basic optical functions of the cornea are the transmission and refraction of light. Reduction in the transmission function is due to corneal opacification and is created by an array of sources, all of which amount to opacification of the visual axis. In most cases, opacification of the cornea—whether it’s from a stable, post-viral scar or progressive edema caused by Fuch’s dystrophy or any of the other numerous causes—is clearly apparent on slit lamp exam, and its effect on vision is intuitively understood. Pathologies that affect the refraction of light, however, are often less noticeable. Even more prominent forms of corneal irregularity like keratectasia can create diagnostic challenges as, despite their severity, slit lamp findings are often subtle or absent altogether. Milder forms of corneal irregularity are just as perplexing and even less conspicuous.

Compounding the challenge of identifying vision loss caused by corneal irregularity, corneal shape change is often an overlooked result of one of several common corneal conditions; as such, many of us focus on addressing the condition and neglect to consider its impact on vision.

**ABOUT THE AUTHOR**
Dr. Bronner is a staff optometrist at the Pacific Cataract and Laser Institute of Kennewick in Washington.
**Epithelial Basement Membrane Dystrophy.** The association between epithelial basement membrane dystrophy (EBMD) and recurrent corneal erosion (RCE) is well known. Many optometrists, however, are less familiar with the propensity of EBMD to create irregular astigmatism, which results from the continued presence of epithelial abnormalities (i.e., “maps” and “dots”) in or around the visual axis. These deposits, as they increase with time, lead to subtle elevation changes in their distribution, which can impact the corneal curvature and cause astigmatism. RCE typically occurs more frequently in the early stages of a patient’s dystrophy, but irregular astigmatism is increasingly prevalent in the latter stages of the disease, and with advancing age may even be the more common sequela.1

Astigmatism resulting from EBMD is generally mild, but can range from subtle to significant. Further, these refractive changes are sometimes irregular enough to cause reduction in best spectacle corrected acuity and, because the areas involved are often small, irregularity caused by the condition may escape even the ability of corneal topography to detect. This makes additional testing—such as the diagnostic RGP spherocylindrical over-refraction, which can help differentiate between sources of vision loss—necessary options to have at our disposal.

In cases when BSCVA is reduced, the EBMD has become pathogenic and treatment for its visual effects is warranted. Regarding treatment, certain methods (i.e., hyperosmotic drops and anterior stromal puncture) commonly used to treat RCE associated with EBMD are unsuccessful in managing the effect on vision, but the other therapies for the condition (i.e., corneal debridement with or without diamond burr polishing and phototherapeutic keratectomy) are effective for treating both RCE and irregular astigmatism associated with EBMD. Note that first differentiating vision loss caused by cataract and severe EBMD is a critical initial treatment step in older patients.

**Salzmann’s Nodular Degeneration.** Salzmann’s nodules are another frequently encountered clinical entity that can be overlooked when assessing a patient with reduced vision clarity. The nodules are typically peripheral and benign, but when prominent, they can cause epithelial erosion and discomfort. Similar to with EBMD, astigmatism can also result from the presence of these lesions, with greater impact from larger or more central nodules because—as with any alteration in corneal curvature—the closer to the visual axis, the greater the impact on visual acuity. Unlike with EBMD-associated astigmatism, however, corneal topographers are typically more sensitive to the changes associated with Salzmann’s nodules due to their dramatic effect on anterior corneal elevation.

Treatment of Salzmann’s nodules should immediately be considered in cases when vision becomes impacted. Superficial keratectomy and peeling is effective at both removing the nodules as well as eliminating corneal and refractive irregularities associated with them. If the patient is considering cataract surgery, nodule removal will enable the clinician to more accurately predict lens power, allowing for a more stable postoperative refractive course, making it again critical to differentiate vision loss associated with the nodules from that caused by cataract.

**Dry Eye.** The tear film plays an integral role in maintaining corneal health and clarity as well of continuing education credit is pending for this course. Check with your state licensing board to see if this counts toward your CE requirements for relicensure.

