Alfred T. Kamajian

The Lowdown on High-Tech IOLs

Peek at several IOL technologies that your international colleagues are using.

By Annie Stuart, Contributing Writer

CATARACT SURGERY HAS COME A LONG WAY SINCE THE EARLY 1980S, when the FDA first approved intraocular lenses (IOLs) for use in the United States. Since that time, patient interest in personalized visual solutions has mushroomed, and the market has responded with a great diversity of designs, materials, and approaches.

However, much of that innovation reaches international markets before it comes to the United States. For curious U.S. ophthalmologists, *EyeNet* offers an armchair traveler's look at several lenses available abroad that represent a potentially significant advance in IOL technology. In the opinion of *EyeNet* Cataract Section Editor Kevin M. Miller, MD, new and innovative IOLs include the Alcon IQ PanOptix trifocal; Zeiss AT LISA trifocal and trifocal toric IOL; RxSight Light Adjustable Lens; Morcher Xtra Focus Pinhole aperture IOL; and Rayner Sulcoflex IOL. Below, international and U.S. ophthalmologists talk about their experiences with and insights about these and similar lenses.

Although Dr. Miller noted that many accommodative lenses are also in the pipeline, he did not include any in his list, as all are a long way from possible introduction in the United States. In fact, the lenses mentioned in this article aren't guaranteed to achieve FDA approval in the United States—though some have completed or are about to start clinical trials, possibly paving their way for introduction into American practices.

Trifocal Lenses: The Promise of Spectacle Independence

With increasing use of computers, tablets, and smartphones in recent years, more patients desire better intermediate vision. This also happens to be the range of vision essential for activities such as cooking, gardening, and viewing the speedometer in a car, said A. John Kanellopoulos, MD, who practices in Athens, Greece, and in New York City. The development of trifocal IOLs has gone a long way in addressing this need.

Lens design. Diffractive multifocal lenses work based on a diffractive optical element on an intraocular lens that also provides a different point of focus on the optical axis, said Sheraz M. Daya, MD, at the Centre for Sight in East Grinstead, United Kingdom. Because they are diffractive, he said, they have properties of constructive interference, creating several focal points depending on the diffractive order.

"This design is quite clever because the second order of the intermediate range (+1.75 with FineVision, for example) doubles and coincides with the reading addition (+3.50), thus harnessing light that would otherwise be lost and adding to the focal point at near," said Dr. Daya. "In the past, it was thought that bifocality was the ultimate because interfering with another focal point—adding a third point of focus—would cause visual abnormalities, such as halos and vision disturbances when driving. As it turns out, that's not the case."

With trifocal IOLs, said Dr. Kanellopoulos, the diffractive pattern manipulates the light so that a portion of the light energy is taken to a different focus or to one of the principal foci so it is not lost, as happens with conventional diffractive bifocal designs.

These are 3 of the trifocal IOLs now available outside the United States—the FineVision trifocal lens (PhysIOL), AT LISA trifocal IOL (Carl Zeiss Meditec), and AcrySof IQ PanOptix (Alcon).

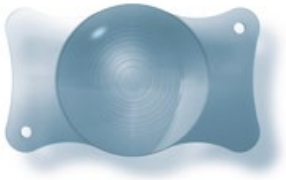
All 3 companies now offer toric trifocals, which correct astigmatism in addition to other refractive errors. This reduces the need for additional surgical procedures such as relaxing incisions, LASIK, PRK, or asigmatic keratotomy. Dr. Daya uses a femtosecond laser to correct astigmatism up to 1.5 D. "Past that point, I choose a toric lens," he said.

FineVision. Codesigned by Damien Gatinel, MD, at the Rothschild Ophthalmology Foundation in Paris, the first trifocal lens on the market contains 2 overlapping diffractive zones (1 for distance and near vision and 1 for distance and intermediate focus) of more than 30 optical steps, thus decreasing in height from the center of the lens to the periphery, said Dr. Kanellopoulos.

