Refractive Surgery 2014
Mission 20/20

Program Directors
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The Annual Meeting of ISRS
Sponsored by the International Society of Refractive Surgery (ISRS)

McCormick Place
Chicago, Illinois
Friday–Saturday, Oct. 17–18, 2014

Presented by:
The American Academy of Ophthalmology
2014 Refractive Surgery
Subspecialty Day Planning Group

On behalf of the American Academy of Ophthalmology and the International Society of Refractive Surgery it is our pleasure to welcome you to Chicago and Refractive Surgery 2014: Mission 20/20, the Annual Meeting of the International Society of Refractive Surgery.
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CME Credit

Academy’s CME Mission Statement
The purpose of the American Academy of Ophthalmology’s Continuing Medical Education (CME) program is to present ophthalmologists with the highest quality lifelong learning opportunities that promote improvement and change in physician practices, performance or competence, thus enabling such physicians to maintain or improve the competence and professional performance needed to provide the best possible eye care for their patients.

2014 Refractive Surgery Subspecialty Day Meeting Learning Objectives
Upon completion of this activity, participants should be able to:

- Evaluate the latest techniques and technologies in refractive surgery
- Compare the pros and cons of various lens- and corneal-based modalities, including presbyopic and toric IOLs
- Identify the current status and future of laser refractive lens surgery using femtosecond lasers
- Describe the increasing importance that refractive surgery plays in the practice of every subspecialty in ophthalmology
- Identify evolving surgical approaches for presbyopia

2014 Refractive Surgery Subspecialty Day Meeting Target Audience
The intended audience for this program is comprehensive ophthalmologists; refractive, cataract, and corneal surgeons; and allied health personnel who are performing or assisting in refractive surgery.

2014 Refractive Surgery Subspecialty Day CME Credit
The American Academy of Ophthalmology is accredited by the Accreditation Council for Continuing Medical Education to provide continuing medical education for physicians.

The American Academy of Ophthalmology designates this live activity for a maximum of 14 AMA PRA Category 1 Credits™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

Self-Assessment Credit
This activity meets the Self-Assessment CME requirements defined by the American Board of Ophthalmology (ABO). Please be advised that the ABO is not an accrediting body for purposes of any CME program. The ABO does not sponsor this or any outside activity, and the ABO does not endorse any particular CME activity. Complete information regarding the ABO Self-Assessment CME Maintenance of Certification requirements are available at http://abop.org/maintain-certification/part-2-lifelong-learning-self-assessment/cme/.

NOTE: Credit designated as “self-assessment” is AMA PRA Category 1 Credit™ and is also preapproved by the ABO for the Maintenance of Certification (MOC) Part II CME requirements.

Teaching at a Live Activity
Teaching instruction courses or delivering a scientific paper or poster is not an AMA PRA Category 1 Credit™ activity and should not be included when calculating your total AMA PRA Category 1 Credits™. Presenters may claim AMA PRA Category 1 Credits™ through the American Medical Association. Please contact the AMA to obtain an application form at www.ama-assn.org.

Scientific Integrity and Disclosure of Financial Interest
The American Academy of Ophthalmology is committed to ensuring that all CME information is based on the application of research findings and the implementation of evidence-based medicine. It seeks to promote balance, objectivity and absence of commercial bias in its content. All persons in a position to control the content of this activity must disclose any and all financial interests. The Academy has mechanisms in place to resolve all conflicts of interest prior to an educational activity being delivered to the learners.

Attendance Verification for CME Reporting
Before processing your requests for CME credit, the Academy must verify your attendance at Subspecialty Day and/or AAO 2014. In order to be verified for CME or auditing purposes, you must either:

- Register in advance, receive materials in the mail and turn in the Final Program and/or Subspecialty Day Syllabus exchange voucher(s) onsite;
- Register in advance and pick up your badge onsite if materials did not arrive before you traveled to the meeting; or
- Register onsite.

CME Credit Reporting
South, Level 2.5; Academy Resource Center, Booth 508
Attendees whose attendance has been verified (see above) at AAO 2014 can claim their CME credit online during the meeting. Registrants will receive an email during the meeting with the link and instructions on how to claim credit.

Onsite, you may report credits earned during Subspecialty Day and/or AAO 2014 at the CME Credit Reporting booth.

Academy Members: The CME credit reporting receipt is not a CME transcript. CME transcripts that include AAO 2014 credits entered onsite will be available to Academy members on the Academy’s website beginning Nov. 14, 2014.

NOTE: CME credits must be reported by Jan. 15, 2015. After AAO 2014, credits can be claimed at www.aao.org.
The Academy transcript cannot list individual course attendance. It will list only the overall credits spent in educational activities at Subspecialty Day and/or AAO 2014.

**Nonmembers:** The Academy will provide nonmembers with verification of credits earned and reported for a single Academy-sponsored CME activity, but it does not provide CME credit transcripts. To obtain a printed record of your credits, you must report your CME credits onsite at the CME Credit Reporting booths.

**Proof of Attendance**

The following types of attendance verification will be available during AAO 2014 and Subspecialty Day for those who need it for reimbursement or hospital privileges, or for nonmembers who need it to report CME credit:

- CME credit reporting/proof-of-attendance letters
- Onsite Registration Form
- Instruction Course Verification Form

Visit the Academy’s website for detailed CME reporting information.
2014 ISRS Award Winners

2014 José I Barraquer Lecture and Award

The José I Barraquer Lecture and Award honors a physician who has made significant contributions in the field of refractive surgery during his or her career. This individual exemplifies the character and scientific dedication of José I Barraquer MD—one of the founding fathers of refractive surgery.

Doyle Stulting MD PhD

Doyle Stulting MD PhD is director of the Stulting Research Center, Woolfson Eye Institute, professor of ophthalmology emeritus at Emory University and adjunct professor of ophthalmology at the Moran Eye Institute.

Dr. Stulting received his MD degree and PhD in microbiology and immunology from Duke University. He completed his internal medicine internship and residency at Washington University’s Barnes Hospital and his ophthalmology residency at the University of Miami, Bascom Palmer Eye Institute. Dr. Stulting completed a fellowship in cornea and external disease at Emory University, where he practiced, taught and performed research from 1982 to 2010.

In 2010, he left Emory University to found the Stulting Research Center at Woolfson Eye Institute, where he conducts a variety of clinical trials in cataract, refractive surgery, cornea and external disease.

For 10 years, Dr. Stulting was a member of the FDA Ophthalmic Devices Panel and completed a term as chair of the panel in 1998. He is past president of the American Society for Cataract and Refractive Surgery, has served on the Board of Directors of the EyeBank Association of America, is a member of the Board of Directors of the Georgia Eye Bank and is co-medical director of the Georgia Eye Bank. Dr. Stulting recently completed a 10-year term as editor-in-chief of the journal Cornea and is on the Editorial Board of other journals.

Dr. Stulting was awarded the American Academy of Ophthalmology’s Senior Honor Award and the FDA’s Citation for Excellence, Commitment, and Outstanding Service in Protecting the Public. He also received the prestigious Paton Award from the EyeBank Association of America.

Casebeer Award

The Casebeer Award recognizes an individual for his or her outstanding contributions to refractive surgery through nontraditional research and development activities.

Farhad Hafezi MD PhD

Farhad Hafezi MD PhD is professor of ophthalmology at the University of Geneva, Switzerland, and clinical professor of ophthalmology at the Keck School of Medicine at the University of Southern California (USC) Los Angeles.

Dr. Hafezi’s clinical expertise involves refractive laser and anterior segment surgery with special emphasis on the cornea. His known specialties include corneal crosslinking (CXL and PACK-CXL) and complication management after refractive laser surgery.

Philanthropically, Dr. Hafezi is a cofounder of Light for Sight. This initiative’s mission is to eliminate preventable blindness among children / adolescents with keratoconus, with a special emphasis on the Down population.

Dr. Hafezi has received numerous awards, including the highest national awards of Switzerland and Belgium and most recently, the 2014 ARVO Foundation / Carl Camras Translational Research Award. He is an associate editor of the Journal of Refractive Surgery and an editorial board member of Translational Vision Science and Technology and Current Eye Research.
Founders’ Award

The Founder’s Award recognizes the vision and spirit of the Society’s founders by honoring an ISRS member who has made extraordinary contributions to the growth and advancement of the Society and its mission.

Sonia Yoo MD

Currently professor of ophthalmology with a joint appointment in biomedical engineering and associate medical director at Bascom Palmer Eye Institute, University of Miami Miller School of Medicine, Dr. Yoo received her BA at Stanford University and her MD at Case Western Reserve University. She completed her residency and fellowship at Massachusetts Eye and Ear Infirmary, Harvard Medical School, in 1998.

Dr. Yoo serves as the incoming program chair of the Refractive Surgery Subspecialty Day program of the American Academy of Ophthalmology and serves on the Academy’s Practicing Ophthalmologists Curriculum Refractive Management / Intervention Panel for refractive surgery. She is a board member of the American Society of Cataract and Refractive Surgery and is on the board of directors for the Cornea Society. She is a reviewer for numerous journals, including the Archives of Ophthalmology, Ophthalmic Surgery, Lasers and Imaging, Cornea, Journal of Cataract and Refractive Surgery, Journal of Refractive Surgery, Eye, British Journal of Ophthalmology and Ophthalmology. Additionally, she serves on the editorial boards of the Cornea Society, the Journal of Refractive Surgery, the Journal of Cataract and Refractive Surgery, and Ophthalmic Surgery, Lasers and Imaging.

Kritzinger Memorial Award

The Kritzinger Memorial Award recognizes an individual who embodies the clinical, educational and investigative qualities of Dr. Michiel Kritzinger, who advanced the international practice of refractive surgery.

William J Dupps Jr MD PhD

Dr. William Dupps joined the staff of the Cleveland Clinic Cole Eye Institute in 2006 with appointments in ophthalmology, biomedical engineering, and transplantation. He also serves as adjunct faculty in the Department of Biomedical Engineering at Case Western Reserve University and the Department of Chemical and Biomedical Engineering at Cleveland State University.

After graduating with a bachelor’s degree in chemical engineering from Purdue University, he completed an MS and a PhD in biomedical engineering at The Ohio State University under a Presidential Fellowship and earned his medical degree with honors as a fellow in the Medical Scientist Training Program. He completed an ophthalmology residency at the University of Iowa Department of Ophthalmology and Visual Sciences, a fellowship in ocular gene therapy at the National Eye Institute, and a two-year Cornea and Refractive Surgery Fellowship at the Cole Eye Institute. He specializes in refractive surgery, corneal transplantation and cataract surgery.

With funding from the National Institutes of Health and Research to Prevent Blindness and an Ohio Third Frontier Innovation Platform Award, Dr. Dupps leads one of field’s top interdisciplinary research teams in translational ocular biomechanics. His early work helped define the basic biomechanical response to corneal refractive surgery, and he has since made significant contributions to the understanding of corneal ectatic disease and the development of novel approaches to optimizing corneal surgery through computational modeling. Dr. Dupps received the Achievement Award for service to the American Academy of Ophthalmology and a Distinguished Alumnus Award from The Ohio State University College of Engineering.

Dr. Dupps has been associate editor of the Journal of Cataract & Refractive Surgery since 2007. He has published over 70 journal articles and 14 book chapters and has delivered over 100 invited presentations. He holds several patents and received the Cleveland Clinic’s first Early Career Innovation Award in 2009 for founding OptoQuest, a Cleveland Clinic company that is commercializing systems for improving corneal and refractive surgery outcomes through patient-specific structural simulation.
Lans Distinguished Award

The Lans Distinguished Lecturer Award honors Dr. Leedert J Lans. Given annually, the award is given to an individual who has made innovative contributions in the field of refractive surgery, especially in the correction of astigmatism.

George O Waring IV MD FACS is an assistant professor of ophthalmology, the director of Refractive Surgery at the Medical University of South Carolina (MUSC), Storm Eye Institute, and serves as the medical director at Magill Vision Center. Dr. Waring also serves as adjunct assistant professor of bioengineering at the College of Engineering and Science at Clemson University.

Dr. Waring IV completed his Doctor of Medicine degree at the Emory University School of Medicine. He completed his subspecialty fellowship training in Cornea and Refractive Surgery under the world-renowned mentorship of Daniel S Durrie MD in Overland Park, Kansas.

Dr. Waring IV is a diplomat of the American Board of Ophthalmology. He has received numerous awards and distinctions for excellence in ophthalmology, including the American Academy of Ophthalmology’s (the Academy’s) Achievement Award and the Intraocular Implant and Refractive Society’s Gold Medal Award. He has been recognized as one of the nation’s Top Doctors in Ophthalmology by Castle Connolly’s Guide to America’s Top Ophthalmologists, and as a Top Ophthalmologist and Leading Physician of the World by the International Association of Ophthalmologists.

Dr. Waring IV is a founding member of the American College of Ophthalmic Surgeons and the prestigious Vanguard Ophthalmology Society and is active in numerous other societies. He serves as the director for the Academy’s annual Laser Refractive Surgery Course.

Dr. Waring IV is the senior editor for the Academy’s Ophthalmic News and Education Subcommittee on Refractive Management. He is the chief medical editor of Millennial Eye, a groundbreaking all-digital publication targeted to future leaders in ophthalmology. He also serves as the Refractive Surgery Section editor for the Academy’s EyeNet Magazine.

Lifetime Achievement Award

The Lifetime Achievement Award honors an ISRS member who has made significant and internationally recognized contributions to the advancement of refractive surgery over his or her career.

Noel Alpins MD FACS is an active cataract and refractive surgeon and is the medical director of NewVision Clinics in Melbourne, Australia. Dr. Alpins has spoken widely on cataract and refractive surgery topics and has been a keynote speaker at many Australian and international meetings. He pioneered small-incision cataract surgery in Victoria and is a founder and current member of the Excimer Laser & Research Group. He is also an associate fellow at the University of Melbourne, where he completed his Diploma of Ophthalmology in 1977 and received his FRACS prior to commencing practice in general ophthalmology. He is on the Royal Australian and New Zealand College of Ophthalmologists scientific program committee. He is on the editorial boards of the Journal of Cataract and Refractive Surgery, Ocular Surgery News, Eurotimes and the International Scholarly Research Network (ISRN) series of journals. He has published widely in these and other ophthalmic information journals and has authored more than 20 book chapters. Dr. Alpins has developed new techniques in the treatment and analysis of astigmatism. He has developed the ASSORT computer program for astigmatism calculation for toric implants and vector analysis and for outcomes analysis of cataract and refractive surgery. Among other recognitions, Dr. Alpins received the 2006 Gold Medal from the International Academy for Advances in Ophthalmology and gave the Council Lecture at the 2010 Annual Scientific Congress of the Royal Australian and New Zealand College of Ophthalmologists (RANZCO). In 2012 he received the ISRS Lans Distinguished Award. He has been an Australia Day Ambassador since 2011.
Presidential Recognition Award

The Presidential Recognition Award is a special award that honors the recipient’s dedication and contributions to the field of refractive surgery and to the ISRS.