**Disclosure Statement:** Dr. Bronner has no relevant financial disclosures.
as promoting a stable refractive media. The widely held concept of the tear film as a lens is perhaps more esoteric than clinically appreciable, but the average precorneal tear film carries significant refractive power, typically around 43 diopters. Due to the extremely thin nature of the precorneal tear film, uniform changes will have minimal impact on its refractive power. However, in poorly spreading, non-uniform tear films, these changes can result in 1.3D of higher-order aberrations, which are significant and, due to their constantly changing nature, can be impossible to quantify with standard equipment. Further, as corneal dessication occurs in response to insufficient tear quality, both the transmission and refraction of light functions will be impacted as the resultant punctate epithelial erosions create zones of opacity and localized changes to corneal curvature as well.

Instability of vision, therefore, is an extremely valuable predictor of underlying dry eye, even when cursory examination shows a generally normal ocular surface. In lieu of other pathology that might explain fluctuating vision, such as heavy vitreous syneresis or Fuch’s dystrophy, patients who report this symptom should undergo a more extensive dry eye evaluation and a therapeutic trial aimed at improving quality and quantity of the tear film.

• **Pterygium.** It’s no surprise that pterygium can induce astigmatism: as these lesions grow onto the cornea, they cause progressive flattening of the horizontal corneal meridian. Similar to other corneal pathologies, the more central these lesions are, the more prominent their refractive effect is; this effect can be significant, even in mild pterygium. Fortunately, quantifying the magnitude of pterygium-based changes in an astigmatic eye is as easy to do as evaluating the progression of with-the-rule astigmatism over time in an eye with pterygium. As with both Salzmann’s nodules and EBMD, a high percentage of the pterygium-induced astigmatism should dissipate four to six weeks after treatment of the growth.

• **History of Refractive Surgery.** Post-surgical ectasia is an uncommon though well-documented cause of reduced vision and corneal irregularity in patients who undergo refractive surgery. Most cases of post-refractive surgery ectasia mirror the development of keratoconus: the thinning effect of the surgery destabilizes the cornea, making it unable to hold a regular shape. This leads the patient to develop progressively worse refractive error and corneal irregularity. Eyes affected by postsurgical ectasia will often need to be corrected with a GP, hybrid or specialty soft lens, and in severe cases may even need to undergo corneal transplantation.

It’s not just these pathologic corneas, however, that cause reduced vision in eyes that have had previous refractive surgery—the scenario can also occur in an eye with no obvious destabilization, but with significant flattening from aggressive LASIK, PRK or RK. Unfortunately, while crosslinking will help a patient with post-refractive surgery ectasia, nothing short of a corneal transplant can address vision loss associated with excessive corneal flattening. If the patient chooses to forgo surgery, a reverse geometry GP lens can provide adequate correction.

**TOOLS OF THE TRADE**

Fortunately, a number of instruments exist to make identifying corneal irregularity easier. Corneal topography is our most relied-upon technique for diagnosing corneal irregularity. I use the Pentacam (Oculus), a Scheimpflug instrument that provides pachymetric information, power distri-
bution and posterior corneal elevation measures. Regardless of which instrument you prefer, however, a good topographer is incredibly valuable for assessing the anterior segment and generally will be able to identify the vast majority of cases of corneal irregularity.

Of course, keep in mind that no single instrument can catch all forms of irregularity or accurately measure corneal curvature, power or axis of astigmatism in all cases. Many of us make the mistake of blindly trusting our preferred device, even when the measurements aren’t adding up. Instead, when things aren’t making sense, broaden your view and consider that you may be dealing with faulty readings. In such a case, there are other tests to use.

- **Keratometry.** I’ll be the first to admit that I rely too much on topography and too little on manual keratometry when assessing my patients, and that this reliance comes at a cost. This is often the case when data acquisition and processing goes from manual to automated.