"The apodized surface provides a higher power for reading at its center," said Dr. Daya, "which makes sense because when you're reading, the pupil constricts." When the pupil aperture becomes larger, added Dr. Kanellopoulos, the peripheral steps are progressively exposed, with increasing amounts of light available for distance vision and less light dedicated to the near and intermediate focal points. "This gradual decrease of the step height from center to periphery has been shown to reduce halos, which are generated by defocused light under mesopic and scotopic light conditions," he said.

By the end of 2017, the FineVision trifocal will be available in a hydrophobic material, said Dr. Daya. "This material helps prevent capsular opacification and secures the IOL in the eye, reducing tilting or shifting, which is important because any tilt whatsoever with trifocals decreases functionality."

AT LISA. With a plate haptic design and preloaded into an injector, the AT LISA uses a diffractive pattern that provides trifocal function only over the central 4.34-mm region of the IOL, with a more conventional bifocal diffractive pattern extending from 4.34 mm to 6.0 mm diameter, said Dr. Kanellopoulos. "Differing from the FineVision, the trifocal diffractive structure asymmetrically directs incident light to distant (50%), intermediate (20%), and near (30%) focal points, independent of pupil diameter (up to 4.5 mm)," he said.



AcrySof IQ PanOptix. "For simplicity's sake, this IOL can be viewed as a quadrifocal IOL manipulated to act as a trifocal," said Dr. Kanellopoulos. The extended intermediate focal point (120 cm) is redistributed to the distance focal point for amplified performance and results in the creation of 3 foci: distance, intermediate at 60 cm, and near at 40 cm, he said. "At a 3-mm pupil diameter, PanOptix transmits 88% of light to the retina, possibly more light than the FineVision and AT LISA," said Dr. Kanellopoulos.

Benefits and best candidates. Trifocals are the best choice for patients with bilateral cataracts who desire spectacle independence, said Tim Schultz, MD, at Ruhr University Eye Hospital in Bochum, North Rhine-Westphalia, Germany. For instance, studies have shown that more than 95% of patients with trifocal IOLs become spectacle independent.[1-3] "Especially under good light conditions, patients are happy," he said. "The newer toric versions are also getting very good results for distance, intermediate, and near vision in patients with astigmatism."[4]

The lenses can benefit anyone without a contraindication for a multifocal lens, added Dr. Daya, such as macular degeneration, advanced glaucoma, or increased risk for diabetic retinopathy. "In my practice, more than

95% of patients receive a trifocal lens, including my 87-year-old mother." Patient satisfaction appears to be much better than with older models of bifocal IOLs, added Dr. Kanellopoulos, but larger prospective studies will offer more concrete data.

Potential challenges. As with many lenses, there are challenges with trifocal IOLs.

Communicating with patients. Patient preparation is key, said Dr. Schultz. It's important to counsel patients so they know what to expect.

Surgical challenges. There is a learning curve in adjusting the A-constant because it is different from the one surgeons are accustomed to using, said Dr. Kanellopoulos. Since keratometry and biometry are quite challenging, surgeons can employ intraoperative aberrometry for better outcomes. In addition, said Dr. Schultz, in very high myopes with astigmatism, the toric versions of the IOL can potentially rotate. A capsule tension ring may reduce rotations in these eyes.

Visual outcomes. Although light allocation and the introduction of a third focal point with trifocal IOLs may provide a wide range of vision, these features could also impact the quality of near and distance vision, said Dr. Kanellopoulos. "Emmetropia is quite crucial in the success of these lenses. Even small residual refractive errors can limit visual performance and may require enhancements with laser vision correction (LVC)." Additionally, some patients cannot tolerate the retina's process of neurally adapting to multiple images, he said, and this may require that the IOL be explanted and exchanged.

Visual side effects. Compromise of the posterior capsule is a relative contraindication to using the trifocal lenses, as all 3 models are single-piece foldable for endocapsular implantation, said Dr. Kannelopoulos. Glare, halos, ghost images, and asthenopia are other possible side effects, although Dr. Daya has not had to explant lenses on account of unbearable night vision troubles. When it comes to night vision, however, it may still be somewhat challenging to read very small letters in dim light, added Dr. Schultz.