Prof. Zoltan Z Nagy has been working in ophthalmology since 1986. Currently he is the head of the Department of Ophthalmology at Semmelweis University, Budapest, Hungary, and serves as a dean of the Faculty of Health Sciences.

Dr. Nagy first started practicing refractive surgery in Hungary in 1992, performing refractive procedures including PRK, LASIK, epi-LASIK, LASEK, PTK, and femto-LASIK. He discovered the effect of harmful ultraviolet-B during corneal avascular wound healing, which was published in *Ophthalmology* in 1997. Dr. Nagy was the first person in the world to perform femtolaser-assisted cataract surgery, in 2008.

In 2010 Dr. Nagy received the Waring Medal for the best publication in *Journal of Refractive Surgery*. In 2012 he received the Casebeer Award from the International Society of Refractive Surgery (ISRS) in recognition for his pioneering role and scientific contribution in femtolaser-assisted cataract surgery. He is an invited speaker in many European and international congresses. He is a board member of the Executive Board of the International Society of Refractive Surgeons (ISRS) and a co-opted member of the ESCRS Board (European Society of Cataract and Refractive Surgeons). Currently Dr. Nagy serves as a president of the Hungarian Society of Cataract and Refractive Surgeons (SHIOL), and in 2012 he received an invitation to the editorial board of the *Journal of Cataract and Refractive Surgery* and also to the *Journal of Refractive Surgery*.

Minoru Tomita MD PhD

Dr. Minoru Tomita received his MD license from Aichi Medical University in 1998 and his PhD from the Department of Ophthalmology and Pathology at Kansai Medical University in Osaka in 2002. He went on to complete his post-doctoral fellowship at Harvard Medical School in 2003.

In 2005, Dr. Tomita won the Best Fellow Paper award from Schepens Eye Institute, Department of Ophthalmology, Harvard Medical School. He began serving as executive medical director of the Sinagawa LASIK Center in Tokyo, Japan, in 2007 and joined Wenzhou University in China as an adjunct clinical professor in 2012.

In 2014, Dr. Tomita started his own refractive practice, the Tomita Minoru Eye Clinic Ginza in Tokyo, where he serves as medical director.
23rd Richard C Troutman MD DSc (Hon) Prize

The Troutman Prize recognizes the scientific merit of a young author publishing in the Journal of Refractive Surgery. This prize honors Richard C Troutman MD DSc (Hon).

Dr. Brian Armstrong graduated from Vanderbilt University School of Medicine in Nashville, Tennessee. During residency at the Vanderbilt Eye Institute where he served as chief resident, he developed a passion for corneal disease while working with mentors Uyen Tran MD and the late Denis O’Day MD. He then matched for fellowship at Cole Eye Institute at the Cleveland Clinic to train in cornea and refractive surgery.

At Cole Eye, Dr. Armstrong’s passion for corneal research was sparked—his chosen focus was in corneal biomechanics and crosslinking. During his time at Cole Eye and with the help of many colleagues, he performed a large rabbit study comparing outcomes of standard corneal crosslinking with those of various methods of transepithelial crosslinking. This work was published in the Journal of Refractive Surgery in May 2013.

In the fall of 2011, Dr. Armstrong went into practice with the Mid-Atlantic Permanente Medical Group in Washington, DC, where he has practiced as a cornea and external disease specialist. In 2013 he was appointed assistant chief of the Department of Ophthalmology and was recognized for his clinical and surgical skills, being included on the Super Doctors Rising Stars list for the Washington, DC / Baltimore / Northern Virginia region.
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Keck School of Medicine  
University of Southern California

David Smadja MD  
Bordeaux, France  
MD, Bordeaux University Hospital

Juan Carlos Serna MD  
Mexico City, Benito Juarez, Mexico

Michael E Snyder MD  
Cincinnati, OH  
Faculty and Board of Directors  
Cincinnati Eye Institute  
Volunteer Faculty  
University of Cincinnati
Jonathan D Solomon MD
Bowie, MD
Director of Refractive / Cataract Surgery
Solomon Eye Physicians & Surgeons
Clinical Researcher
Bowie Vision Institute

Aleksandar Stojanovic MD
Tromsø, Norway
Senior Consultant in Charge of
Refractive Surgery and Keratoconus
Eye Department
University Hospital, Tromsø
Medical Director
SynsLaser Clinic, Tromsø and Oslo

Audrey R Talley-Rostov MD
Seattle, WA
Partner, Cornea, Cataract and Refractive
Surgeon
Northwest Eye Surgeons
Medical Advisory Board
SightLife

Roger F Steinert MD
Irvine, CA
Irving H Leopold Professor and Chair of
Ophthalmology
Gavin Herbert Eye Institute
University of California, Irvine

Karl G Stonecipher MD
Greensboro, NC
Medical Director
TLC Greensboro

Gustavo E Tamayo MD
Bogotá, DC, Colombia
Director, Bogotá Laser Refractive
Institute
Member, Executive Committee ISRS

Julian D Stevens DO
London, United Kingdom
Consultant Ophthalmic Surgeon
Moorfields Eye Hospital London

R Doyle Stulting MD PhD
Atlanta, GA
Director, Stulting Research Center
Woolfson Eye Institute
Professor Emeritus
Emory University

Vance Michael Thompson MD
Sioux Falls, SD
Assistant Professor of Ophthalmology
University of South Dakota School of Medicine
Minoru Tomita MD PhD
Tokyo, Japan
Executive Medical Director
Shinagawa LASIK Center

David T Truong MD
Dallas, TX

Paolo Vinciguerra MD
Milan, Italy
Ophthalmology Department
Istituto Clinico Humanitas Rozzano

George O Waring III MD FACS
Atlanta, GA
Professor Emeritus of Ophthalmology
Emory University
Ophthalmologist
Woodhams Eye Clinic

Mitchell P Weikert MD
Houston, TX

Robert J Weinstock MD
Largo, FL
Director of Cataract and Refractive Surgery
The Eye Institute of West Florida

Helen K Wu MD
Chestnut Hill, MA
Assistant Professor of Ophthalmology
Tufts University School of Medicine
Director of Refractive Surgery
New England Eye Center

Sonia H Yoo MD
Miami, FL
Professor of Ophthalmology
Bascom Palmer Eye Institute
Professor of Ophthalmology
University of Miami Miller School of Medicine

Roger Zaldivar MD
Mendoza, Argentina
Ophthalmologist and Medical Director
Instituto Zaldivar S.A.
## Refractive Surgery 2014: Mission 20/20
The Annual Meeting of the International Society of Refractive Surgery
Sponsored by ISRS

**FRIDAY, OCT. 17, 2014**

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
<th>Presenter</th>
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<tbody>
<tr>
<td>7:00 AM</td>
<td>CONTINENTAL BREAKFAST</td>
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<tr>
<td>8:00 AM</td>
<td>Opening Remarks</td>
<td>A John Kanellopoulos MD*</td>
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<td></td>
<td>* Indicates that the presenter has financial interest.</td>
<td>No asterisk indicates that the presenter has no financial interest.</td>
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### Keynote Lecture

8:05 AM  | FDA Update on LASIK  
Malvina B Eydelman MD  

### Section I: Corneal Crosslinking

**Moderator:** A John Kanellopoulos MD*

**Panelists:** Theo Seiler MD PhD, Ronald R Krueger MD*, R Doyle Stulting MD PhD*

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<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>8:15 AM</td>
<td>Introduction and Self-assessment</td>
<td>A John Kanellopoulos MD*</td>
</tr>
<tr>
<td>8:17 AM</td>
<td>Combining Crosslinking and Excimer Laser Normalization</td>
<td>Vance Michael Thompson MD*</td>
</tr>
<tr>
<td>8:23 AM</td>
<td>Combining Prophylactic Crosslinking in Routine LASIK: Pro</td>
<td>George D Kymionis MD PhD*</td>
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<tr>
<td>8:29 AM</td>
<td>Combining Prophylactic Crosslinking in Routine LASIK: Con</td>
<td>William J Dupps MD PhD*</td>
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<tr>
<td>8:35 AM</td>
<td>Refractive Customized Crosslinking Applications— Theory and Clinical Results</td>
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<tr>
<td>8:41 AM</td>
<td>Pediatric Crosslinking Application: Expanding Indications and International Clinical Data</td>
<td>Farhad Hafezi MD PhD*</td>
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<tr>
<td>8:47 AM</td>
<td>Clinical Outcome of Topography-Guided Photorefractive Keratectomy With Crosslinking for Ectasia After LASIK</td>
<td>Simon P Holland MD*</td>
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<tr>
<td>8:52 AM</td>
<td>Different Clinical Outcomes of Standard, Accelerated, and Transepithelial Accelerated Corneal Collagen Crosslinkings for Keratoconus Treatment: One-Year Study</td>
<td>Minoru Tomita MD PhD*</td>
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<tr>
<td>8:57 AM</td>
<td>Transepithelial Iontophoresis Corneal Collagen Crosslinking for Progressive Keratoconus: One-Year Clinical Results</td>
<td>Paolo Vinciguerra MD*</td>
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<td>9:02 AM</td>
<td>Long-term Outcomes of Combined Small-Incision Lenticule Extraction and Simultaneous Intrastromal Crosslinking in Keratoconus (Aztec Protocol)</td>
<td>Enrique O Graue Hernandez MD</td>
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<td>9:07 AM</td>
<td>Femtosecond-assisted Intrastomal Corneal Crosslinking for Moderate Keratoconus</td>
<td>Miltos O Balidis MD PhD DO</td>
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<tr>
<td>9:12 AM</td>
<td>Advocating for Patients</td>
<td>Stephanie Jones Marioneaux MD</td>
</tr>
<tr>
<td>9:17 AM</td>
<td>Discussion and Self-assessment</td>
<td>A John Kanellopoulos MD*</td>
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### Keynote Lecture

9:29 AM  | How Is Crosslinking Being Adopted in the United States?         | Peter S Hersh MD*                             |

9:39 AM  | REFRESHMENT BREAK                                                  |                                                |

10:09 AM | ISRS Awards                                                        |                                                |

* Indicates that the presenter has financial interest.

No asterisk indicates that the presenter has no financial interest.
### Section II:  Presbyopia—Lasers vs. IOLs

**Moderator:** Ronald R Krueger MD*

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<thead>
<tr>
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<tbody>
<tr>
<td>10:29 AM</td>
<td>Introduction and Self-assessment</td>
<td>Ronald R Krueger MD*</td>
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<tr>
<td>10:31 AM</td>
<td>Spectrum of Laser Vision Correction Platforms and Profiles for Expanding Depth of Focus</td>
<td>Theo Seiler MD PhD*</td>
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<tr>
<td>10:38 AM</td>
<td>Corneal Inlays Are Better Than Corneal Laser Solutions</td>
<td>Gustavo E Tamayo MD*</td>
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<tr>
<td>10:45 AM</td>
<td>Small Aperture Inlays Are the Least Compromising for Expanding Depth of Focus</td>
<td>Damien Gatinel MD*</td>
<td>16</td>
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<tr>
<td>10:52 AM</td>
<td>Trifocal IOLs Are the Most Effective in Presbyopic Cataract Surgery</td>
<td>John So-Min Chang MD*</td>
<td>21</td>
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<tr>
<td>10:59 AM</td>
<td>LASIK and Monovision</td>
<td>Ioannis G Pallikaris MD*</td>
<td>23</td>
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<tr>
<td>11:04 AM</td>
<td>Longitudinal Survey Comparing Patient Satisfaction With LASIK vs. Contact Lenses: One- and 2-Year Surveys</td>
<td>Marianne O Price PhD*</td>
<td>24</td>
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<tr>
<td>11:09 AM</td>
<td>Comparison of Depth of Focus and Mesopic Contrast Sensitivity in Small-Aperture Inlay, Accommodating IOL, and Multifocal IOL Patients</td>
<td>Jay Stuart Pepose MD PhD*</td>
<td>25</td>
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<tr>
<td>11:14 AM</td>
<td>Visual Outcomes and Accommodation Amplitude With a New Accommodative IOL, the AkkoLens Lumina</td>
<td>Jorge L Alió MD PhD*</td>
<td>25</td>
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<tr>
<td>11:19 AM</td>
<td>Discussion and Self-assessment</td>
<td>Ronald R Krueger MD*</td>
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### Section III:  Video Lens Complications

**Moderators:** Amar Agarwal MD*, William J Fishkind MD FACS*

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<tr>
<th>Time</th>
<th>Title</th>
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<tbody>
<tr>
<td>11:31 AM</td>
<td>Introduction and Self-assessment</td>
<td>Amar Agarwal MD*</td>
<td></td>
</tr>
<tr>
<td>11:33 AM</td>
<td>Late Refractive Multifocal IOL / Capsular Bag Subluxation</td>
<td>Richard S Hoffman MD*</td>
<td>26</td>
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<tr>
<td>11:38 AM</td>
<td>IOL Scaffold: For Nucleus and IOL Exchange</td>
<td>Roger F Steinert MD*</td>
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<tr>
<td>11:43 AM</td>
<td>Posterior Chamber Rupture in a Refractive IOL Patient</td>
<td>David F Chang MD*</td>
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<tr>
<td>11:48 AM</td>
<td>It Takes Two to Tango: Pre-Descemet Endothelial Keratoplasty With Glued IOL</td>
<td>Amar Agarwal MD*</td>
<td>31</td>
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<tr>
<td>11:53 AM</td>
<td>Posterior Capsular Rupture</td>
<td>Robert H Osher MD*</td>
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<td>11:58 AM</td>
<td>Reusable Dislocated IOLs</td>
<td>Stratos Gotzaridis MD</td>
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<tr>
<td>12:03 PM</td>
<td>Discussion and Self-assessment</td>
<td>William J Fishkind MD FACS*</td>
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<td>12:15 PM</td>
<td>LUNCH—Hall D</td>
<td>ISRS Members-only Lunch and Program—E354</td>
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### Section IV:  Laser Refractive Lens Surgery on Trial: Is It Really Better?