While the keratometer can’t precisely quantify corneal irregularity as well as more modern technology, its ability to qualitatively demonstrate corneal irregularity with mire distortion is impressive. Additionally, the dynamic information it provides about the refractive health of the tear film is not something that can be appreciated on a topography printout.

You can think of a good topography report as a high resolution photograph and a keratometer as a low resolution video. No matter how superior the image quality is with the topographer, the dynamic information you get with a keratometer cannot be fully replaced by the still image. Though I still don’t use this device as much as I probably should, when I am having trouble making sense of topographic data, I will often use a keratometer to get this qualitative information about the refractive nature of the cornea.

- **Retinoscopy.** Retinoscopes are easily one of the most essential clinical tools of the optometric profession, yet increasingly young optometrists are moving away from using them in favor of autorefractors. However, while an autorefractor can help save time during the average exam, much like the difference between manual keratometry and topography, manual retinoscopy provides qualitative feedback that autorefraction lacks.

By definition, irregular corneas do not follow the typical distribution of power (i.e., regular meridian separated by 90 degrees) present in a normal cornea. Instead, the retinoscopy streak across an irregular cornea will encounter zones of differing corneal power across one sweep, which leads to a scissoring or other abnormal reflex. This is often the first clue that demonstrates a patient may have an irregular cornea. If you encounter a patient with reduced vision and you can’t quite pinpoint what is happening, a very simple, quick test is to pick up the retinoscope and perform a quick evaluation of the patient’s reflexes.

- **Rigid Gas Permeable Diagnostic Over-refraction.** Early in my residency at Davis Duehr Dean in Madison, Wis., my primary instructor, Chris Croasdale, MD, asked me to perform a diagnostic GP over-refraction on a patient of his. Embarrassingly, I had to tell him that I had no idea what he was talking about.

Dr. Croasdale graciously explained that a diagnostic GP over-refraction is a
technique to measure correctable vision in a way that also corrects corneal irregularity and so allows approximation of the relative contributions of reduced vision from both corneal and other pathology.

Diagnostic GP over-refraction has since become one of my most valuable clinical tools that I teach to all of my residents. While time consuming, this test provides detailed data regarding the source of a patient’s vision loss and is particularly helpful when trying to separate out the cornea’s role from that of other pathology. The concept is simple: using a reasonably fitting GP lens with a subsequent spherocylindrical over-refraction performed in the phoropter, corneal irregularity—even that which is too subtle to identify with topography—can be corrected and thus indirectly identified. This allows the clinician to roughly quantify the amount of vision loss from irregularity, as opposed to that caused by opacity; for example, with a paracentral corneal scar.

Just as importantly, it allows the clinician to differentiate between corneal vision loss and other sources, such as cataract, enabling them to determine the most efficacious treatment for the patient in question. A commonly encountered, confusing clinical scenario involves a patient who presents for a cataract evaluation with best-corrected vision of 20/40 who also has significant EBMD, or who perhaps has had aggressive RK surgery in the past. Using a diagnostic lens will allow you to determine the true etiology of the patient’s reduced vision. If, for example, the patient corrects to 20/20 with the GP in place, the cornea is likely the sole cause of the patient’s reduced vision. If they only correct to 20/40, however, then the cornea is probably not a contributor, and if the patient corrects to somewhere in between, then the cataract and the cornea are both somewhat involved.

I typically use the Dyna intra-limbal GP (Lens Dynamics) when performing GP over-refraction because I’ve found it to be relatively easy to handle, fit and center on an irregular cornea. While obviously the test is most reliable with a reasonable lens fit, a perfect fit is not absolutely necessary; an adequately centered lens without a bubble should suffice in most cases.

