



AMERICAN SOCIETY OF CATARACT AND REFRACTIVE SURGERY

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Dear Colleague,

***Congratulations!*** The moderator and panelists chose your paper as the “**Best Paper of Session**” in Session 2-N: Keratorefractive Presbyopia Correction: Corneal Inlays, Scleral Implants. As you may know, more than a thousand papers are submitted each year to be considered for the ASCRS Symposium on Cataract, IOL, and Refractive Surgery by ophthalmologists from around the world. It is an accomplishment to have your paper accepted for presentation, and quite an honor for it to be named among the very best.

In addition to our offering congratulations, we would like to thank you for contributing to the high quality educational experience that ASCRS strives to offer Symposium attendees. It is presentations such as yours that keep ophthalmologists coming back to ASCRS year after year.

Best Paper of Session winners will be listed in *EyeWorld Today*, our meeting newspaper, and/or your presentation (slides and audio) will be available on our website at [www.ascrs.org](http://www.ascrs.org) under Post Meeting Recourses.

We look forward to seeing you next year in Chicago, Illinois and hope that you will once again make an important contribution to the ASCRS Symposium experience.

Sincerely,

A handwritten signature in black ink that reads "Roger F. Steinert, MD". The signature is fluid and cursive.

Roger F. Steinert, MD  
ASCRS Program Chair

# BEYOND 20/20 IN 2020

What's next for laser refractive surgery?

by Sean Henahan



**L**aser refractive surgery has come a long way in a short time. Visual outcomes continue to improve while the incidence of adverse effects continues to decrease. Many of the challenges of 10 and 20 years ago have been addressed, leaving the question, what's next? What does the future hold for the laser and refractive surgery?

"I believe that it is time to speak of 'super vision' again, but based on a different concept than 10 years ago. We have to get away from the 'eagle vs. the frog vision' concept and speak more in terms of 'natural' instead of 'super' vision," Ioannis Pallikaris MD, PhD, Institute of Vision and Optics, University of Crete School of Medicine, Heraklion, Crete, Greece observed.

Starting in the present moment, LASIK is the dominant refractive surgical procedure, with many surgeons performing a majority of surgeries with an all-laser approach, ie, a femtosecond laser to cut the flap, and an excimer laser to perform the ablation. Pre-op assessment typically includes refractive, topographic and wavefront analysis.

Results of recent large-scale reviews demonstrate why this approach has become so popular. Large-scale studies now report a majority of patients achieving 20/20 or better, with an increasing percentage achieving uncorrected acuity of 20/16 or better.

Some of the best results with LASIK ever seen were reported at the XXVIII Congress of the ESCRS in Paris by David J Tanzer MD, a staff surgeon (and former fighter pilot) at the Naval Medical Centre in San Diego, CA, US. He presented a series of patients, all pilots, who underwent wavefront-guided LASIK with femtosecond flap creation. By two weeks after surgery, all of the patients had 20/20, and 94 per cent had 20/16 or better uncorrected visual acuity. After four weeks, 97 per cent were 20/16, and 87 per cent were 20/12, and all were qualified to fly. The patients also had

"When it comes to the future, there are three kinds of people: those who let it happen, those who make it happen, and those who wonder what happened"

John M Richardson Jr

a greater than 50 per cent increase in low contrast acuity.

Wavefront-guided LASIK with femtosecond laser flap cutting has rapidly become the most common form of laser vision correction. Most of the major manufacturers now offer a combination platform to facilitate these procedures. Debates of the near future are likely to focus on the best method of eye tracking and registration, wavefront vs. Fourier-based evaluations, and the virtues of the various different femtosecond and excimer lasers.

Lasers are faster and more accurate, trackers are better at dealing with cyclotorsion, and complications are fewer. So where to go from here?

"The next frontier is improving predictability of outcomes. We've pushed pretty hard in terms of wavefront algorithms, and they do exceedingly well, but I think there are cases, both virgin eyes and previously operated eyes, that will probably benefit better from topographic guidance. We can expect to see better laser algorithms and better lasers. I think we are going to see solid-state lasers, smaller beams, and better interaction between the laser and data acquired from other instruments such as topographers and wavefront sensors. These improvements will combine to produce even better visual results than we see today," Perry S Binder MD, clinical professor of ophthalmology, non-salaried, Gavin Herbert Department of Ophthalmology, UC Irvine, CA, US, told *EuroTimes*. Dr Binder is also medical director for AcuFocus, and a medical monitor for Abbott Medical Optics.

As good as LASIK has become, it still

has some issues. These include dry eye, and post-op ectasia, which appears to have declined significantly, but can still be a problem.