**Judge:** Sonia H Yoo MD*

**Jury:** Sheraz M Daya MD*, Richard S Hoffman MD*, Boris Malyugin MD PhD*

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<th>Time</th>
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<tr>
<td>1:45 PM</td>
<td>Introduction and Self-assessment</td>
<td>Sonia H Yoo MD*</td>
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<tr>
<td>1:47 PM</td>
<td>Laser Surgery Is More Efficient: Pro</td>
<td>Burkhard Dick MD*</td>
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<tr>
<td>1:53 PM</td>
<td>Laser Surgery Is More Efficient: Con</td>
<td>Michael E Snyder MD*</td>
<td>38</td>
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<tr>
<td>1:59 PM</td>
<td>Discussion and Verdict</td>
<td>Sonia H Yoo MD*</td>
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<tr>
<td>2:02 PM</td>
<td>Laser Surgery Is Safer: Pro</td>
<td>Kevin M Miller MD*</td>
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<tr>
<td>2:08 PM</td>
<td>Laser Surgery Is Safer: Con</td>
<td>Shahzad I Mian MD*</td>
<td>41</td>
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<tr>
<td>2:14 PM</td>
<td>Discussion and Verdict</td>
<td>Sonia H Yoo MD*</td>
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<tr>
<td>2:23 PM</td>
<td>Laser Surgery Yields Better Visual Outcomes: Con</td>
<td>Bonnie A Henderson MD*</td>
<td>43</td>
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<tr>
<td>2:29 PM</td>
<td>Discussion and Verdict</td>
<td>Sonia H Yoo MD*</td>
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<tr>
<td>2:32 PM</td>
<td>Conclusion and Self-assessment</td>
<td>Sonia H Yoo MD*</td>
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**Break With the Experts**

2:35 PM – 3:20 PM

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<th>Topic</th>
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<tr>
<td>Cataract and IOL Complications</td>
<td>Amar Agarwal MD*</td>
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<td>Douglas D Koch MD*</td>
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<tr>
<td>Collagen Crosslinking</td>
<td>Theo Seiler MD PhD</td>
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<td>A John Kanellopoulos MD*</td>
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<tr>
<td>Corneal Inlays</td>
<td>Ioannis G Pallikaris MD*</td>
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<td>David R Hardten MD*</td>
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<td>Elevation Corneal Tomography</td>
<td>Renato Ambrósio Jr MD*</td>
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<td>Roberto Pineda II MD*</td>
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<tr>
<td>Laser Refractive Lens Surgery</td>
<td>Zoltan Nagy MD*</td>
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<td>Eric D Donnenfeld MD*</td>
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<td></td>
<td>William J Fishkind MD FACS*</td>
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<td>John A Hovanesian MD*</td>
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<tr>
<td>Intracorneal Rings</td>
<td>Aylin Kılıç MD</td>
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<td>Efekan Coskunseven MD</td>
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<td>Laser Vision Correction Enhancements</td>
<td>R Doyle Stulting MD*</td>
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<td>J Bradley Randleman MD</td>
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<tr>
<td>Phakic IOLs</td>
<td>Alaa M Eldanasoury MD*</td>
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<td>Gustavo E Tamayo MD*</td>
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<tr>
<td>Planning IOL Powers</td>
<td>Bonnie A Henderson MD*</td>
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<td>David F Chang MD*</td>
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<tr>
<td>Presbyopic IOL Pearls</td>
<td>Damien Gatinel MD*</td>
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<td>Robert J Cionni MD*</td>
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<td>Toric IOL Pearls</td>
<td>Roger F Steinert MD*</td>
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<td>Neda Shamie MD*</td>
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**Section V: Interactive Consultations—Lens Refractive Surgery**

Moderator: John A Hovanesian MD*

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<tr>
<td>3:20 PM</td>
<td>Introduction and Self-assessment</td>
<td>John A Hovanesian MD*</td>
</tr>
<tr>
<td>3:22 PM</td>
<td>Patient: “I Don’t Want to Wear Reading Glasses After My Cataract Surgery. What Are My Options?”</td>
<td>Jack T Holladay MD MSEE FACS*</td>
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<tr>
<td>3:25 PM</td>
<td>Doctor Response to: “I Don’t Want to Wear Reading Glasses After My Cataract Surgery. What Are My Options?”</td>
<td>Helen K Wu MD*</td>
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<tr>
<td>3:28 PM</td>
<td>Discussion</td>
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</table>
### Section VI: ESCRS Symposium—All About PresbyLASIK

Moderators: Roberto Bellucci MD*, Ioannis G Pallikaris MD*

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<th>Time</th>
<th>Session</th>
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<td>Introduction and Self-Assessment</td>
<td>Roberto Bellucci MD*</td>
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<tr>
<td>4:18 PM</td>
<td>Optical Problem of Multifocal Corneas</td>
<td>Pablo Artal MD PhD*</td>
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<td>4:26 PM</td>
<td>Evolution of Bi- aspheric Presbyopic Correction Over 2k Treatments</td>
<td>Pierre Baudu MD</td>
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<td>4:34 PM</td>
<td>Bilateral Hyperopic and Presbyopic LASIK</td>
<td>Andrea Ryan MBBS MRCS</td>
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<td>4:48 PM</td>
<td>Laser-Blended Vision for Presbyopia Correction</td>
<td>Dan Z Reinstein MD*</td>
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<td>4:56 PM</td>
<td>PresbyLASIK in Pseudophakia</td>
<td>Thomas Kohnen MD PhD FEBO*</td>
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<tr>
<td>5:04 PM</td>
<td>Applying and Avoiding PresbyLASIK</td>
<td>Ioannis G Pallikaris MD*</td>
</tr>
<tr>
<td>5:12 PM</td>
<td>Discussion</td>
<td></td>
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<tr>
<td>5:21 PM</td>
<td>Conclusion and Self-Assessment</td>
<td>Roberto Bellucci MD*</td>
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<tr>
<td>5:23 PM</td>
<td>Closing Remarks</td>
<td>Sonia H Yoo MD*</td>
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SATURDAY, OCT. 18, 2014

7:00 AM CONTINENTAL BREAKFAST

8:00 AM Opening Remarks
Sonia H Yoo MD*
A John Kanellopoulos MD*

<table>
<thead>
<tr>
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<tr>
<td>8:05 AM</td>
<td>Introduction and Self-assessment</td>
<td>Amar Agarwal MD*</td>
</tr>
<tr>
<td>8:07 AM</td>
<td>Nightmare Case of Recurrent Epithelial Ingrowth After LASIK</td>
<td>David R Hardten MD*</td>
</tr>
<tr>
<td>8:12 AM</td>
<td>The Complex Open Sky Triple Procedure</td>
<td>Alan N Carlson MD*</td>
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<tr>
<td>8:17 AM</td>
<td>Flap Complications</td>
<td>Natalie A Afshari MD*</td>
</tr>
<tr>
<td>8:22 AM</td>
<td>Descemet Membrane Endothelial Keratoplasty Nuances</td>
<td>Francis W Price Jr MD*</td>
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<td>8:27 AM</td>
<td>Contact Lens-Assisted Crosslinking for Thin Corneas</td>
<td>Soosan Jacob FRCS*</td>
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<tr>
<td>8:32 AM</td>
<td>Pseudophakic Corneal Edema</td>
<td>Sadeer B Hannush MD*</td>
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8:37 AM Discussion and Self-assessment
Amar Agarwal MD*

8:47 AM Keynote Lecture
Mitomycin C: Uses and Abuses in Corneal and Refractive Surgery
Randy J Epstein MD*

9:49 AM Conclusion and Self-assessment
Ronald Luke Rebenitsch MD

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<thead>
<tr>
<th>Time</th>
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<td>Introduction and Self-assessment</td>
<td>Ronald R Krueger MD*</td>
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<td>Traditional Methods for Astigmatism Magnitude Selection and Axis Alignment</td>
<td>Douglas D Koch MD*</td>
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<td>10:48 AM</td>
<td>Photographic/Topographic</td>
<td>Jonathan D Solomon MD</td>
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<td>10:55 AM</td>
<td>3-D Video Registration</td>
<td>Robert J Weinstock MD*</td>
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<tr>
<td>11:02 AM</td>
<td>Intraoperative Automated Cyclorotation Adjustment (Verion)</td>
<td>Robert J Cionni MD*</td>
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<tr>
<td>11:09 AM</td>
<td>Intraoperative Automated Cyclorotation Adjustment (Calisto)</td>
<td>Roger F Steinert MD*</td>
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<td>11:16 AM</td>
<td>Intraoperative Aberrometry (Talbot Moire)</td>
<td>Alan Richard Faulkner MD*</td>
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<td>Intraoperative Aberrometry (Sequentially Shifting)</td>
<td>Jay Stuart Pepose MD PhD*</td>
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11:30 AM Discussion of Jury and Verdict

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<tr>
<td>11:45 AM</td>
<td>Conclusion and Self-assessment</td>
<td>Ronald R Krueger MD*</td>
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**ISRS President’s Update**

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<th>Presenter</th>
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<tr>
<td>1:17 PM</td>
<td>ISRS President’s Update</td>
<td>Ronald R Krueger MD*</td>
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**Keynote Lecture**

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<tr>
<td>1:19 PM</td>
<td>Keynote Lecture: Posterior Elevation Tomography for Keratoconus Screening</td>
<td>Mitchell P Weikert MD*</td>
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**Section X: New Technology in Corneal Diagnostics**

Moderator: A John Kanellopoulos MD*
Panelists: Arthur B Cummings MD*, Terry Kim MD*, J Bradley Randleman MD

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<td>Clinical Correlation of Topography, Tomography, and OCT in Cornea Imaging</td>
<td>Costas H Karabatsas MD*</td>
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<td>Cynthia Roberts PhD*</td>
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<td>Aleksandar Stojanovic MD</td>
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<td>Cornea Densitometry and Ocular/Corneal Scatter Measurements</td>
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<td>Brillouin Corneal Imaging and Biomechanical Assessment</td>
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<td>Interferometry a Quantitative Measure for Corneal Biomechanics: Recent Advances</td>
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<td>Comparative Study of Cornea and Anterior Segment Biometric Features Between Scanning Slit Beam Technology, Placido Disk Topography, and a Scheimpflug Imaging System</td>
<td>Juan Carlos Serna MD</td>
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<td>Naoyuki Maeda MD*</td>
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<td>Enhanced Ectasia Susceptibility Screening Based on Clinical Data and Pentacam</td>
<td>Isaac O Ramos MD</td>
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<td>Comparison of Metrics Obtained With Discriminant Analysis and Decision Trees for the Detection of Subclinical Keratoconus</td>
<td>Jens Buehren MD</td>
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<td>Discussion and Self-assessment</td>
<td>A John Kanellopoulos MD*</td>
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**Section XI: The Journal of Refractive Surgery’s Hot, Hotter, and Hottest: Late Breaking News**

Moderator: J Bradley Randleman MD, Marcony R Santhiago MD

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<td>Introduction and Self-assessment</td>
<td>J Bradley Randleman MD</td>
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<td>Introduction of the Troutman Prize</td>
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<td>Troutman Prize: Biological and Biomechanical Responses to Traditional Epithelium-off and Transepithelial Riboflavin-UVA CXL Techniques in Rabbits</td>
<td>Brian K Armstrong MD</td>
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* Indicates that the presenter has financial interest.
No asterisk indicates that the presenter has no financial interest.
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<td>Femtosecond Cataract Innovations</td>
<td>Burkhard Dick MD*</td>
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<td>Photo-Activated Chromophore for Infectious Keratitis Crosslinking and the Impact of Fluorescein on the Antimicrobial Efficacy of Photoactivated Riboflavin in Corneal Collagen Crosslinking</td>
<td>Farhad Hafezi MD PhD*</td>
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<td>David T Truong MD</td>
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<td>Julian D Stevens DO*</td>
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<td>David Smadja MD*</td>
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<td>Osama I Ibrahim MD PhD*</td>
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<td>Corneal Coupling—Its Importance in Incisional and Ablative Procedures</td>
<td>Noel A Alpins MD FACS*</td>
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<td>J Bradley Randleman MD</td>
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<td>Closing Remarks</td>
<td>Sonia H Yoo MD*</td>
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* Indicates that the presenter has financial interest.
No asterisk indicates that the presenter has no financial interest.
FDA Update on LASIK

Malvina Eydelman MD

I. LASIK
   A. Regulation of the devices in the United States
   B. 2008 Advisory Panel
   C. FDA initiatives to improve safety

II. LASIK Quality of Life Collaboration Project
   A. Overview of the project
   B. Goals of phases

III. Development of Patient Reported Outcomes (PROs)
   A. FDA Guidance document
   B. Patient perspective increasingly incorporated in the evaluation of devices
   C. Development objectives for PRO used in LASIK studies

IV. Web vs. Paper Administration of Ophthalmic Questionnaires
   Viable alternative to paper administration

V. PROWL-1
   A. Sample of the questionnaire
   B. Overview of design
   C. Demographics
   D. Result of the psychometric evaluation
   E. Association of PRO with clinical parameters

VI. PROWL-2
   A. Overview of design
   B. Demographics
   C. Result of the psychometric evaluation
   D. Association of PRO with clinical parameters

VII. Summary
   A. Comparison of results between military and civilian populations
   B. Consistency with previous hypotheses
   C. Need to assess impact of patient symptoms in refractive procedures

VIII. Future Steps
   A. Publicly available questionnaire to measure patient symptoms
   B. With additional development work, newly developed questionnaire can be utilized in other refractive settings

References
3. USFDA website. “LASIK” Available at: www.fda.gov/LASIK.
Combining Crosslinking and Excimer Laser Normalization

Renato Ambrósio Jr MD

I. Introduction: Defining Refractive and Therapeutic Surgery

A. Refractive surgery’s goal is to improve the refractive state of the eye, thereby decreasing (or eliminating) dependency on glasses or contact lenses.

Success is measured by improvement in uncorrected vision (for distance and near).

B. Therapeutic surgery is typically indicated when there is a limitation caused by corneal pathology. Therapeutic surgery aims to improve or restore vision, to improve best spectacle-corrected visual acuity (BSCVA) or distance corrected visual acuity (DCVA); refractive result is not the primary goal.

Therapeutic surgery is, by definition, an alternative to avoid or delay corneal transplant.

II. Refractive surgery technologies are related to major advances for diagnosing and treating ectatic corneal diseases (ECDs).