Current status. In 2010, the FineVision IOL was the first trifocal to be introduced, but all 3 of these models are now used widely around the world, said Dr. Kannelopoulos. Despite some minor differences, he said, several peer-reviewed reports have found generally similar clinical results for these trifocal IOLs.

Although the FDA approved the first extended-depth-of-focus IOL last year with the Tecnis Symfony,[5] it has yet to approve any of the trifocal IOLs.

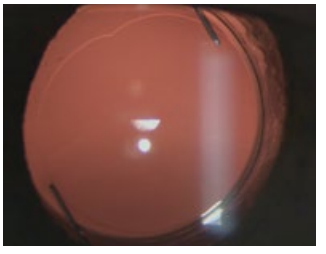
The Light Adjustable Lens: Customization After Surgery

Cataract surgeons have long been challenged to achieve precise refractive results. "In fact, a Swedish study[6] using national data showed that we reach desired refraction in only around 50% of patients," said Dr. Schultz. "But with RxSight's Light Adjustable Lens (RxLAL), we can now do an office-based alignment after surgery and get the refraction the patients want."

Lens design. Codeveloped by Daniel M. Schwartz, MD, founder of RxSight (formerly Calhoun Vision) in Pasadena, California, the lens has a foldable, 3-piece silicone platform with a 6-mm, square-edged optic, said Dr. Schultz. The lens material is a flexible silicone polymer matrix with mobile, photosensitive macromers.

About 2-4 weeks after surgery, when wound healing is complete, the physician does a simple office procedure, which takes just a few minutes, said Dr. Schultz. The physician uses a small contact lens to stabilize the eye and applies a cool, low-intensity beam of ultraviolet (UV) light, using a digital light source similar to a slit lamp. Where light strikes, macromers respond, adding thickness and reshaping the lens.

"Working with the patient, you can try different refractions until you achieve the ideal prescription," said Dr. Schultz, "and then lock it in with another dose of light to the whole optic." Steven D. Vold, MD, of Vold Vision in Fayetteville, Arkansas, implanted many RxLALs during a U.S. clinical trial in which physicians did 2 adjustments and 2 lock-in sessions to ensure the power didn't shift. Dr. Vold suspects this protocol will eventually evolve to minimize the number of office visits required.



Light-adjustable lens 7 years after implantation.

Benefits and best candidates. As it provides 2 D of correction for hyperopia, myopia, and astigmatism, the lens can be used with most patients, said Dr. Schultz, who is part of Burkhard Dick's and Fritz Hengerer's group, which has used it with more than 400 patients and achieved excellent outcomes. The lens is best, however, for those who have a clear idea of the activities they want to do after surgery, he said. In addition, it may be particularly helpful in correcting residual astigmatism, whether naturally occurring or surgically induced. Also, the IOL already has an optimized A-constant, said Dr. Schultz.

"The optics on this lens are incredibly good—the best of any I've seen," said Dr. Vold, who's used nearly every lens on the market in the United States. "I used to dance around the office when I got a patient to 20/20 after cataract surgery, but with this lens, more than half have achieved 20/15 or better."

Potential challenges. Patient selection is very important, said Dr. Vold. "For example, you don't want