The key to reducing problems associated with both dry eye and ectasia is in better identifying who is and who is not a good candidate for LASIK. Newer diagnostic approaches such as combining Placido and Scheimpflug imaging modalities (Galilei, Ziemer) to evaluate corneal thickness and curvature are helping in this regard. However, the next horizon appears to be developing technology for assessing corneal biomechanics.

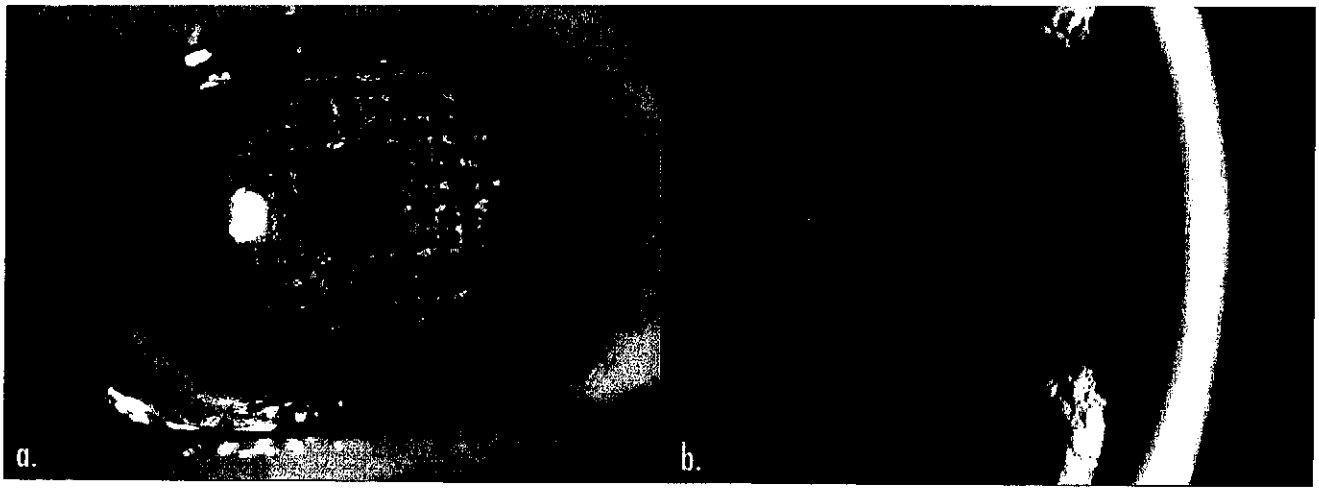
"We're just scratching the surface in this area. We don't have a good instrument yet. The Ocular Response Analyzer (Reichert) is a start, but it is just not sensitive enough. Although Bill Dupps MD from Cleveland Clinic is doing a fabulous job analysing corneal changes with the ORA, we don't yet have good metrics we can apply to a given cornea. For example, we know that sometimes thinner corneas are not weaker, and thicker corneas can be weaker biomechanically, and we don't understand all of the reasons why. In the future we hope to identify and rule out those candidates that might develop ectasia by using topographic and biomechanical analysis," says Dr Binder.

It is also important to determine which patients might do better with surface ablation or some form of lens correction. It is now clear that there are limits to hyperopic PRK and LASIK. Many patients might be better served by clear lens extraction or phakic IOL surgery, he added.



*In the future we hope to identify and rule out those candidates that might develop ectasia by using topographic and biomechanical analysis*

Perry S Binder MD



Femtosecond laser treatment of the crystalline lens for accommodation restoration (a) immediately after laser delivery, and (b) one week following treatment. There is no sign of progressive cataract formation, and no symptomatic dysphotopsia experienced by the patient when a central clear zone is maintained.

Post-op dry eye continues to be the number one complaint following LASIK. In the immediate term, clinical researchers are evaluating alterations to the size and location of the flap in an effort to improve wound healing and reduce post-LASIK dry-eye symptoms. Eric Donnenfeld MD and colleagues conducted a prospective comparison in which 40 eyes of 20 consecutive patients received bilateral simultaneous myopic LASIK with 150-kHz femtosecond laser flaps and wavefront-guided ablations. The eyes that had an elliptical flap with 150-degree reverse side cut angles and a 4.00mm hinge had better corneal sensation than those that received traditional round flaps with 70-degree side cut angles and 3.00mm hinges. The researchers believe this approach prevents resection of the vital peripheral corneal fibres, improving patients' post-op comfort. A related study found a similar benefit for a 140-degree reverse side cut compared with a 30-degree side cut in femtosecond flap creation.