CONCLUSION

The cornea is the primary refractive media of the eye and is one of the most straightforward parts of ocular anatomy to perform a basic assessment of: there is no need for additional condensing lenses or special manipulation, beyond placing the patient in front of the slit lamp and turning the instrument on. Perhaps it’s for these reasons that its role in subtle vision loss is often overlooked—we are fooled into thinking that as long as the structure is essentially clear on slit lamp exam, that no deficit exists in its ability to transmit light, it should behave as expected. Confounding things further is the fact that our other trusted ways of measuring corneal function may also provide spurious results on occasion. In these cases, where things aren’t quite adding up, it’s important to consider subtler corneal-related causes of vision loss and the use of older and alternate means of testing.

1. Which symptom may be generated by EBMD in the absence of an RCE?
   a. Severe pain.
   b. Vision loss due to chronic, subtle corneal edema.
   c. Vision loss due to corneal irregularity.
   d. All of the above.
2. Which of the following statements is true regarding the symptoms associated with EBMD?
   a. Painful erosions seem to be most common late in the course of the disease.
   b. Vision effects of the dystrophy seem to be most common late in the course of the disease.
   c. Astigmatism associated with EBMD is typically of high magnitude.
   d. Topographers are 100% sensitive to the astigmatism generated by EBMD.
3. Which would describe the most definitive treatment option for the vision effects of EBMD?
   a. Anterior stromal micropuncture.
   b. Application of amniotic tissue to an RCE.
   c. Vision effects of the dystrophy seem to be most common late in the course of the disease.
   d. Topographers are 100% sensitive to the astigmatism generated by EBMD.
4. Which of the following statements is false?
   a. Salzmann’s nodules typically impact vision due to axial opacity.
   b. Salzmann’s nodules typically impact vision due to axial irregularity.
   c. Salzmann’s nodules may cause abnormalities in tear pooling with subsequent discomfort.
   d. Salzmann’s nodules occur more frequently in women than in men.
5. How does treating sources of corneal vision prior to cataract surgery improve outcomes?
   a. It increases stability of refraction postoperatively.
   b. It leads to more accurate keratometric data to base IOL selection on.
   c. It increases the stability of refraction postoperatively.
   d. All of the above.
6. Refractive and keratometric data after debridements and superficial keratectomies will generally be stable by:
   a. One day postoperatively.
   b. Upon re-epithelialization.
   c. Six weeks postoperatively.
   d. Six months postoperatively at the earliest.
7. Patients with prior refractive surgery may have their vision impacted in which way?
   a. Prescriptive drift.
   b. Post-refractive surgery ectasia.
   c. Excessive flattening of the central cornea.
   d. All of the above.
8. How can you most accurately separate out vision loss from prior RK from that associated with cataracts?
   a. Cataracts cause progressive worsening of vision in middle age, while vision loss associated with RK will not worsen over time.
   b. Diagnostic RGP over-refraction will correct most corneal abnormalities associated with RK, leaving corneal-reduced visual acuity as the primary remaining source.
   c. Gaze symptoms will worsen only due to the presence of cataracts.
   d. Manifest refraction will correct RK-associated refraction effectively, leaving corneal-reduced visual acuity as the primary remaining source.
9. Which describes the value associated with acquiring keratometric measures using a manual keratometer?
   a. Qualitative data is easily assessed.
   b. Quantitative data is superior with this technique.
   c. The device more accurately measures the dioptric power of the cornea.
   d. Quantification of irregularity.
10. Which best summarizes the potential impacts dry eye can have on vision?
    a. Dry eye can cause changes in corneal clarity.
    b. Dry eye can cause changes in corneal curvature.
    c. Dry eye can cause changes in corneal curvature.
    d. All of the above.

Doctor, Why Is My Vision Blurry?

Valid for credit through June 1, 2018

Online: This exam can also be taken online at www.reviewofcontactlenses.com.
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Answers to CE exam:
1. a. 2. a. 3. a. 4. a. 5. b.
6. a. 7. a. 8. a. 9. a. 10. a.