Tim Schultz, MD

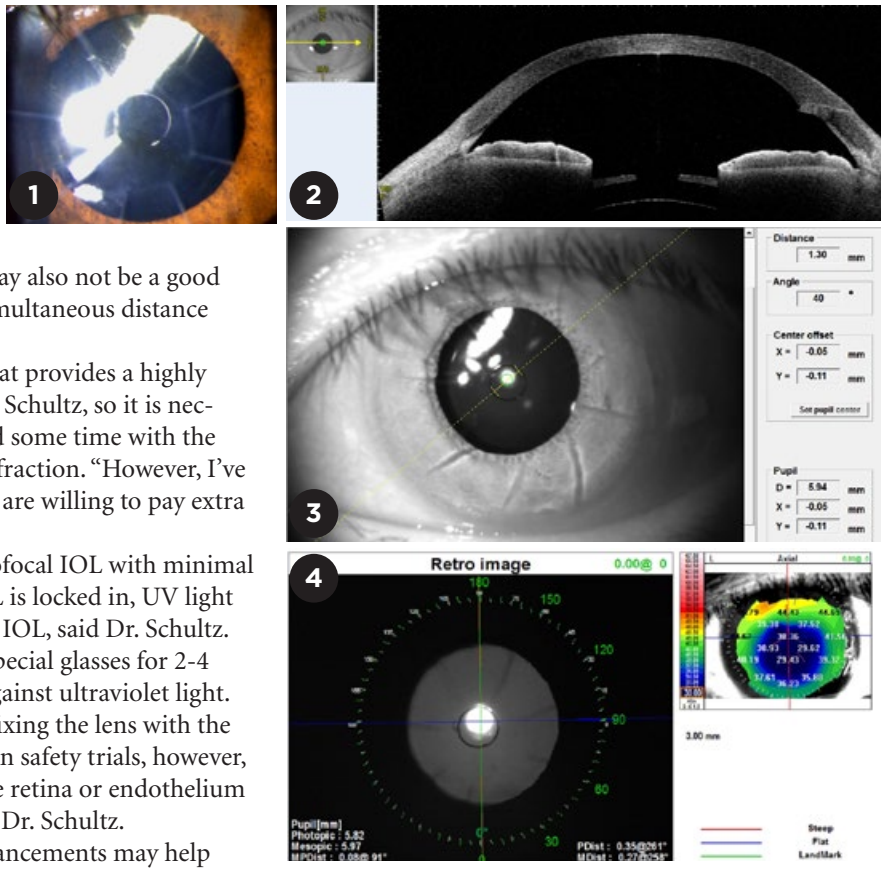
to put these lenses in people with herpetic disease because the light treatment can activate the herpesvirus. In addition, a silicone lens may not be ideal in patients at risk for severe retinal issues such as diabetic retinopathy and retinal detachment." The lens may also not be a good choice for patients who want simultaneous distance and near vision in the same eye.

This is a smart technology that provides a highly personalized treatment, said Dr. Schultz, so it is necessary to work closely and spend some time with the patient to achieve the desired refraction. "However, I've found that many of my patients are willing to pay extra for it."

The IOL behaves like a monofocal IOL with minimal halo and glare, but until the IOL is locked in, UV light can change the refraction of the IOL, said Dr. Schultz. Therefore, patients must wear special glasses for 2-4 weeks after surgery to protect against ultraviolet light. Compliance is critical to avoid fixing the lens with the wrong power, added Dr. Vold. "In safety trials, however, we've seen no problems with the retina or endothelium from the dose of UV light," said Dr. Schultz.

Dr. Vold said that future enhancements may help further improve the device. For example, he is hopeful the company will develop a better injector system, as well as a single-piece lens for ease of use.

Current status. Dr. Schultz's hospital was involved in early trials of the lens, which has been available in Europe since 2008. Phase 3 clinical trials in the United States are now closed. "After a year of follow-up, the company has gone to the FDA for approval, which they hope to receive some time in 2018," said Dr. Vold.



Imaging from a patient in whom the XtraFocus lens was implanted to help correct corneal aberrations resulting from her earlier radial keratotomy. (1) External photography, (2) anterior segment OCT, (3) central hole caliper, and (4) transillumination.

XtraFocus Pinhole Implant: Addressing Corneal Aberrations

Patients with severe corneal aberrations will likely become the main beneficiaries of an IOL developed by Claudio Trinidade, MD, from Instituto de Oftalmologia Cançado Trindade in Belo Horizonte, Brazil.

Lens design. Dr. Trindade introduced the innovative concept of a small-aperture IOL, said Robert H. Osher, MD, at the College of Medicine, University of Cincinnati and Cincinnati Eye Institute. Similar to a piggyback IOL, the XtraFocus Pinhole Implant (Morcher) is implanted in the ciliary sulcus during either a primary cataract surgery or in a secondary procedure.

Its foldable black hydrophobic acrylic material blocks light by creating an occlusive shield surrounding the aperture, said Dr. Osher.

"The central 1.3-mm pinhole allows a straight ray of light through the pupil, which reduces the visual impact of corneal aberrations," he said. "Its genius is that it blocks visible light but is transmissible by infrared light, which allows physicians to view the retina with optical coherence tomography."