A John Kanellopoulos MD, medical director of the Laservision Institute, Athens, Greece, and professor of ophthalmology at the New York University, Medical School in New York City, US, presented in 2010, at the ESCRS meeting in Paris and the AAO meeting in Chicago, a novel refractive procedure that utilises a continuous wave laser to "shrink" the half anterior stroma in concentric ring fashion without affecting the corneal epithelium that is cooled with a sapphire applanating cone. The tissue shrinkage flattens predictably the cornea, and the procedure is completed with transepithelial (epithelium-on) CXL with 12mW/cm<sup>2</sup> fluence and 0.1 per cent riboflavin enhanced with high concentration BAK preservative in order to facilitate transepithelial absorption. The novel technique is painless and in the first case follow-up up to 16 months appears to be very stable.

#### Cross-linking for post-LASIK

**ectasia** Following promising studies with the use of corneal collagen cross-linking (CXL) for the treatment of progressive keratoconus, many wondered if this might also be effective in the treatment of post-LASIK ectasia. Clinical trial results suggest that the answer might be yes.

Dan Epstein MD, University Hospital, Zurich, and colleagues conducted an 18-month follow-up study of 23 patients with documented post-LASIK ectasia who had been treated with CXL. Patients showed a statistically significant mean improvement in best-corrected acuity. Mean uncorrected and mean spherical equivalent refraction did not show significant differences. Topography maps showed marked reductions, and keratometry readings were stable. Mean central corneal thickness decreased significantly. This does suggest that the treatment did stop the progression of the ectasia.

Dr Kanellopoulos has proposed a novel technique for managing post-LASIK ectasia. He evaluated a method of under-the-flap, partial, topography-guided therapeutic ablation (tLASIK) combined with simultaneous collagen cross-linking. Seven eyes had a partial topography guided ablation within the original flap, followed by instillation of 0.1 per cent riboflavin solution within the flap and then cross-linking with UVA irradiation for 10 minutes. Visual function improved during a 15-month mean follow-up and the mean keratometry reading decreased by 2.4 D. Two eyes did regress within one year. This novel approach has the advantage of minimal discomfort and recovery time, it appears though not to be as efficient as the Athens Protocol (combined topo-guided partial PRK and CXL) in the management of post-LASIK ectasia.

A number of surgeons, including Dr Kanellopoulos, are now conducting clinical studies of cross-linking and refractive laser surgery. One question being actively

investigated is whether it is better to use a combined or sequential approach when using the two techniques.

Additionally, Dr Kanellopoulos has reported using CXL as a prophylactic adjunct in higher risk femto-LASIK surgery (thinner corneas, high myopia-ESCRS 2009, 2010) as well as higher fluence CXL utilising 5, 6, 10 and 12mW/cm<sup>2</sup> in order to shorten the CXL procedure time from 30 minutes to under 10 minutes.

"Cross-linking at time of surgery, makes sense in many ways, as long as you are not damaging the endothelium. You are killing keratocytes, and you are putting UV light a lot closer to the endothelium, so we need to study that. But if we can predictably strengthen some of these thinner corneas, it could help. The problems with cross-linking are the predictability of outcome, and the degree of refractive change one can get. We are just now learning, through the work of Dr John Marshall and others, what this procedure does morphologically as well as optically to the cornea," noted Dr Binder.

#### Variety of presbyopic treatments

The other primary issue that LASIK really has yet to deal effectively with may well be the major consumer demand of the future, presbyopia treatment. The field of refractive surgery is characterised by innovation and experimentation. This is certainly true when it comes to presbyopia.

One approach, multifocal ablation, either on the surface of the cornea, or under a flap, has been investigated for many years. Although there are some reports of success, it has generally proved difficult to replicate them. It is still possible that this approach may prove itself with better algorithms and newer technologies, but that remains to be seen.

Intrastromal ablation is getting a lot of attention as a potential treatment for presbyopia. This approach uses a femtosecond laser to steepen the cornea from the inside out. Invented by Colombian

refractive surgeon Luis Ruiz MD, the IntraCor® (Technolas Perfect Vision) technique reshapes the central cornea through the creation of circular concentric intrastromal incisions created with a femtosecond laser, without disturbing the epithelium or the endothelium.

To date, most studies with IntraCor have involved presbyopic hyperopes and presbyopic emmetropes. Two-year data now available for a study conducted by Mike D Holzer MD, University of Heidelberg, Germany, showed stable refractive outcomes for 25 patients with preoperative hyperopia of as much as 6.0 D. The mean uncorrected near visual acuity improved from 20/100 to 20/30. Postoperative recovery was fast and painless, and to date there has been no regression or weakening of the cornea. Questions remain about the effect of this procedure on distance vision. Haloes and glare were reported by some patients in the immediate post-op period, but tended to resolve over time.