A. ECDs represent a “new subspecialty” for corneal surgeons. See Ambrósio R, et al. “Advances in diagnosis and treatment of keratoconus: are we facing a new subspecialty?” www.youtube.com/watch?v=mVQE7n0u3ZI.

B. However, surgery for ECD should be considered as therapeutic.

1. For restoring vision and/or
2. For preventing ectasia progression (averting visual loss)

III. Refractive laser vision correction (LVC) is contraindicated in patients with keratoconus or related ECD.

A. Iatrogenic ectasia (or keratectasia) is a severe complication of LVC.

B. New concepts for diagnosing ECD: Defining preclinical disease states using advanced diagnostic technologies:

1. Placido disk-based corneal topography and ultrasound thickness
2. Scheimpflug cornea and anterior segment tomography (CAST)
3. Optical coherence tomography (OCT-CAST)
4. Corneal biomechanical assessment
   a. Corneal deformation to air pulse (Reichert ORA, Oculus Corvis ST)
   b. Brillouin scattering
5. Ocular wavefront aberrometry

6. Ocular biometry with anterior chamber depth and axial length measurements

C. Detecting ectasia susceptibility is critical for indicating and planning LVC (safety and efficacy).

1. Different refractive procedures have different impacts on corneal structure.
2. Impact of the surgical procedure is related to the number and depth of collagen fibers that are severed.

D. Patient education is fundamental for proper consent and to lead to conscious understanding of the risk of ectasia and need for proper follow-up and avoidance of eye rubbing.

IV. Corneal collagen crosslinking (CXL) for ECD represents a new paradigm for corneal surgical procedures.

A. Introduced by Prof. Theo Seiler and collaborators

1. Dresden Protocol
   a. Corneal debridement, followed by stromal saturation with riboflavin (B2) and ultraviolet A (UVA, 30 minutes at 3 mW/cm²)
   b. Minimal thickness: > 400 microns
2. Proven efficiency for halting the progression of ectasia: stability (bulging and thinning)
3. Effect also for improving corneal shape and improving corrected vision

B. Combination with other therapeutic procedures: surface ablation, intracorneal ring segments

C. Athens Protocol: Advanced Custom Therapeutic Surface Ablation + CXL

V. Excimer laser normalization or therapeutic ablation is not the same as the PTK mode.

A. Customization is essential.

B. Topography-guided

C. Concept of stress distribution

D. PTK for epithelial removal

E. PTK with smoothing agent

VI. Improvements on CXL approach

A. Faster or accelerated, based on Bunsen-Roscoe law of reciprocity so that the constant radiant exposure is 5.4 J/cm²

B. Augmenting the concentration of the riboflavin solution

C. Optimization of the UVA beam profile
VII. Conclusions

A. Surgery for ECD should be therapeutic with refractive result as a secondary goal.

B. Goal is (should not be) not to eliminate glasses.

C. Combining CXL with refractive LVC (PRK) or small-incision lenticular extraction (SMILE) or LASIK is not well studied yet.

References


Combining Prophylactic Crosslinking in Routine LASIK: Pro

Vance Thompson MD

Introduction

Over 20 million LASIK procedures have been performed worldwide to date. Being one of the principle investigators in the FDA-monitored clinical trial on LASIK in the early 1990s, I can say that we have learned a significant amount about the benefits and risks of this corneal reshaping procedure that changed the way we deliver eye care. For instance, we know that the higher the correction or the more tissue removal, the higher the risk of visually significant regression of effect. We also know that a significant risk that we would love as LASIK surgeons to eliminate for our patients is weakening the cornea to the point that leads to an ectasia, leading to corneal transplantation. In this presentation I would like to discuss the reasons we should look closely at prophylactically using corneal crosslinking to stiffen and thus strengthen the cornea during LASIK.

Background Observations

It has been proven that corneal collagen crosslinking (CXL) effectively strengthens and significantly stabilizes corneas that have been weakened in ectatic and keratoconic patients. It has also been shown that LASIK can weaken the cornea, especially in thinner corneas or higher corrections. Knowing that LASIK, especially at higher corrections, can lessen corneal strength, along with knowing that crosslinking can increase corneal strength, it seems quite reasonable to consider combining these two procedures to make certain that LASIK treatments are more stable physically and refractively.

I personally am not comfortable with using crosslinking to perform LASIK on patients I would have not performed LASIK on anyway (ie, those at risk for ectasia after LASIK). But I have performed LASIK long enough that when an ectasia occurs in a patient who was qualified as a good candidate in every way, it makes me want to look closely at this exciting way to strengthen the cornea during the surgery. In this presentation I will explain why leaving the cornea in a state of strength that is closer to its pre-LASIK state is worth considering.

References


Combining Prophylactic Crosslinking in Routine LASIK: Con

George D Kymionis MD PhD

Introduction
The introduction of corneal collagen crosslinking (CXL) as a treatment option for ectatic corneas has changed not only the treatment approach in patients with ectatic diseases but the whole philosophy of corneal surgery. The successful combination of CXL with PRK in improving visual acuity and corneal irregularity in patients with ectasia has led some refractive surgeons to support the application of prophylactic CXL in all patients undergoing LASIK.

Arguments That Favor the Combination of CXL and LASIK
The main concern of surgeons performing LASIK procedures is the postoperative risk of ectasia. Since the application of CXL offers biomechanical stabilization of the cornea, the expectation has risen that the combined method will provide a “safety net” in the prevention of creating ectatic corneas postoperatively. Even patients with “high-risk” corneas, detected topographically, may be converted to “low-risk” patients with the appropriate combination protocol. In addition, the proposition of an extra procedure to the patient provides financial benefits to the surgeon performing it.

Knowledge Earned From the Experience of Combining CXL With Refractive Surgery
The use of CXL combined with refractive surgery has demonstrated that the effect of the method in corneal flattening and reduction in patients’ refraction is continuous and long lasting. Moreover, there are several risks of the combined treatment, including under- or no response / effect, induction of corneal scarring and infiltrates, and endothelial damage.

Concerns Against the Combination of CXL With LASIK as a Routine Procedure
The unpredictable nature of the synergic refractive effect of LASIK and CXL and the long-term refractive effect reported in CXL are facts that should discourage surgeons from adopting the combined procedure as a routine method. In addition, the patient is exposed to the increased intra- and postoperative risks of undergoing a second invasive procedure, such as infection risk due to increased exposure time, risk of stromal keratocyte loss, and risk of endothelium damage. The performance of routine CXL at the time of a primary LASIK case may also affect ocular structures, including the conjunctiva, the limbal stem cells (due to UVA exposure) and the crystalline lens, and increased risk of haze formation.

On the other hand, the cases of post-LASIK ectasia (which is the main reason for performing the combined procedure) have decreased during the last few years, thanks to the application of better preoperative screening devices and algorithms and more accurate flap thickness creation (with the broad use of femtosecond lasers). The total incidence of postrefractive ectasia is estimated to be 1 out of 5000 cases.

Conclusions
It is evident that routinely performing a combination of CXL with LASIK in all patients includes greater risks than the benefits it provides. It is strongly advised that surgeons should avoid performance of CXL on LASIK cases as a routine method until all the risks and benefits of the method have been determined. In “high-risk” cases, there are several treatment options that may be considered, such as PRK, phakic IOLs, or even aborting the procedure.
Refractive Customized Crosslinking Applications—Theory and Clinical Results

William J Dupps Jr MD PhD

Corneal ectasia and its associated refractive errors are an important cause of impaired vision-related quality of life. While corneal collagen crosslinking (CXL) represents a major therapeutic advance, with demonstrated efficacy for disease stabilization, clinicians lack clear guidance on optimal patient selection and treatment approach. By virtue of several factors—the cornea’s accessibility to imaging, the well-defined functional relationship between corneal geometry and retinal image quality, the pivotal role of corneal biomechanical properties in determining its shape, and the potential for delivery of selective spatial stiffening patterns—CXL is an ideal target application for simulation-based treatment optimization.

In this presentation, an engineering approach to patient-specific design of customized CXL treatments is outlined. Results from finite element analysis-based computational modeling experiments suggest that (1) CXL parameters can be optimized in patient-specific simulations in corneal ectasia to greatly increase visual gains over standard treatment approaches and (2) novel patterns of CXL treatment can be tested in a virtual environment and leveraged to treat more common disorders of vision, including myopia and astigmatism, without destabilizing approaches such as incisions or photoablation. Collectively, the results support the value of in silico treatment optimization prior to clinical CXL treatment, point to new tools for integrated measurement and modeling in support of this goal, and open pathways to individualized keratoconus treatments that can maximize topographic improvement and extend the therapeutic range of CXL to patients unlikely to benefit from current treatment paradigms.
Pediatric Crosslinking Application: Expanding Indications and International Clinical Data

Farhad Hafezi MD PhD

Introduction
In the past years, corneal collagen crosslinking with riboflavin and UV-A has been used to stop the progression of postoperative ectasia and keratoconus. Whereas in postoperative ectasia the age of onset depends on the age of the patient at the time of surgery, keratoconus starts in childhood and shows the most aggressive progression in the second and third decade of life. Therefore, since 2012, a number of studies have investigated the clinical outcome of CXL in children and adolescents, but also the percentage of children and adolescents showing keratoconus progression once the initial diagnosis has been made.

The terms “children” and “adolescents” are usually defined by age, and there are several definitions available. The most commonly used are the definitions provided by the international organizations: Childhood, as defined by the United Nations High Commissioner of Human Rights, is the period before 18 years of age, whereas the United Nations Children’s Fund (UNICEF) defines adolescence as young people between age 10 and 19 years.

Background Observations
Summarizing the results of CXL performed in children and adolescents, the following statements can be made:

Duration of the effect
There is controversy over whether the effect of CXL in children and adolescents is as long lasting as in adults. As demonstrated by Vinciguerra et al and Caporossi et al, at 12 and 24 months after CXL, pediatric corneas showed a significant flattening, known from the studies in adults. However, Chatzis et al demonstrated that at 36 months, K-max did not show a significant reduction of readings when compared to the preoperative values, but rather stable readings.

Progression of keratoconus in children and adolescents
The study by Chatzis et al investigated how many patients would indeed progress once the diagnosis of keratoconus has been made. They showed that progression of keratoconus occurred in 88% of children and adolescents. Many surgeons therefore adopted the attitude to treat keratoconus as soon as the diagnosis has been made, without awaiting confirmation of progression.

Location of the cone
A recent study by Soeters and colleagues investigated differences in CXL between children, adolescent, and adult patients. Analyzing data at 1 year after CXL, they found that “before CXL, cones of pediatric keratoconic corneas were located more centrally than in the two older age groups. After CXL, pediatric corneas showed more corneal flattening and more corrected distance visual acuity improvement.”

Safety of pediatric CXL
All studies published so far have shown that CXL in the pediatric population seems to be equally as safe as CXL in adults.

References
Clinical Outcome of Topography-Guided Photorefractive Keratectomy With Crosslinking for Ectasia After LASIK

Presenting Author: David T Lin MD
Coauthors: Simon P Holland MD, Cheon Hwai Johnson Tan MBBS, Gregory Moloney MD**, Christian R Diaz MD**

Purpose: To evaluate simultaneous topography-guided photorefractive keratectomy with collagen crosslinking (TG PRK/CXL) for ectasia after LASIK. Methods: Fifty-six eyes with post-LASIK ectasia were treated with Allegretto WaveLight laser (AW) with TG PRK/CXL. Clinical outcomes were evaluated. Results: Thirty-one of 56 eyes treated by AW with 12 months follow-up. Fifty-eight percent had UCVA ≥ 20/40. Fifty percent gained ≥ 2 lines BCVA, and none lost ≥ 2 lines. Mean reduction in astigmatism (RIA) was 2.47 ± 1.87 D. Spherical equivalent was reduced from −1.25 ± 3.04 to −0.40 ± 1.40. All but 3 patients symptomatically improved. Complications were delayed epithelialization beyond 1 week in 2 patients and visually symptomatic haze in 1 case, with none showing progression at 1 year. Conclusion: Early results with TG PRK/CXL show promise as an effective and safe treatment for post-LASIK ectasia.

Different Clinical Outcomes of Standard, Accelerated, and Transepithelial Accelerated Corneal Collagen Crosslinkings for Keratoconus

Purpose: To report the 1-year results of transepithelial corneal collagen crosslinking (I-CXL) for ectasia after LASIK. Methods: Fifty-six eyes with post-LASIK ectasia were treated with Allegretto WaveLight laser (AW) with TG PRK/CXL. Clinical outcomes were evaluated. Results: Thirty-one of 56 eyes treated by AW with 12 months follow-up. Fifty-eight percent had UCVA ≥ 20/40. Fifty percent gained ≥ 2 lines BCVA, and none lost ≥ 2 lines. Mean reduction in astigmatism (RIA) was 2.47 ± 1.87 D. Spherical equivalent was reduced from −1.25 ± 3.04 to −0.40 ± 1.40. All but 3 patients symptomatically improved. Complications were delayed epithelialization beyond 1 week in 2 patients and visually symptomatic haze in 1 case, with none showing progression at 1 year. Conclusion: Early results with TG PRK/CXL show promise as an effective and safe treatment for post-LASIK ectasia.

Long-term Outcomes of Combined Small- Incision Lenticule Extraction and Simultaneous Intrastromal Crosslinking in Keratoconus (Aztec Protocol)

Presenting Author: Enrique O Graue Hernandez MD
Coauthors: Guillermo Garcia De La Rosa MD, Arturo J Ramirez-Miranda MD, Alejandro Navas MD

Purpose: To report long-term outcomes of simultaneous small-incision lenticule extraction (SMILE) and intrastromal corneal collagen crosslinking (CXL) in keratoconus. Methods: Inclusion criteria: topographic diagnosis of keratoconus, corrected distance visual acuity ≥ 20/40, and expected residual corneal thickness > 400 μ before CXL. Patients were treated with SMILE followed by intrastromal CXL. Follow-up was done at Day 1 and 1, 3, 6, 12, and 24 months. Results: Fifteen eyes were included. Mean age, 29.9 years. Median follow-up was 20 months. Preoperative and postoperative spherical equivalents were −4.3 and 0.08 D, respectively. Postop mean uncorrected distance visual acuity was 0.08 logMAR (Snellen 20/20-20/60). No eyes lost 2 lines; 93% percent were within 1 D of intended refraction. Conclusion: SMILE and CXL seems to be safe, effective, and stable in keratoconus.