Benefits and best candidates. This IOL is designed for patients with significant corneal aberrations, irregular astigmatism, or even severe iris defects that cannot be corrected, said Dr. Osher. That includes patients with keratoconus, as well as those who've experienced corneal scarring or trauma from 1 or more refractive corneal procedures, such as radial keratotomy (RK), LASIK, or penetrating keratoplasty, said Luca Gualdi, MD, with the Studio Oculistico Gualdi in Rome.

"If it is used as a secondary implant in the sulcus of eyes with normal corneas and monofocal IOLs, the XtraFocus can also increase the depth of focus, allowing improved near vision without the use of glasses," he said, adding that the occlusive device does not hamper peripheral vision.

Retinal pathologies in general, glaucoma, and central corneal opacities or haze are the main contraindications for this device, said Dr. Gualdi. Using early prototypes of the device, he had excellent results with 3 patients.

Courtesy of Luca Gualdi, MD

About 3 years ago, Dr. Osher was the first to implant the XtraFocus in an American patient. The woman had undergone RK in the 1980s and had recently been referred to Dr. Osher. "She had sutures in her cornea and 11 diopters of astigmatism, with glare and photophobia that couldn't be corrected but was so intense she'd become housebound."

Calling the results "spectacular," Dr. Osher said her astigmatism was significantly reduced, allowing her to read 20/40, and later improving further to 20/30 and 20/25. "More importantly, the IOL reduced her glare, light sensitivity, and all the aberrations that were keeping her from enjoying her life," he said.

Potential challenges. Morcher made a few adaptations to the IOL based on Dr. Osher's experience as well as that of his patient. This included tapering the cylinder at the aperture to prevent unwanted reflections of light and developing an injector that could be compatible with the lens. The haptics were also opened, eliminating the closed-loop design, making the lens easier to implant, he said.

Its use as a piggyback lens does come with potential challenges, said Dr. Osher. "For example, any time you put an extra lens into the eye, you want to be careful about a pupillary block, angle closure, intralenticular opacification, and completely removing ophthalmic viscoelastic devices. And, of course, you're concerned about getting a second lens through a smaller incision and not creating more astigmatism." However, he pointed out that the Morcher-designed injector addresses this issue.

Although Dr. Gualdi found that working with the lens involved a short learning curve, he said surgeons at first may find it a little challenging to handle this lens, which is thinner than others. In addition, to achieve the desired results, it is critical to carefully center the lens, he said.

Current status. The device was recently CE Marked and is currently available in the European market. According to Dr. Trindade, Michael Snyder, MD, from Cincinnati, is currently engaged with Morcher to develop a clinical trial in the United States.

Sulcoflex: A Supplementary Lens

Another type of piggyback lens, the Sulcoflex (Rayner), is implanted through a 2-mm incision behind the iris into the sulcus. "It's a less aggressive option for managing refractive surprises than is replacing the lens in the capsular bag," said Dr. Daya.

Lens design. The Sulcoflex is a hydrophilic acrylic injectable IOL with undulating haptics and posterior haptic angulation. "The haptics are quite bulky for positioning in the sulcus. When explanting them, I found that they were often covered by a layer of pigment, which means that they were reacting with the ciliary body," said Marie-José Tassignon, MD, PhD, of the University Hospital Antwerp in Belgium.

Benefits and best candidates. The company has designed the IOL with a range of powers, allowing for spherical correction of residual pseudophakic ametropia, multifocal correction of pseudophakic presbyopia, and toric correction of residual pseudophakic corneal astigmatism. Dr. Daya has chosen not to use the multifocal Sulcoflex lens because he's had patients who've experienced night vision issues such as halos following implantation.

The IOL can be used in a primary piggyback procedure or as an enhancement following implant surgery.

Piggyback procedure. "Before the trifocal lenses had toric offerings, I used this as a way of correcting high astigmatism as a primary procedure," said Dr. Daya. "I would put the trifocal lens in the bag and then add the Sulcoflex toric lens on top. It produced good outcomes, but now that I have access to trifocal toric lenses, I don't bother with 2 lenses."