Dr Holzer conducted another study in which he used a modified IntraCor femtosecond laser pattern for the correction of emmetropic presbyopes. At 12 months, patients showed mean improvements in near uncorrected visual acuity from 0.69 logMAR (range 0.30 – 0.80) to 0.10 logMAR (range 0.00 – 0.20). Mean uncorrected distance visual acuity was 0.00 logMAR (range 0.10 – -0.20) preoperatively and 0.10 logMAR (range 0.20 – -0.10) at 12 months. The procedure is quick and safe, and patient satisfaction is high, according to Dr Holzer.

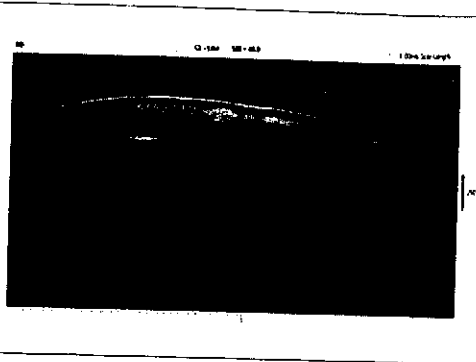
Predictability and side effects are two issues associated with the intrastromal femtosecond laser approach to presbyopia treatment. In some cases, patients do not respond to the treatment at all. This raises the question, what would be the next step for such a patient? Problems with glare and haloes also need to be addressed.

New variations on the intrastromal femtosecond laser front are being evaluated. Gustavo Tamayo MD director, Bogotá Laser

Courtesy of A. John Kanellopoulos MD



A cornea pictured 14 months after the novel CW-CXL procedure - the fine white circles in the anterior stroma are still visible



The OCT of the same cornea at 14 months documenting the anterior stromal shrinkage

Refractive Institute, Colombia is currently conducting a study of the efficacy and safety of a new intrastromal femtosecond ablation, with a specially designed T shape that leaves the centre for distance vision and the periphery for near vision. He plans to treat the non-dominant eyes of 50 emmetropic presbyopes. He believes this approach should improve near vision with the advantage of protecting the central area providing better overall quality of vision.

The Intralase femtosecond laser (AMO) is also being evaluated for intrastromal laser correction of presbyopia. Francisco Sánchez León MD and colleagues at Instituto Novavision, Naucalpan, Mexico, conducted a prospective clinical study treating presbyopes and mild hyperopes, targeting for good uncorrected near vision. At three months, patients demonstrated stable uncorrected near visual acuity with a mean gain of four lines of near visual acuity and no change in best-corrected distance vision, he has reported.

An entirely different approach to presbyopia treatment involves using the femtosecond laser to increase the flexibility of the crystalline lens with the hope of restoring accommodative vision. Marcus Blum MD and colleagues at Augenhilfkunde, Helios Klinikum Erfurt, Erfurt, Germany, reported some early promising results at the last ARVO conference.

Earlier in vitro studies showed that the femtosecond laser (VisuMax FS, CZM) could successfully make well-centred microincision on the lens. Subsequent animal studies showed that this could be done in living eyes with no ill effects on the retina, and no cataract formation. Dr Blum called the tests 'promising', suggesting that clinical trials in humans should be considered eventually.

Ron Krueger MD, medical director, Department of Refractive Surgery at the Cleveland Clinic's Cole Eye Institute studied the same idea in a different way. His team used computer modelling to evaluate the

potential of femtosecond laser treatment (LensAR) of the crystalline lens for presbyopia. They then progressed to human cadaver eyes and ultimately to living rabbits and monkeys. These studies supported the notion that the laser did indeed reduce lens stiffness in cadaver eyes. The animal studies showed no cataract formation for as long as two years. The group has begun clinical trials in the Philippines under the direction of Dr Harvey Uy, and so far the investigated laser patterns with an optical clear central zone are showing no signs of progressive cataract formation, but with yet unpredictable changes in accommodation using both objective and subjective testing

#### The return of thermal collagen shrinkage?

Many versions of thermal collagen shrinkage have been tried as treatments for presbyopia and hyperopia over the past 20 years, such as laser thermal keratoplasty, and all have failed. Problems have included serious side effects including damage to Bowman's membrane, and instability of the refractive outcome. Nonetheless, there is some optimism surrounding a new thermal approach known as the Kerarex procedure (Avedro). This approach delivers a single low energy microwave pulse to the cornea using a dielectrically shielded microwave emitter that contacts the epithelial surface. This raises the temperature of the selected region of corneal stroma to approximately 65°C, shrinking the collagen and forming a toroidal lesion in the upper 150 microns of the stroma. Next the system cools the surface of the cornea during the treatment to isolate and protect Bowman's membrane from the thermal effects of the microwave energy. The lesion created during the Kerarex procedure is intended to flatten the central cornea to achieve myopic correction without compromising the biomechanical integrity of the cornea. Kerarex is currently under clinical investigation in Europe for treating myopia and keratoconus.