Femtosecond Femtosecond-assisted Intrastomal Corneal Cross-linking for moderate keratoconus

Presenting Author: Mitos O Balidis DO PhD

Purpose: To evaluate femto-assisted intrastomal cross-linking for moderate keratoconus. Design: Prospective study. Methods: 12 eyes of 9 patients (6 male), with moderate keratoconus (K > 53.00 D and/or inferior steepening > 1.00 D in the superior half minimum corneal thickness > 420 μ, studied. Results: CDVA initially decreased at first month (p=0.157), followed by marked improvement at 3rd and 12th month postop (p=0.042) (Fig.2). Significant reduction in astigmatic power (p=0.016), eccentricity (p=0.044), and thinnest point 1-year postop (p=0.043). Conus remained stable, Kmax unchanged and Kmin increased after the first postop month (p=0.034) Conclusions: Riboflavin injected intrastromally in precisely designed pocket is a painless procedure, with fast rehabilitation. Maximal effect occurs at the area of pocket and its close vicinity.

** The co-author has not submitted financial interest disclosure information as of press date.
2014 Advocating for Patients

Stephanie J Marioneaux MD

Ophthalmology’s goal in protecting quality patient eye care remains a key priority for the American Academy of Ophthalmology (the Academy). All Eye M.D.s should consider their contributions to the following three funds as (a) part of their costs of doing business and (b) their individual responsibility in advocating for patients:

- Surgical Scope Fund (SSF)
- OPHTHPAC® Fund
- State Eye PAC

Your Eye M.D. colleagues serving on the Academy’s Secretariat for State Affairs commit many hours on your behalf while strategizing and collaborating with state ophthalmology society leaders to ensure the success of Surgery by Surgeons. Their ultimate goal—protecting quality patient eye care in the states—requires a robust Surgical Scope Fund, and we need every single Eye M.D. to step up to the plate and deliver with their checkbooks.

The Academy’s federal advocacy arm works to protect ophthalmology practices from payment cuts, burdensome regulations, and scope of practice threats, as well as to advance the profession by promoting funding for vision research and expanded inclusion of ophthalmology in public and private programs. It is critical for our OPHTHPAC Fund to also be strong.

Surgical Scope Fund

The Surgical Scope Fund (SSF) provides grants to state ophthalmology societies to support their legislative, regulatory and public education efforts. Since its inception, the Surgery by Surgeons campaign, in partnership with state ophthalmology societies and with support from the SSF, has helped 31 state/territorial ophthalmology societies reject optometric surgery proposals.

2014 has proved to be a challenging year, with several battleground states facing major optometric surgery initiatives. A number of state ophthalmic societies benefited from SSF disbursements and were able to successfully implement patient safety advocacy campaigns to defeat attempts by optometry to expand its scope of practice to include surgery. The Nebraska Academy of Eye Physicians and Surgeons was successful in its patient advocacy and public education efforts to derail legislation that would have granted optometrists the authority to perform eyelid surgery and injections. Additionally, the Arizona Ophthalmological Society succeeded in protecting patients by stopping legislation that would have allowed optometrists to gain authority to perform injections. The SSF is also at work assisting ophthalmic societies with their efforts to protect patients in California, Delaware and Massachusetts.

Proactively, the Georgia Society of Ophthalmology introduced a bill that would establish a formal definition of “surgery” into state law. While the legislative session expired before the bill could advance, Georgia ophthalmologists will be back in 2015 in an effort to pass this important safeguard for their patients.

2014 was certainly not without its challenges. Despite a vigorous battle for patient safety on the part of the Tennessee Academy of Ophthalmology, the Tennessee Medical Association and the Academy, the legislature passed a bill allowing optometrists to inject anesthesia into the eyelids. Previously, optometrists were authorized to perform only therapeutic injections and any surgical procedure that required no more than a topical anesthetic. And in Louisiana, the Academy, the Louisiana Ophthalmology Association and the Louisiana State Medical Society vigorously opposed legislation that would authorize optometrists to perform certain scalpel and laser surgeries and injections. On June 1, 2014, Louisiana Governor Bobby Jindal signed into law a laser surgery bill that will allow optometrists to perform scanning laser trabeculoplasty and argon laser trabeculoplasty glaucoma surgery procedures, as well as YAG capsulotomy surgery procedures, with the completion of as little as 32 hours coursework. The Academy’s Secretariat for State Affairs knows from past experience that with this success in Louisiana, organized optometry will push hard in 2015 to see if they can gain additional surgery states. This is why everyone must “advocate for patients,” engage in the state political process and aggressively support the SSF.

California, Delaware and Massachusetts remain “in play” and are still faced with active O.D. surgery legislation. When it comes to state legislation of any kind, California and Massachusetts are often considered bellwether states for the rest of the nation. Now more than ever, your contribution to the SSF is needed as a critical tool of the Surgery by Surgeons campaign to protect quality surgical care for our patients. The Academy relies not only on the financial contributions to the SSF from individual Eye M.D.s and their business practices, but also on the contributions made by ophthalmic state, subspecialty and specialized interest societies. The American Society of Cataract & Refractive Surgery (ASCRS) contributed to the Surgical Scope Fund in 2013, and the Academy counts on its contributions in 2014.

OPHTHPAC® Fund

OPHTHPAC is a crucial part of the Academy’s strategy to protect and advance ophthalmology’s interests in key areas, including physician payments from Medicare as well as protecting ophthalmology from federal scope-of-practice threats. Established in 1985, today OPHTHPAC is one of the largest and most successful political action committees in the physician community. In the past, Politico highlighted OPHTHPAC as one of the most successful health PACs in strategic giving. By making strategic election campaign contributions and independent expenditures, OPHTHPAC helps us elect friends of ophthalmology to federal leadership positions, ultimately resulting in beneficial outcomes for all Eye M.D.s. For example, in the 2012 election cycle, OPHTHPAC was able to help retain 20 physicians in Congress. Among the significant impacts of OPHTHPAC are the following:

- Prevented onerous national patient prescription requirements for compounded drugs and preserved access to most ophthalmic compounded drugs for office use
- Averted significant cuts to Medicare payments due to the Sustainable Growth Rate (SGR) formula

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- Prevented onerous national patient prescription requirements for compounded drugs and preserved access to most ophthalmic compounded drugs for office use
- Averted significant cuts to Medicare payments due to the Sustainable Growth Rate (SGR) formula
Protected practice expense increases for ophthalmology when other specialties sought legislative carve-outs

Protected ophthalmologists’ ability to provide in-office diagnostic testing without triggering self-referral violation

Prompted congressional action that helped reduce ophthalmology’s multiple procedure payment reduction

Secured appointment of full-time ophthalmology national program director in the U.S. Department of Veterans Affairs

Provided further exemptions from both the Electronic Prescribing and Meaningful Use EHR penalties

Leaders of ASCRS are part of the Academy’s Ophthalmic Advocacy Leadership Group (OALG), which has met for the past seven years in January in the Washington, D.C., area to provide critical input and to discuss and collaborate on the Academy’s advocacy agenda. The topics discussed at the 2014 OALG meeting included a focus on the collaboration needed among the Academy and its OALG partners on the issue of compounding. As a 2014 Congressional Advocacy Day (CAD) partner, ASCRS ensured a strong presence of refractive specialists to support ophthalmology’s priorities as nearly 400 Eye M.D.s had scheduled CAD visits to members of Congress in conjunction with the Academy’s 2014 Mid-Year Forum in Washington, D.C. ASCRS remains a crucial partner with the Academy in its ongoing federal and state advocacy initiatives.

State Eye PAC

We all must also support our respective State Eye PACs, because state ophthalmology societies cannot count on the Academy’s SSF alone. The presence of a strong State Eye PAC providing financial support for campaign contributions and legislative education to elect ophthalmology-friendly candidates to the state legislature is also critical. The Secretariat for State Affairs strategizes with state ophthalmology societies on target goals for state eye PAC levels.

ACTION REQUESTED: Advocate for your patients!!

Academy Surgical Scope Fund contributions are used to support the infrastructure necessary in state legislative/regulatory battles and for public education. PAC contributions are necessary at the state and federal level to help elect officials who will support the interests of our patients. Contributions to each of these three funds are necessary and should be considered the costs of doing business. Surgical Scope Fund contributions are completely confidential and may be made with corporate checks or credit cards, unlike PAC contributions, which must be made by individuals and are subject to reporting requirements.

Please respond to your Academy colleagues who are volunteering their time on your behalf to serve on the OPHTHPAC* and Surgical Scope Fund** Committees, as well as your state ophthalmology society leaders, when they call on you and your subspecialty society to contribute. Advocate for your patients now!

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State EyePAC

Support for candidates for State House and Senate

Campaign contributions, legislative education

Campaign contributions, legislative education

Contribution limits vary based on state regulations.

Contributions are on the public record depending upon state statutes.
How Is Crosslinking Being Adopted in the United States?

Peter S Hersh MD

Keratoconus (KC) and post-LASIK ectasia are noninflammatory processes in which the cornea deforms in association with thinning and biomechanical weakening.¹ The incidence of keratoconus in the literature is approximately 1/2000, and likely more as more subtle cases are uncovered using the newer screening techniques currently used in refractive surgery. In addition, hundreds of cases of post-LASIK ectasia have been reported.² Both of these diseases are progressive, resulting in worsening irregular astigmatism. Because of the optical aberrations caused by this progressive distortion and bowing of the cornea, patients usually require rigid or complex curvature contact lenses to achieve good functional vision; spectacle correction frequently does not result in acceptable quality of vision.

Corneal collagen crosslinking (CXL) has emerged as a promising technique to slow or stop the progression of KC and ectasia. In this procedure, riboflavin (vitamin B2) is administered in conjunction with ultraviolet A (UVA, 365 nm). The interaction of riboflavin and UVA causes the formation of reactive oxygen species, leading to the formation of covalent bonds within and between collagen molecules, or other stromal architectural changes, with consequent biomechanical stiffening of the cornea.³

To date, crosslinking is not FDA approved. There are, however, several clinical trial programs being undertaken in the United States and avenues of participation for the U.S. ophthalmologist.

Collagen Crosslinking Procedure

In the method initially popularized by Wollensak and colleagues,⁴ the central 9-mm epithelium is first removed by mechanical debridement. Riboflavin (0.1% in 20% dextran) is then administered topically every 2 minutes for a total of 30 minutes. Following riboflavin administration, riboflavin absorption throughout the corneal stroma and anterior chamber is confirmed on slitlamp examination. A stromal thickness of 400 μm or more is suggested for safety of the corneal endothelium. The cornea is then exposed to UVA 365 nm light for 30 minutes at an irradiance of 3.0 mW/cm². During ultraviolet exposure, administration of riboflavin is continued every 2 minutes. Other techniques, including accelerated crosslinking using UVA of higher power and transepithelial riboflavin administration, are currently under development.

Results of Corneal Collagen Crosslinking

As part of a multicenter U.S. clinical trial, we recently completed a randomized, controlled clinical trial of CXL for the treatment of KC and ectasia.⁵ Eighty-five eyes were included (KC 56, ectasia 29).

Visual Acuity Outcomes

UCVA

Preoperative UCVA was 20/137 (logMAR 0.83), worsening to logMAR 0.91 at 1 month, and then improving over time until 1 year, with UCVA 20/117 (logMAR 0.76). Looking at ectasia eyes alone, there was an improvement of 0.11 logMAR over the year.

BSCVA

Preoperative BSCVA was 20/45 (logMAR 0.34, worsening to logMAR 0.38 at 1 month, and then improving over time until 1 year, with UCVA 20/34 (logMAR 0.24). Looking at ectasia eyes alone, there was an improvement of 0.07 logMAR over the year.

Subjective optical symptoms

Patients completed a subjective questionnaire, ranking symptoms on a scale from 1 to 5 (1 = none, 2 = mild, 3 = moderate, 4 = marked, 5 = severe). At 1 year after CXL, improvements in night driving, reading, diplopia, glare, halo, and starbursts were statistically significant. No significant improvement was seen in photophobia, dryness, fluctuations in vision, or pain.

Optical outcomes

Maximum topometric keratometry (K-max)

Preoperative K-max was 58.5, worsening to 59.8 at 1 month, and then improving over time until 1 year, with K-max 56.9 (ie, a 1.6 D flattening effect). Looking at ectasia eyes alone, there was an average improvement of 1.0 D over the year. 30.6% of eyes flattened by 2.0 D or more, and 3.3% steepened by 2.0 D (ie, progression was stabilized or improved in 96.5% and progression continued in 3.5%).

Refraction and astigmatism

There was no statistically significant change in manifest refraction spherical equivalent (pre: -8.63 D, post: -7.77 D), absolute refractive astigmatism (pre: 4.76, post: 4.81), vectoral analysis of surgically induced astigmatism, or topographically derived simulated K (pre: 4.94, post: 4.76).

Corneal topography indices

Quantitative descriptors of corneal topography were measured with the Pentacam topographer, and included 7 indices: index of surface variance (ISV), index of vertical asymmetry (IVA), keratoconus and central keratoconus indices (KI, KCI), minimum radius of curvature (Rmin), index of height asymmetry (IHA), and index of height decentration (IHD). One year after CXL, there were significant postoperative improvements in ISV, IVA, KI, and Rmin (P < .001). As with other outcomes, there was a general worsening of topography indices at 1 month, followed thereafter by improvement. There were no significant differences between the KC and ectasia subgroups.

Higher-order aberrations (HOAs)

Corneal and total ocular HOAs were measured using the Pentacam Scheimpflug topographer and the LADARWave aberrometer, respectively. Looking at corneal HOAs, total HOA, total coma, 3rd order coma, and vertical coma significantly decreased at 1 year after CXL (P < .001). For total ocular HOAs, total HOA, total coma, 3rd order coma, and trefoil decreased.
and cone location. Postoperative improvement in maximum uncorrected distance visual acuity (UDVA), CDVA, maximum P
CXL-associated corneal haze keratoconus. Recovery of corneal thickness was more rapid in ectasia than in
from baseline to 12 months (mean change −6.6 µm; 
P < .001). At 1 year, pachymetry remained slightly decreased
and ectasia subgroups.

Characteristics Influencing Outcomes
To determine preoperative patient characteristics that may
predict topography and visual acuity outcomes of CXL, we
performed multiple regression and odds ratio analysis to
determine independent predictors of changes in topography-derived maximum keratometry (K) and corrected distance visual acuity (CDVA). The study comprised 104 eyes (66 keratoconus, 38 corneal ectasia). Preoperative characteristics included sex, age, uncorrected distance visual acuity (UDVA), CDVA, maximum keratometry (K), corneal thickness, corneal haze, disease group, and cone location. Postoperative improvement in maximum K was defined as flattening of 2.0 D or more, and worsening as steepening of 1.0 D or more. Improvement in CDVA was defined as a gain of 2 lines or more, and worsening as a loss of 1 line or more.