Enhancement. For patients who've previously had a cataract operation, said Dr. Daya, this provides an option for correction of any residual refractive error. "If the company developed a trifocal Sulcoflex lens," he added, "that might make it possible for patients with the older monofocal lenses to become spectacle free."

Dr. Tassignon was involved with the Sulcoflex soon after its release, about 7 years ago. "Because our center is relatively well known for handling difficult cases, we had performed many IOL exchanges for dissatisfied patients," she said. As an alternative, she began implanting the Sulcoflex in some patients to correct their residual refractive errors.

Although she said the multifocal Sulcoflex is useful in certain cases, especially in children, she said the results of a clinical study she conducted were somewhat disappointing. Some patients were very happy with the results and could see both near and far, she said. But about half of the study participants were unhappy, and around 40% asked to have the lens explanted. Dr. Tassignon suspects that the dual-optic system is responsible because it is less precise and can create more aberrations than does a single lens. Fortunately, the lens is easily explanted, she said.

Potential challenges. None of Dr. Tassignon's patients have experienced serious complications from the presence of the lens. "However, because it is positioned in the sulcus, you have to consider preoperatively whether or not the eye can accommodate it," she said, adding that ophthalmologists often don't think enough about the lens design and biometric parameters of the eye, which can then lead to surprises. Dr. Daya agreed: "The diameter and width of patients' sulci differ, as well as the space between the iris and the capsule. That variation

can influence how well a lens will behave inside the eye."

Fixation is a potential challenge. "If the lens moves, there's a danger of pigment dispersion, which can cause inflammation and glaucoma or uveitis," said Dr. Daya. And although the large haptics increases stability of the lens, added Dr. Tassignon, it can also cause irritation of the iris, which required removal of the IOL in one of Dr. Daya's patients.

To help with fixation, especially with a toric lens, Dr. Daya sometimes stitches the IOL into the iris to keep it from moving. "In 4 cases, I actually opened up the anterior capsular bag and moved the Sulcoflex so there were 2 lenses inside the bag." These maneuvers require manipulation inside the eye and should be explained to patients in advance, he said.

It's important to consider the biocompatibility of the lens materials, said Dr. Tassignon. She has found that a buildup of deposits, requiring cleaning, can occur around the add-on lens or between the 2 lenses, even when they are in separate spaces. Years ago, she proposed the concept of adding a sticker to the existing lens—calling it "a true add-on lens" and suggesting that eliminating the interface might minimize these kinds of interactions.

Current status. According to Rayner, the Sulcoflex is not yet approved for use in the United States.

Coming Attractions?

Whether trifocal IOLs, customized treatment, or add-on devices for solving intransigent refractive problems, cataract surgeons have a lot to be excited about. "Toric IOLs have also been a pivotal paradigm change in my personal practice over the last 12 years," said Dr. Kanellopoulos, who uses them in about 80% of routine cataract procedures.

Dr. Schultz has been involved in trials with the Acufocus IC-8 IOL, which he's looking forward to using. "Its small aperture works like a pinhole, allowing only a straight line of light in," he said. "This produces more near vision, but without some of the disadvantages of multifocal IOLs."

Medicem has developed an extended depth-of-focus lens without haptics, inserted through a 2-mm incision, said Dr. Daya. "Within 24-48 hours of insertion into the capsular bag, it grows from 7.0 mm to 9.2 mm. The lens has 'polyfocal' optics and, in many ways, is analogous to the human crystalline lens. The visual outcomes are very satisfactory—and with such a large optic, the view of the retina is unbelievable."

Dr. Kanellopoulos predicts even greater advances to come: "Future development of electronic lenses that are adjustable in power and magnification and might include sensors that measure body temperature, glucose, or hormones may one day revolutionize cataract surgery altogether!"

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Steven D. Vold, MD Physician at Vold Vision in Fayetteville, Arkansas. *Relevant financial disclosures: Calhoun Vision: S.*

NOTE: Kevin M. Miller, MD, who selected the lenses that were discussed, is professor of ophthalmology at UCLA Stein Eye Institute in California. *Relevant financial disclosures: Alcon: C,L,S; Calhoun Vision: S.*

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