Another popular aspect of the

femtosecond laser is its ability to create very precise channels or pockets in the cornea, suitable for the placement of refractive inlays. There are three types of corneal inlays, each expressing a different aspect of visual optics of the human eye, used to restore near and intermediate vision in presbyopic patients.

Flexivue-Microlens (Presbia) inlay is a 3mm diameter inlay inserted in 300 microns of the anterior stroma of the cornea. Having a peripheral zone of refractive power and a central zone without refractive power, it offers a bifocal element in the optical system of the human eye.

The AcuFocus Corneal inlay 7000 (ACI 7000, AcuFocus Inc.), utilises the pinhole effect to increase depth of focus.

Preshlyens (Revision) is a disc-like inlay that changes curvature and refraction of the anterior cornea when placed under a superior hinged lamellar LASIK flap.

Prof Pallikaris reports one-year very promising results of Flexivue inlay implantation in the corneal stroma of the non-dominant eye of 41 patients. Six months after treatment 85 per cent of patients have achieved uncorrected near visual acuity of 20/20. Mean uncorrected distance visual acuity in the operated eye has reduced, while mean uncorrected binocular distance visual acuity remained 20/20. 100 per cent of patients stated that they have got rid of their glasses for near, 80 per cent perceive their uncorrected near visual acuity as excellent and 80 per cent of the patients perceive their uncorrected binocular distance visual acuity as unchanged.

Gunther Grabner MD, University Eye Clinic, Paracelsus University, Salzburg, Austria, reported his results with one such inlay, the Kamra (AcuFocus), at the Paris ESCRS Congress. The Kamra uses the aperture concept to improve near and intermediate distance in presbyopes. It has an overall diameter of 3.8mm and has a 1.6mm central aperture which blocks unfocused light and allows focused light

into the eye. The result is an increased depth of field.

A three-year follow-up study of presbyopic emmetropes showed a mean gain of 4.6 lines of uncorrected near visual acuity and the mean uncorrected distance visual acuity was 20/20 with a mean loss of 0.8 lines. Uncorrected intermediate visual acuity was 20/32 or better in 95 per cent of eyes and 20/20 or better in 50 per cent of eyes. The improved near and intermediate visual acuity came at the cost of some loss of visual acuity in the treated eye, Dr Grabner said.

Another recent study suggested that combining the inlay with LASIK could also provide functional near vision for ametropic presbyopes.

The PresbyLens (ReVision Optics) corneal inlay uses a different optical strategy. The 2.0mm diameter inlays are placed under a thin flap or within a pocket to steepen the cornea. In early clinical trials the PresbyLens appears to improve near and intermediate vision, with very little loss of distance vision.

The femtosecond laser also plays a key role in a novel approach known as lenticule extraction. Called variously refractive lenticule extraction (Relex), femtosecond lenticule extraction (Flex), and small-incision lenticule extraction (SMILE), the femtosecond laser is used to carve a lenticule intrastromally. That lenticule is then removed via a flap or small incision. The hope is that this approach might be better for higher myopia, would induce fewer higher order aberrations, and might carry less risk of ectasia.

Rupal S Shah MD, New Vision Laser Centres, Vadodara, India has considerable experience with femtosecond lenticule extraction. He conducted a prospective study in 21 patients (36 eyes) with myopia and myopic astigmatism. Most patients showed statistically significant improvements in visual acuity at three months' follow-up. However, nine eyes had lenticule failure requiring follow-up LASIK.

Other groups, including researchers at the Solomatin Eye Centre in Riga Latvia, have reported that FLEX procedures produce equivalent visual outcomes to LASIK, with early indications of reduced induction of higher order aberrations.

#### Nanosecond lasers on the horizon

Theo Sellar MD, PhD, chairman of the Department of Ophthalmology at the University of Zurich in Switzerland, is an early pioneer in laser vision correction. His pioneering spirit continues, as seen in a new study evaluating the use of a pulsed nano-second laser for flap creation. Working in pig eyes, his group used a nanosecond laser system to produce smooth and precise flaps. The nanosecond laser did not create any tissue bridges, or any effects of filamentation, known to occur with femtosecond lasers. The early research hints that a safer, faster way to cut flaps may be coming soon.