We found that eyes with a preoperative CDVA of 20/40 or worse were 5.9 times (95% confidence interval [CI], 2.2-6.4) more likely to improve 2 Snellen lines or more. Eyes with a maximum K of 55.0 D or more were 5.4 times (95% CI, 2.1-14.0) more likely to have topographic flattening of 2.0 D or more. No preoperative characteristics significantly predicted worsening of visual acuity or corneal topography. Thus, patients with worse preoperative CDVA and higher K values, particularly with a CDVA of 20/40 or worse or a maximum K of 55.0 D or more, were most likely to have improvement after CXL. No preoperative characteristics were predictive of CXL failure.

The Future of Corneal Collagen Crosslinking
A number of crosslinking studies are under way in both the United States and internationally. Of interest are the development of accelerated crosslinking techniques using UV sources of higher power, as well as riboflavin formulations that may penetrate the intact corneal epithelium and thus not require epithelial removal. The role of oxygen in crosslinking is being studied, with new methods to enhance the crosslinking effect under development. In addition, crosslinking as an adjunct to LASIK, topography-guided crosslinking, and guided crosslinking for the correction of refractive errors suggest crosslinking as a potential multifaceted platform for improvement of corneal biomechanics and future corneal treatments for a range of corneal disorders.

Study Conclusions
Corneal collagen crosslinking is a very promising new modality
to decrease the progression of ectatic corneal diseases and in the
future may be a mainstay in the early treatment of keratoconus
and other corneal ectasias. In our study, 96% of patients were
stable or had topographic improvement over the year after CXL.
Significant improvements were found in keratometric steepness,
UCVA, BSCVA, subjective optical outcomes, KC topography
indices, and higher-order aberrations. These findings corroborate
those found in a number of other studies. Corneas tend to thin
and develop a mild haze after CXL, both of which resolve to
baseline over the first year. CXL clinical outcomes follow a gen-
erally definable time course, with worsening at 1 month, a return
to baseline at 3 months, improvement at 6 and 12 months, and
stabilization beyond 1 year.

We did find some possible differences between postopera-
tive CXL outcomes in keratoconus patients and those in ectasia
patients. Both visual acuity and topography results appeared
more robust in keratoconus eyes. The cause of a potential dif-
ference between keratoconic corneas and ectatic corneas is, as
yet, unclear. Biomechanical differences caused by the LASIK
flap; possible differences in the riboflavin diffusion rate in post-
LASIK corneas, especially at the flap interface; and intrinsic
pathophysiologic differences between keratoconus and ectasia
may all contribute to the different responses to CXL between the
2 groups. Furthermore, the ectatic corneas in this study tended
to have more peripheral cones than did the keratoconus corneas.
Previous work from our group has shown that peripheral cones
may not exhibit as robust a topography change as more central
cones. Despite these findings, stabilization was found in both the
keratoconus and ectasia groups.

Crosslinking in the United States
Crosslinking is not FDA-approved in the United States. While
the approval process proceeds, a number of avenues are open to
U.S. surgeons.

1. Multicenter, industry-sponsored Investigational New Drug
   (IND) clinical trials: Avedro, Inc.
2. Society-sponsored multicenter clinical trials
   a. ACOS-sponsored
   b. 100 investigational sites
   c. Study monitored by Avedro
3. Physician-sponsored multicenter IRB trials: CXL-USA
4. Individual physician IND trials

References

Spectrum of Laser Vision Correction Platforms and Profiles for Expanding Depth of Focus

Theo Seiler MD PhD
Corneal Inlays Are Better Than Corneal Laser Solutions

Gustavo E Tamayo MD

Corneal inlays are probably the safest surgery developed for presbyopia. Although it has some drawbacks and complications, it is by nature better understood by patients and doctors. The main indication for a corneal inlay is the presence of presbyopia, and therefore it is a surgery suited for those so-called young presbyopes, people between 40 and 55 years of age. Up to today, although there are ongoing investigations in this matter, the indication is presence of presbyopia without any accompanying refractive defect.

Several advantages over excimer laser refractive surgery can be mentioned:

1. It is monofocal surgery, and therefore patients may prefer the idea of surgery in only one of the eyes, the nondominant.
2. Completely reversible surgery. Removal of the inlay, removes the effects completely.
3. Very simple surgery—only 5 minutes with the use of a femtosecond pocket
4. With the contact lens trial, patients can understand in advance the changes in vision they are going to have after surgery.
5. Binocularly there are no changes in distance vision and/or contrast sensitivity vision.
6. Fewer requirements in regard to corneal thickness or biomechanical stability
7. No risk of inducing ectasia
8. Surgery can be upgraded, replacing the inlay in case it is needed or a new problem has appeared.
9. Although centration is critical, as in any refractive procedure for presbyopia, recenteration after surgery is a very easy task.
10. It is not invasive surgery, and therefore complications are small and easily driven by the surgeon.
11. Dry eye is not an additional problem of this surgery.

In the presentation, we will discuss the benefits that are shared with laser surgery in the cornea and the ones that are unique for the corneal inlays.

Disadvantages of corneal inlays:

1. Small monofocality. This must be understood by the patient in order to tolerate it.
2. Small decrease in distance visual acuity/or contrast sensitivity in the operated eye (not noticeable in binocular surgery)
3. With age, the effect can be lost and change of the inlay or another type of surgery may be needed.
4. Small percentage of removal of inlays due to visual symptoms

Our own results will be discussed with long-term follow-up (5 years).
Small Aperture Inlays Are the Least Compromising for Expanding Depth of Focus

**Damien Gatinel MD**

I. Why Choose A Corneal Inlay?

Since 1949 when Dr. Jose Barraquer first published the concept of a corneal inlay, the idea of correcting vision using a tissue-sparing, removable device became an attractive option for surgeons and patients. The inlay is implanted in the nondominant eye.

II. Small Aperture Optics

A. The Kamra small-aperture inlay works by blocking unfocused peripheral light rays with the inlay, while isolating the more focused central and paracentral rays through its central 1.6-mm aperture, thereby narrowing the blur circle. (See Figure 1)

B. This extends depth of focus, improving both near and intermediate vision with minimal impact on distance vision.

C. Ideal refraction prior to implantation is emmetropia or low myopia (0/−0.75 D).

III. Evolution of the Inlay

A. Sixth-generation small-aperture design reliably extends depth of focus, resulting in improved near and intermediate vision without significant compromise in distance vision.

B. Made from the combination of polyvinylidene difluoride (PVDF) and nanoparticles of carbon, this ultrathin inlay is well tolerated in the eye, as demonstrated through long-term use in IOL haptics, animal testing, and over 5 years of clinical use.

C. Microperforations support normal corneal metabolic process while minimizing visual quality disturbance. (See Figure 2)

IV. Uninterrupted Range of Vision

A. Patients gain 3 lines of near acuity on average by 1 week and an additional line by 1 month.

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**Figure 1.**

**Figure 2.** Inlay design.
B. On average, patients achieve J2 for uncorrected near visual acuity and 20/20 for uncorrected distance visual acuity. (See Figure 3)

C. 92% of patients achieved 20/20 or better UCDVA and J3 or better UCNVA when their postop MRSE was equal to or between −0.50 D and −0.75 D.

D. 99.6% of patients had BCDVA of 20/25 or better at 12 and 24 months. (See Figure 4)

E. Only 1.03% lost 2 or more lines of BCDVA at 24 months, 99.6% of patients had a BCDVA of 20/25 or better, and no patient had BCDVA worse than 20/30.

F. 90% of patients worldwide, treated with a pocket procedure, are within ± 1.00 D of their intended refractive correction at 12 months. (Typical removal rate is 1.2% for pocket procedures).

V. Distance Stereopsis

Assessment of distance stereoacuity pre- and post-inlay implantation showed no change in mean distance stereoacuity scores.

![Figure 5. Pocket procedures.](image5.png)

![Figure 3. Uncorrected near and distance acuity.](image3.png)

![Figure 4. Best corrected distance visual acuity.](image4.png)

![Figure 6. Mean distance stereoacuity.](image6.png)
VI. Contrast Sensitivity

Binocular contrast sensitivity remains essentially unchanged in all lighting conditions and has demonstrated better performance than binocular contrast sensitivity with multifocal and accommodating IOLs. (See Figures 7 and 8)

VII. Visual Field

A. Visual field will remain normal with no formation of a scotomas or significant changes in pattern standard deviation from baseline.

B. No statistically significant differences were found between extent and total visual field area between implanted and nonimplanted eyes in a series of patients. (See Figure 9)

VIII. Long-term Stability

Improvements achieved after implantation of a small-aperture corneal inlay are maintained over the long term despite the progression of presbyopia. (See Figures 10, 11, and 12)
Mean UCDVA decreases by 1 line after implantation from 20/16 to 20/20.
Both eyes show age-related hyperopic refractive change over time.

Mean UCNVA improves 3.2 lines between pre-op and 1 month.
Near vision remains constant over long-term follow-up.
Fellow eye continues to degrade as presbyopia progresses.

Figure 9. Uncorrected distance visual acuity. Data courtesy of Dr. Gunther Grabner.

Figure 10. Uncorrected distance visual acuity. Data courtesy of Dr. Gunther Grabner.

Figure 11. Uncorrected near visual acuity. Data courtesy of Dr. Gunther Grabner.
IX. Patient Satisfaction

In a series of 3196 patients, at 1 year, 95% reported they were satisfied with their vision and that their dependence on reading glasses significantly improved. (See Figure 13)

X. Removability

A. Implantation of a corneal inlay is a simple procedure. In the event that an inlay needs to be removed, the process is simple and visual acuities recover quickly to preoperative levels.

B. Early removal results in faster return and stabilization of vision.
   1. Both uncorrected and best corrected visual acuities recovered by 1 month and stabilized by 3 months.
   2. 97% recovered their pre-inlay BCDVA by 6 months.
   3. All patients had 0.17 logMAR or better BCDVA pre-inlay and at 6 months following removal.

C. Other presbyopia-correcting procedures are still an option for patients following removal.

XI. Summary

A small-aperture inlay is the least compromising for expanding depth of focus because:

A. The procedure is minimally invasive.

B. The small aperture provides uninterrupted range of vision.

C. Distance stereopsis is maintained despite monocular implantation.

D. Near and intermediate vision are improved with little to no effect on distance vision.

E. The outcomes are unaffected by progression of presbyopia.

F. Quality of vision is excellent.

G. If necessary the inlay is removable and the patient maintains the same options for presbyopia progression.
Trifocal IOLs Are The Most Effective in Presbyopic Cataract Surgery

John So-Min Chang MD

I. Bifocals can provide good vision at both distance and near, but intermediate vision is important for:
   A. Computer work
   B. Chatting with others in “normal” distance
   C. Shopping / supermarket shelf / mahjong

II. Trifocal Multifocal IOLs on the Market
   A. AT LISA Trifocal (Carl Zeiss) (see Figure 1)

   Figure 1.

   B. Finevision Trifocal IOL (PhysIOL)
      1. Optic: Aspheric trifocal diffractive
      2. Material
         a. 25% hydrophilic acrylic (25% of water content)
         b. Copolymer of 2-hydroxyethylmethacrylate (HEMA) and 2-ethoxyethylmethacrylate (EOEMA) using ethylene glycol dimethacrylate (EGDMA) as linking agent
      3. Filtration: UV and blue light blocker
      4. Optic body diameter: 6.15 mm
      5. Overall diameter: 10.75 mm
      6. Angulation: 5°
      7. Power: from +10 D to +35 D (0.5-D steps)

   Figure 2.

   C. Pupil-dependent trifocal IOL

   Figure 3.

III. Early Experience of Trifocal IOL Compared to the Bifocal IOL
   A. OT period: 10/2012 – 9/2013
   B. Median follow-up: 6 months (1 to 11 months)
   C. Trifocal
      1. 20 eyes of 13 patients
      2. Age: 59.9 ± 7.87 years old (50 to 74)
      3. Grade 1-3 cataracts
      4. Preop sphere: -4.86 ± 4.31 D (range: +1.00 to -10.75 D)
      5. Preop cylinder: 0.73 ± 0.41 D (range: 0.00 to +1.25 D)
6. IOL implanted
   a. Mean power: +15.45 ± 3.89 D (10 to 22 D)
   b. Lens inserted through 2.2 wound size
   c. Astigmatism
      i. Limbal relaxing incision if astigmatism > 1.0 D
      ii. On axis if < 1.0 D

D. Bifocal
1. 47 eyes of 28 patients
   a. Age: 52 ± 5.3 years old (40 to 62)
   b. Grade 1-3 cataracts
2. Preop sphere: -1.45 ± 3.95 D (range: 3.75 to -12.50 D)
3. Preop cylinder: 0.45 ± 0.46 D (range: 0.00 to +1.75 D)
4. IOL implanted
   a. Mean power: +19.93 ± 5.06 D (8.0 to 27.5 D)
   b. Lens inserted through 2.2 wound size
   c. Astigmatism
      i. Limbal relaxing incision if astigmatism > 1.0 D
      ii. On axis if < 1.0 D

E. Result
1. Trifocal
   a. Safety: No eyes lost vision
   b. UCVA
      i. Intermediate UCVA: 85% 20/25, 100% 20/32 or better
      ii. Near UCVA: 85% 20/25, 100% 20/32 or better
      iii. Distance UCVA: 100% 20/20 or better
   c. BCVA
      i. Intermediate BCVA: 85% 20/25, 100% 20/32 or better
      ii. Near BCVA: 85% 20/25, 100% 20/32 or better
      iii. Distance BCVA: 100% 20/20 or better
   d. Average overall satisfaction: 3.94 out of 5
   e. Halo and glare mild
   f. Spectacle independence: Trifocal 83% vs. bifocal 80%

2. Bifocal
   a. Safety: No eyes lost vision
   b. UCVA
      i. Intermediate UCVA: 28% 20/25, 47% 20/32 or better
      ii. Near UCVA: 53% 20/25, 85% 20/32 or better
      iii. Distance UCVA: 74% 20/20, 83% 20/25 or better
   c. BCVA
      i. Intermediate BCVA: 11% 20/25, 32% 20/32 or better
      ii. Near BCVA: 68% 20/25, 96% 20/32 or better
      iii. Distance BCVA: 96% 20/20 or better, 100% 20/25 or better
   d. Average overall satisfaction: 3.78 out of 5
   e. Halo and glare mild
   f. Spectacle independence: Trifocal 83% vs. bifocal 80%

IV. Conclusion
Trifocal IOLs can obtain excellent vision at intermediate without sacrificing both the distance and near compared to bifocal IOLs. Trifocal IOLs are the most effective in presbyopic cataract surgery.
In recent years, several surgical methods have been proposed for presbyopia treatment. Among other techniques, corneal inlay implantation is considered the least invasive. Corneal inlays are placed under stromal flaps or inside stromal pockets made by femtosecond laser in the nondominant eye. Different models use different mechanisms to compensate for accommodation loss, such as positive refractive power, change of anterior corneal curvature, or increase of the depth of field by fixed small aperture.