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Rate the effectiveness of how well the activity:
11. Met the goal statement: 1 2 3 4 5
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13. Will help improve patient care: 1 2 3 4 5
14. Avoided commercial bias/influence: 1 2 3 4 5
15. How do you rate the overall quality of the material? 1 2 3 4 5
16. Your knowledge of the subject increased: 1 2 3 4 5
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Please retain a copy for your records. LESSON 111478, RO-RCCL-0615
Rigid gas permeable (GP) contact lenses have long been a staple of the contact lens industry; however, when soft contact lenses (i.e., hydrogels and silicone hydrogels) took the industry by storm in the 1990s and early 2000s, there was talk of these hard lenses becoming extinct. Indeed, only an estimated 10% of all contact lens patients wear GP or hybrid lens designs, while the other 90% of wearers use soft contact lenses.1 In the face of such statistics and the continued evolution of soft lenses to better address patient needs, it is certainly pertinent to question the future of GP lenses.

Innovations discussed at this year’s Global Specialty Lens Symposium, however, may shed light on some exciting new directions we’re headed in.

• **GP Multifocals.** At a panel on the future of multifocal contact lenses, GP lens guru Ed Bennett, OD, of the University of Missouri–St. Louis College of Optometry discussed recent GP lens trends—including the improvement of hybrid multifocals, the use of GP multifocals for post-refractive surgery patients, improved high-add aspheric multifocals and scleral multifocals—and predictions regarding their role in the clinical practice in the next few years.

  Interestingly, Dr. Bennett pointed out that while practitioner preference for prescribing multifocals over other contact lens options has increased from 59% to 70% in recent years, many practitioners are still under-prescribing multifocal contact lenses.2 GP lenses are in fact a great option for both patients with irregular corneas and normal presbyopes, as they provide sharper vision and cost less over time compared with soft multifocal lenses. Some of the most recent innovative GP multifocals include Reclaim (Blanchard), Renovation (Art Optical), Clarity Plus (Accu Lens) and GoldenEye AFM (Valley Contax). These newer designs can be ordered empirically and, more often than not, the first or second lens ends up being the final lens. If you have a patient who appears to be a good GP multifocal candidate, don’t be scared to try some of the latest designs—you might be pleasantly surprised at the results.

• **Myopia Control.** Brien Holden, PhD, CEO of the Brien Holden Vision Institute, stressed in his presentation how significant a problem myopia is worldwide, and that it is the responsibility of eye care professionals to educate patients about the risks of high myopia and available treatment options. In North America, about one-third of individuals were myopic in 2000; this number is expected to increase to 50% by 2030 and 60% by 2050.2 Even more concerning than this percentage increase, however: the risk of certain debilitating, blinding eye diseases increases with high myopia and—this issue is still not being recognized and addressed properly.

  Both soft and rigid contact lenses are available to control myopia: soft lenses such as center-distance multifocals and inverted high minus lenses worn overnight, while GP options include the iSee (GP Specialists) DreamLens (Bausch + Lomb), CRT (Paragon) and Gov series (Global OK-Vision) orthokeratology lenses (Figure 1).3

• **Hybrid Lenses.** Hybrid lens technology, which has experienced some great design advancements in recent years, offers patients the optics of a GP lens with the comfort of a soft lens. The Duette hybrid lens (Synerg-Eyes), which features a silicone hydrogel skirt and a high dK...
GP center, is one such example available for single vision (Duette HD) and presbyopic (Duette Progressive and Duette Multifocal) patients. SynergEyes also offers the UltraHealth hybrid lens to treat keratoconus, and will soon be releasing the UltraHealth FC hybrid lens for oblate corneas due to certain diseases or following radial keratotomy or LASIK procedures.

• **Scleral Lenses.** Scleral contact lenses are undoubtedly one of the hottest topics in GP lenses—in fact, most laboratories have their own proprietary scleral lens design. When scleral lenses re-emerged in 2006, the first designs were primarily spherical (i.e., spherical base curves, secondary curves and edges). Practitioners fitting these lenses, however, discovered that certain adjustments were necessary to achieve a perfect fit due to the toric nature of many patients’ scleras; thus, peripheral curves and toric haptics can now be changed, and some scleral lens designs are available in a front surface toric design for patients with residual astigmatism (Figure 2).

In my experience, I have found that most of the front surface toric scleral lens designs are not as stable as I would prefer, and the vision has not been optimal in several of my patients, but I know that all of the laboratories are working on improving their toric stabilization systems, and I am confident that in the future, the designs will be much improved. For example, many scleral lenses on the market are now available with a multifocal option for presbyopic patients, which is a great option for irregular cornea patients looking to reduce their dependence on reading glasses.

While for some patients, GP lenses are a first choice for refractive correction, for many others, they are a reluctant last resort after all other options have been exhausted. As technology continues to improve, however, I believe that these remarkable lenses will increasingly become one of the patient’s top choices instead. Rumors of their death have been greatly exaggerated!  

Plan your dive and dive your plan. It’s a phrase I said to hundreds of divers when I was a scuba instructor. In addition to adding a layer of safety (if anything seems out of the ordinary, we’d go looking for you—and we’ll know where to look), a plan allows for a more enjoyable dive. To develop a plan, however, you must first do some research. This doesn’t require a degree in oceanography; rather, all you need is to ask the divemaster and boat captain a few questions, such as, Where is the best spot on this reef to see big fish and how are the currents likely to act during our 3 p.m. dive? Based on this “research,” the plan could simply be to jump off the back of the boat and meet directly underneath on the ocean floor for a safety check, after which the group will swim east for five minutes, then spend 20 minutes at 40 feet before swimming back to the boat for five minutes and resurfacing.

PRACTICE MAKES PERFECT

So how does this relate to us as eye care practitioners? Most banks require new practices, whether they are being built from the ground-up or incorporated as part of an existing practice, to have a business plan. Just like having a plan when scuba diving, having a sense of where you’d like to go and knowing when and how you’ll get there ensures you will have a safer (i.e., cost-effective), more enjoyable journey overall.

But, what about having a business plan in place for an established practice? This is less common. Many practitioners have goals (i.e., “increase net profits next year” or “hire a new associate”) but rarely have a specific business plan in place to achieve these goals. And without a definite plan, they run the risk of getting eaten by “sharks”—either online or big box competitors, or changing insurance company and governmental regulations. All of these can affect even the healthiest of practices.

The idea of writing a business plan may seem daunting at first, but for established practices it’s actually quite easy with the help of online templates or software. Assuming your goal is to increase revenue, begin by committing to a number and a timeline. For example, your practice currently grosses $1.4 million and will gross $2.1 million in three years—a consistent 15% increase for three years that is lofty but certainly attainable.

Next, record high-level ways you will achieve that growth, such as increasing second pair eyeglass sales from 7% to 12%, or increasing the percentage of contact lens patients in your practice from 22% to 30%. Note, adding new staff members to handle this influx should also be part of your plan.

With these high-level items in place, it’s time to rely on historical data and add the so-called real meat to your plan. With your profit and loss statements and production/sales reports in front of you, ensure that the achievement of the above items will help you reach your goal of a 15% increase in three years. If so, now you have to evaluate the expense side of things.

With your profit and loss statement in hand, set goals and plan for ways to keep costs in line. For example, the new staff members have to be paid—but where does that money come from? How about from the new revenue your other initiatives generate? With these costs outlined on your plan, you now have a budget for the next few years.

“ONCE YOUR PLAN IS DONE, SHARE IT AND USE IT.”

Finally, be sure to address the same issues new practices have in their plans with each item above. This includes factors like competitive external threats and how you’ll address them as well as future opportunities and competitive advantages that you’ll capitalize on and leverage. And of course, most importantly, once your plan is done, share it with your team and use it. The document you’ve created isn’t simply words on a page. Make future decisions and take steps that are based on your plan, and you will more than likely see the benefits play out in your practice. And don’t forget—enjoy the scenery on your journey!
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