The Presbia Microlens (Presbia; Amsterdam, Netherlands) is a transparent, hydrophilic disc with 3-mm diameter and approximately 15-μm edge thickness. The central 1.6-mm diameter of the disc is plano in power, and the peripheral zone has the additional positive power. The lens has a bifocal optical system that acts as modified monovision and is inserted into the intrastromal corneal pocket.

The Raindrop Near Vision Inlay (ReVision Optics; Lake Forest, Calif., USA) is a thin, transparent, permeable hydrogel implant. It is 1.5-2 mm in diameter and varies in thickness from 10 microns in the periphery to 32 microns in the center. Its refractive index and water content are similar to those of the cornea. It has no additional refractive power.

The Kamra Inlay (AcuFocus, Inc.; Irvine, Calif., USA) is an opaque, ring-shaped inlay made of polyvinylidene fluoride and carbon. It is 5 microns thick, with an outer 3.8-mm diameter and a central 1.6-mm aperture. The ring has 8400 laser-etched holes to facilitate diffusion of aqueous, oxygen, and nutrients through the cornea.

Long-term results show that corneal inlays are a safe and efficient method for improving near vision in presbyopic patients. Furthermore, recent studies have shown that corneal inlays achieve satisfactory near vision in pseudophakic patients after cataract surgery.
Longitudinal Survey Comparing Patient Satisfaction With LASIK vs. Contact Lenses: One- and 2-Year Results

Marianne O Price PhD, Francis W Price Jr MD

Introduction

Contact lenses and LASIK are both more cosmetically and functionally appealing than spectacles for correction of refractive error. Since LASIK is an elective surgical procedure, there has been a tendency to compare its outcomes to an emmetropic, non-operated eye without any comorbidity. However, no method of correcting myopia, astigmatism, or hyperopia is perfect, whether it be glasses, contact lenses, refractive surgery, or going without any correction. Therefore, the appropriate standard of comparison for LASIK should not be a perfect eye but rather another popular method of vision correction, such as contact lenses.

Methods

Patient satisfaction and symptoms are important indicators of efficacy and safety. Therefore, we conducted a survey study to assess patient satisfaction and visual symptoms before LASIK and 1 and 2 years afterward, and we also enrolled successful contact lens wearers, who were surveyed at baseline and 1 and 2 years later, as a control group. The initial surveys were administered online at 22 ophthalmic practices across the United States, as well as at 3 international sites in Singapore, Brazil, and Spain. Links to the annual follow-up surveys were emailed to the study participants on the enrollment anniversaries. No restrictions were placed on the type of contact lenses used or the type of excimer laser or flap creation method for LASIK, so the results provided a broad cross-section of the outcomes obtained with current technology.

Observations

Overall 2000 participants were enrolled; 59% had LASIK and 41% continued with contact lens wear. All participants were between the ages of 18 and 60 years old. Keratoconus, abnormal corneal topography, or multifocal correction were exclusion criteria. Satisfaction rates were high with both methods of vision correction; 96% of participants said they would recommend their method of vision correction to a friend or family member.

The principle questions in which responses differed between study arms were those that asked about night driving or dry eyes. Having some degree of difficulty driving at night because of vision was surprisingly prevalent. At baseline only 40% of respondents reported no difficulty at all, and over 10% reported moderate difficulty. Among those who continued contact lens wear, the responses did not change significantly at 1 or 2 years.

In contrast, among those who had LASIK, the proportion that reported no difficulty driving at night because of vision improved significantly, from 40% before LASIK to 60% 1 year afterward. This improvement was maintained at 2 years. In the contact lens arm, approximately 30% reported having no feelings of dry eyes in the previous week, while 15% reported having dry eye sensation at least half the time. These proportions did not change substantially when the contact lens wearers were resurveyed 1 and 2 years later.

In contrast, the proportion of participants that reported having no feelings of dry eyes decreased at 1 year after LASIK and recovered at 2 years. Those who wore glasses before having LASIK were significantly more likely to report increased dry eye sensation afterward compared with those who were wearing contact lenses before having LASIK. Many glasses wearers are contact lens intolerant because of dry eyes; consistent with this, a substantial proportion of those who wore glasses before having LASIK reported that they had tried contact lens at one time and given up on them.

Conclusions

This study sets an appropriate benchmark for LASIK by comparing it with another popular vision correction option. LASIK and contact lenses both provide more aesthetic and functional vision than glasses, but both entail some risks. The high LASIK satisfaction rate in this study is consistent with that found in earlier studies. Importantly, we found that with current laser technology the LASIK group reported a significant improvement in night driving vision, whereas a reduction in night driving vision after LASIK used to be a concern. In addition, the findings highlight the need for improved dry eye treatments with all forms of vision correction.

References

Comparison of Depth of Focus and Mesopic Contrast Sensitivity in Small-Aperture Inlay, Accommodating IOL, and Multifocal IOL Patients

Presenting Author: Jay Stuart Pepose MD PhD

Purpose: To retrospectively compare monocular defocus curves and binocular mesopic contrast sensitivity of small-aperture intracorneal inlay to 3 presbyopia-correcting IOLs. Methods: Six-month data on defocus curves and mesopic contrast sensitivity scores were compared between Crystalens AO (n = 25), ReSTOR 3.0 (n = 25), Tecnis Multifocal (n = 22), and Kamra inlay (n = 327) treated groups. Results: Continuous functional vision over a 4 D range was achieved by inlay patients when compared to all 3 IOLs. Inlay patients also achieved significantly better contrast sensitivity at all spatial frequencies for the no-glare (P < .05) and glare (P < .0001) conditions. Conclusion: Inlay patients achieved a broader range and better quality of vision than IOL patients.

Visual Outcomes and Accommodation Amplitude With a New Accommodative IOL, the AkkoLens Lumina

Presenting Author: Jorge L Alió MD PhD
Coauthors: Aleksey Simonov MD, Ana Belen Plaza, Alfredo Vega-Estrada MD, Alexander Angelov MD, Javor Angelov MD, Michiel Rombach MD

Purpose: To compare the accommodation response and visual outcomes of the AkkoLens Lumina with those of a monofocal IOL. Methods: Two groups of eyes were differentiated: Group A, 18 eyes implanted with the accommodative AkkoLens Lumina IOL, and Group B, 8 eyes implanted with the monofocal AcrySof SA60AT. Main outcomes measures were near visual acuity (VA), defocus curve, contrast sensitivity, and objective accommodation. Results: Better uncorrected near VA and distance-corrected near VA were found for Group A (P ≤ .01). In the defocus curve, better depth of focus was obtained in Group A for visual acuities of 0.8, 0.6, and 0.4 (P ≤ .02). Higher accommodative response was observed with the accommodative IOLs. Conclusions: The AkkoLens Lumina restores visual function with good near visual acuity due to the accommodation it provides.

**The co-author has not submitted financial interest disclosure information as of press date.**
Late Refractive Multifocal IOL / Capsular Bag Subluxation

Richard S Hoffman MD

This is a case of a 68-year-old female with pseudoexfoliation in her right eye who elected to undergo cataract surgery with Array multifocal IOL implantation in both eyes. At the time of her surgery in the right eye, there was no evidence of zonular weakness or compromise. Due to her pseudoexfoliative condition, it was decided to place a capsular tension ring in the right eye. The patient did well postoperatively; however, 7 years following her initial surgery, the IOL in the right eye developed pseudophacodonesis. Moderate IOL/capsular bag subluxation ultimately developed. Although she was able to maintain a visual acuity of 20/30 through the subluxed lens (in part due to the utilization of the peripheral IOL distant dominant rings), the significant pseudophacodonesis necessitated fixation of the IOL.

Rather than performing an IOL exchange, the decision was made to fixate the in-situ IOL utilizing a scleral fixation technique. Two scleral pockets were created at the 12 and 6 o’clock positions by first placing a 350-micron deep limbal incision and then dissecting each of these posteriorly in the plane of the sclera. A paracentesis was then created just anterior to each of the grooved limbal incisions. Following placement of a dispersive viscoelastic into the anterior chamber, a double-armed 9-0 prolene suture on a long curved needle was passed through the inferior paracentesis and docked into a 27-gauge needle that was passed through the full thickness of the globe, 2 mm posterior to the surgical limbus. One pass of the double-armed suture was in front of the capsular bag complex, and one pass was through the capsular bag and behind the IOL haptic. Previous placement of the capsular tension ring facilitated suture passage since all 360 degrees of the capsular bag could be utilized for fixation, rather than just using the IOL haptics for fixation.

Once the prolene sutures were placed, the needles were removed and the ends of the suture were externalized through the opening of the scleral pocket by placing a Sinskey hook into the pocket and pulling each end out. The sutures were then tightened and tied, allowing the knot to slide under the protective roof of the scleral pocket where overlying conjunctival erosion would be avoided. The same technique would then be utilized for the opposite scleral pocket. Iris hooks could be placed through the paracentesis in order to aid in visualization. By approaching this case in this manner, the original IOL could be salvaged, avoiding the need for an IOL exchange, which would have needed to be performed through a larger incision, with probable vitreous loss.

When performing cataract surgery in patients with pseudoexfoliation, it is probably better to avoid the use of multifocal IOLs due to the small instances of later IOL/capsular bag subluxation. If multifocal IOLs are utilized, refractive multifocal IOLs may be better choices than diffractive multifocal IOLs because of their ability to function better in cases of decentration or mild subluxation. Use of a capsular tension ring in all pseudoexfoliation patients, although considered excessive by some surgeons, gives better options for IOL fixation at a later date if this develops and especially if the IOL haptics are not in the meridian of subluxation.

Selected Readings

IOL Scaffold: For Nucleus and IOL Exchange

Roger F Steinert MD

This video will demonstrate the surgical technique of using an IOL as a scaffold to either protect the posterior capsule or to manage an open posterior capsule. If the posterior capsule breaks during phacoemulsification, insertion of the IOL can help prevent loss of nuclear and cortical material into the vitreous. If the posterior capsule is open and an IOL exchange is required, insertion of the new IOL under the original IOL prior to removing the original IOL can prevent vitreous prolapse.
Posterior Chamber Rupture in a Refractive IOL Patient
IOL Placement Following Posterior Capsular Rupture

David F Chang MD

The management of posterior capsular rupture entails additional decisions about fixation and stability of the intended IOL. This is particularly important with refractive IOLs, such as toric and multifocal implants. Balanced against the patient’s disappointment at not receiving their preferred IOL is the fact that these refractive IOL platforms are much less forgiving of tilt, decentration, misalignment, and residual refractive error. Following posterior capsular rupture, the options for IOL fixation will depend on the size and location of the capsular or zonular defect and the type of IOL contemplated.

Small Posterior Capsular Defect

It may be still feasible to place a single-piece hydrophobic acrylic IOL in the capsular bag if there is a small posterior capsular rent that does not extend to the periphery. It may be possible to avoid extending the capsular rent during IOL implantation because the single-piece haptics open so gradually, which permits some IOL rotation prior to their full extension. The same is generally not true for 3-piece foldable IOLs, whose stiff haptics will rapidly extend any noncircular rent as the IOL is rotated into position.

As conceived by Howard Gimbel, a posterior capsulorrhesis can be considered if the capsular rent is localized without peripheral extension. A dispersive ophthalmic viscosurgical device (OVD) should be placed anterior and posterior to the rent to help immobilize it and to displace the hyaloid face posteriorly. Because the retrocapsular OVD will not be aspirated out, a dispersive agent is less likely to cause a protracted IOP elevation. Locating a free capsule flap is not always possible, but the capsule forceps can grasp one edge of the defect in an attempt to round it off. Because the posterior capsule is so thin, it behaves with the characteristic elasticity of a pediatric anterior capsule. This makes it difficult to control the progression of the advancing tear unless the Little capsule tearout rescue maneuver is employed. The advantage of a posterior capsulorrhesis is the ability to securely fixate a single- or 3-piece IOL within the capsular bag.

Posterior Capsule Defect With Intact Capsulorrhesis

If the capsulorrhesis is intact and of an appropriate diameter, a 3-piece foldable posterior chamber IOL can generally be placed in the ciliary sulcus. If a multifocal IOL is contemplated, it is important that the capsulorrhesis be sufficiently centered on the visual axis. After the 3-piece haptics are first positioned in the sulcus, the optic should be captured behind the capsulorrhesis if possible. Particularly with a larger diameter ciliary sulcus, relying on optic capture instead of the overall haptic length will ensure better centration. First one side of the optic is tilted back and beneath the capsular rim before repeating the same maneuver for the other side. This maneuver can be more challenging following a vitrectomy, however, and may not be possible if the capsulorrhesis diameter is too large, too small, or decentered.

With optic capture, the optic still rests behind the anterior capsule and there is generally no need to adjust the power of the IOL.

With an intact capsulorrhesis, an option for fixating single-piece acrylic IOLs is reverse optic capture (ROC). For example, imagine that the posterior capsule tears as a single-piece acrylic IOL is injected into the bag. Particularly if there is no vitreous prolapse, the surgeon may be reluctant to rotate or exchange the IOL at this point. If so, one option is to perform reverse optic capture (ROC), where the haptics are left in the capsular equator, but the optic is prolapsed forward through the capsulorrhesis. This can be done using two IOL positioning hooks placed behind and anterior to the optic and acting like a pair of chopsticks to maneuver the optic forward.

One advantage of ROC is that the capsulorrhesis can center the optic while preventing lateral subluxation. In addition, the optic effectively blocks vitreous from prolapsing forward. Because the thicker single-piece haptics remain behind the anterior capsule, the risk of iris chafing is low in this situation. However, ROC is not appropriate if there is a large zonular dialysis or if the capsulorrhesis is either decentralized or of too small or large a diameter. In their series of 16 eyes with ROC of single-piece acrylic IOLs, Jones and Oetting reported good results but a slight myopic shift (mean −0.32 D), with only 63% of eyes refracting to within ±0.5 D of the intended target.

Posterior Capsule Defect With Torn Capsulorrhesis

If the capsulorrhesis is also torn, there may still be enough remaining peripheral capsular support to safely position the posterior chamber IOL in the ciliary sulcus. Amidst the stress of managing an unexpected complication, it may be tempting to use the same foldable posterior chamber IOL that was planned for the capsular bag. This is not recommended for several reasons. First, single-piece acrylic IOLs should never be placed in the sulcus, as discussed below.

Second, moving the axial IOL position slightly forward changes the effective power of the lens. Therefore, the IOL power should be decreased by approximately 0.5-1.0 D to compensate for this change in position. The higher the IOL dioptric power, the greater the compensatory reduction in sulcus placement power should be. Therefore, for IOL powers in the low to high 20s, 1.0 D should be subtracted.

Finally, nearly all foldable lenses are ≤13.0 mm long, which is too short for the ciliary sulcus in some eyes. Although the lens may center well in the operating room, if it is too short it can eventually rotate and subluxate peripherally over time. Studies by Werner elucidate one mechanism whereby an IOL that initially centers well within the sulcus could later become decenttered. Using the Artemis ultrasound biomicroscope to measure the sulcus in autopsy eyes, she found that the diameter of the sulcus can vary from one meridian to another. In other words, the sulcus plane may be more oval rather than circular. With eye rubbing or saccades, one might imagine an IOL eventually rotating into the longest diameter meridian, causing it to become decentered.

Studies by Werner and others have also shown that there is no reliable way to gauge the sulcus diameter according to external landmarks. Nevertheless, it is helpful to measure the white-to-
white corneal diameter intraoperatively with calipers. If it measures 11.5 mm or less, a standard 13.0-mm long foldable IOL will probably center well within the ciliary sulcus. At 12.0 mm or larger, I would select the 13.5-mm Staar AQ2010 foldable IOL if capsulorrhexis optic capture were not an option, for the reasons discussed below.

**IOL Selection for Ciliary Sulcus Placement Without Optic Capture**

There are situations in which both the anterior and posterior capsules are torn, but sufficient capsular support remains to support a posterior chamber IOL in the ciliary sulcus. A wrap-around anterior capsular tear that extends into the posterior capsule is an example. Single-piece acrylic IOLs should never be placed into the ciliary sulcus. The overall length of this IOL is too short for sulcus placement, and the thicker, sharp-edged haptics can cause posterior iris chafing, pigment dispersion, and iris transillumination defects. Chronic uveitis, pigmentary glaucoma, microhyphema (UGH) syndrome and cystoid macular edema may result until the offending IOL is removed. In the largest published retrospective study of complications of single-piece acrylic IOLs in the ciliary sulcus, the most common complication was lens decentration, which frequently resulted in symptomatic edge glare.

In contrast, 3-piece posterior chamber IOLs have the advantage of thin, posteriorly angulated C-shaped haptics. Ideally, the anterior optic surface should be smooth and have rounded edges to prevent iris chafing should any posterior iris contact occur. In the absence of suturing or capsulorrhexis capture, proper IOL centration requires adequate capsular support and lateral stability within the ciliary sulcus, and IOLs shorter than 13.0 mm should not be used. Polymethyl methacrylate (PMMA) posterior chamber IOLs with 6.5-mm optics and a 14-mm overall length fulfill these criteria but require a much larger incision.

Among foldable IOLs currently available in the United States, only the Staar Surgical silicone AQ2010V has a 13.5-mm long haptic-haptic length in the 5-30 D power range. Its rounded anterior edge, 10-degree haptic angulation, and slightly larger 6.3-mm optic diameter are additional advantages of this platform. This lens also has a very low amount of spherical aberration (SA), which is also desirable for a sulcus IOL. Surgical facilities can purchase a backup consignment of these IOLs from Staar for a reasonable cost. One potential disadvantage of silicone IOLs, however, is the compromise in surgical visibility should silicone oil or expansile gas ever be required for vitreoretinal surgery.

Among foldable 3-piece hydrophobic acrylic IOLs, the Alcon MA50 model has a 6.5-mm diameter optic but has a square anterior optic edge and an overall haptic length of only 13.0 mm. This IOL has been associated with pigment dispersion following piggyback implantation in the sulcus, and the sharp anterior edge of this optic is therefore undesirable in this location. The AMO Sensar has a rounded anterior optic edge and would be a preferable 3-piece hydrophobic acrylic IOL for sulcus placement.

Negatively aspheric IOLs have become popular as a means of reducing overall ocular SA and improving contrast sensitivity. However, because these IOLs have higher amounts of negative SA (to offset the positive SA from the cornea), they will actually induce more unwanted higher-order aberrations (HOA) if they become tilted or decentered by more than 0.5 mm. For this reason, based on the potential induction of SA and other HOA, it is inadvisable to implant a negatively aspheric IOL in the sulcus if centration within a 0.5-0.8 mm cannot be achieved.

A torn posterior capsule should preclude implantation of an accommodating IOL and may not permit proper alignment of a toric IOL. However, placement of a 3-piece multifocal IOL in the sulcus may be an option, particularly if proper centration can be achieved with capsulorrhexis capture of the optic. However, multifocal IOLs are much less forgiving of any tilt and decentration, and sulcus placement therefore carries a greater risk of refractive power surprise, unwanted images, and HOA.

**References**


It Takes Two to Tango: Pre-Descemet Endothelial Keratoplasty With Glued IOL

Amar Agarwal MD

Pre-Descemet endothelial keratoplasty (PDEK)\(^1\) is the latest iteration in the congregation of various procedures for endothelial keratoplasty that evolved following a detailed description of the pre-Descemet layer (PDL; Dua layer) by Harinder Dua.\(^2\) This technique allows the separation and usage of the PDL, which is an additional 10-micron layer to the conventional Descemet membrane (DM)-endothelium graft.\(^2\) The key to the success of donor graft creation lies in the formation of a Type 1 bubble, which is a central, well-circumscribed, dome-shaped bubble and typically spreads from center to periphery in the donor lenticule.\(^2\) The glued IOL\(^3\) is a well-established form of intraocular haptic fixation for secondary IOL procedures. The combination of PDEK with glued IOL serves the purpose of handling corneal endothelial dysfunction and secondary IOL fixation simultaneously.

Amalgamating the benefits of both these advancements can reap a lot of benefit for the current select scenario of patients. Post-traumatic cases with corneal opacities and lenticular disruption / dislocation present an ideal scenario to take precedence for glued IOL with corneal surgical intervention. Complicated cataract surgeries associated with posterior capsule rupture often lead to corneal decompensation. Corneal edema and decompensation result from failure of the corneal endothelium to maintain deturgescence.

Corneal decompensation beginning many years after IOL implantation may be due to excessive loss of endothelium at the time of surgery, followed by ongoing normal or accelerated attrition of the remaining endothelium. With the recent explosion of keratoplasty techniques for the treatment of corneal diseases, determining when to perform corrective surgery for IOL implantation in the setting of corneal disease is crucial for appropriate surgical planning. Glued IOL has been used previously in multiple situations, including surgical aphakia, traumatic phacocele, dislocated IOL in bag, and in combination with femtosecond-assisted keratoplasty.

Cases with decompensated corneas due to endothelial disorders requiring secondary IOL implantation or an IOL exchange are potential candidates for undergoing PDEK with glued IOL surgery. The main advantage of combining PDEK and glued IOL surgery is that patients undergo a single surgery, attend fewer appointments, and deal with a specific set of postoperative medications. Alternatively, both surgeries can be performed sequentially, wherein glued IOL is performed as an initial procedure followed by PDEK in a second stage.

Pupilloplasty

Pupil disfigurement is often encountered in patients requiring these procedures, and pupil reconstruction forms an important element to avoid the chances of air diversion into the vitreous following the surgery as this might enhance the chances of graft dislocation postoperatively. Pupilloplasty is thereby performed along with PDEK and glued IOL procedure in cases with pupil disfigurement.

Surgical Technique

The initial step (see Figures 1-3) involves successful harvesting of the donor lenticule, followed by the glued IOL procedure (minus the application of glue to seal the scleral flaps), followed by recipient bed preparation and donor lenticule insertion. Application of fibrin glue to seal the scleral flaps then ensues so as to ensure that it is not washed off by the fluids emanating and egressing from the eye.

Step 1: Donor graft preparation

The detailed method of donor graft preparation has been previously described.\(^1\) To mention in brief, an air-filled 5-ml syringe with an attached 30-gauge needle is introduced from the corneoscleral disc with bevel up to the center of the donor lenticule with the endothelial side up. As air is injected, a Type 1 bubble is formed with a distinct edge all around. A trephine of suitable diameter is used to create a mark on the endothelium. The edge of the bubble at extreme periphery is perforated followed by injection of trypan blue into the bubble to stain the graft, which is then cut all around the trephine mark with corneoscleral scissors. The graft is then stored in the storage media.

Step 2

Glued IOL technique consists of making 2 partial scleral thickness flaps approximately 2.5 by 2.5 mm in size and 180 degrees opposite to each other. The epithelium of the recipient eye is often debrided due to epithelium decompensation, which hinders the intraoperative view to a great extent. An anterior chamber (AC) maintainer is introduced in the lower quadrant and a sclerotommy wound is created with a 20-gauge needle approximately 1 mm away from limbus beneath the scleral flaps, and the entire glued IOL surgery is performed till the tucking of the haptics in the scleral pockets.\(^3\) An AC maintainer helps to maintain the AC throughout the surgery, and the use of viscoelastic is deterred as it is important not to leave residual viscoelastic in the AC as it is thought to potentially hamper good adhesion between the donor corneal disc and the recipient corneal stroma.

Step 3

The recipient cornea is marked with a trephine so as to outline the area of DM to be excised. A reverse Sinskey hook is introduced in to the AC and descematorrhexis is performed corresponding to the margins of the epithelial mark. The DM is then stripped off and is removed from the AC. The donor pre-Descemet roll is loaded on to the cartridge of a foldable IOL injector and the spring of the injector is removed (as originally improvised by Francis Price) so as to prevent any damage to the donor graft. The donor roll is injected into the AC and the graft is slowly unfolded with air and fluidics, avoiding any direct contact with the graft so as to minimize the trauma. The PDEK graft rolls like a DMEK graft with the endothelium on the outer side, although due to the splinting effect of PDL the rolling of tissue graft is comparatively less. After proper orientation of the graft, air is injected beneath it to facilitate proper adhesion to the posterior corneal stroma. About 30 minutes is allowed to elapse to
Figure 1. A: Pseudophakic bullous keratopathy. B: Type 1 bubble formed in the donor cornea. C: Two partial thickness scleral flaps are fashioned 180 degrees opposite to each other. Anterior chamber maintainer is introduced in the eye. D: Haptics of the IOL being externalized. E: Pupilloplasty being done. F: Well-shaped pupil formed.

Figure 2. A: Epithelium debrided and the endothelium is scored. B: Graft is loaded on to the cartridge of a foldable IOL injector. C: Graft seen in anterior chamber. D: Unrolling of the graft done with fluidics and air. E: Air injected beneath the graft for proper apposition. F: Stable IOL with well-formed anterior chamber and good graft apposition seen 1 month postoperatively.
facilitate initial donor recipient-corneal disc adherence. Postoperatively, the patient is asked to lay flat in the recovery room for about an hour and also to lay flat for the most part during the first postoperative day.

**Refractive Concern**

Performing IOL implantation before a corneal procedure involves lot of refractive instability and unpredictable keratometry values; therefore, predicting the lens implant power before a corneal procedure can present challenges. Studies of lens power calculations associated with keratoplasty have shown that an effective way of reducing postoperative ametropia is to perform keratoplasty first, followed by lens extraction and IOL implantation at a later date. Flowers et al reported 95% of patients within ± 2.00 D of intended postoperative target refraction following PKP and cataract extraction with IOL placement performed secondarily.

**References**


Figure 3. A: Preoperative photograph. B: Postoperative photograph at 3 months. C: Anterior segment OCT demonstrating 28 microns graft thickness.
Posterior Capsular Rupture

Robert H Osher MD
Reusable Dislocated IOLs

Stratos Gotzaridis MD

Intraocular lenses can be dislocated either due to complications during phaco surgery or due to weakness of the zonules. Replacement with a new IOL is a traumatic procedure.

Using the same IOL and stabilizing its haptics into the sclera is a less traumatic procedure, with no corneal incisions and no damage to corneal endothelium.

An improvement to the existing technique of the scleral fixation of the 3-piece IOL is the scleral fixation of the haptics of the 1-piece IOL.

The videos show the above two techniques.
Laser Surgery Is More Efficient: Pro
Burkhard Dick MD

It was one of the most memorable moments in the history of presidential elections when the candidate during the TV debate looked the audience straight in the eye and, while the incumbent cringed, asked the people head-on: “Are you better off than you were four years ago?”

Ask yourself, my fellow colleagues: Is cataract surgery better off than it was four or five years ago?

What has happened in the meantime is the introduction of the femtosecond laser into the procedure that is the most frequent surgical intervention in industrialized nations. There are many aspects of this technology that can rightfully be called revolutionary. There is no tearing any more when capsulorrhesis is performed, not even conventional cutting but rather a separation by photodisruption. With its imaging systems—like, for instance, the 3-dimensional spectral domain OCT that our platform uses—the surgeon can check intraocular structures and tissues as never before. Femtosecond laser-assisted cataract surgery (LCS) has the potential to be more reproducible, to be (much) more precise, and to be—most importantly—safer for our patients.

More Circular, More Precise: Anterior Capsulotomy

The routinely used capsulorrhesis is manually demanding and cannot guarantee the exact size of an anterior capsule opening. Image-guided femtosecond lasers can perform an anterior capsulotomy with reproducible size and circularity. Several clinical studies have demonstrated that capsulotomies created with the femtosecond laser are significantly more precise in size and reproducibility and that a continuous curvilinear capsulorrhesis (CCC) created with a femtosecond laser results in a more stable refractive result, with less IOL tilt and decentration than a manual CCC.1 Femtosecond lasers made it technically possible to cut an anterior capsulotomy with preset size, circularity, and sufficient strength. We can now implant IOLs that are perfectly in the line of sight and have a good and intraoperatively fixed position and centration, which is essential for toric, multifocal, and aspheric IOLs. We have, for instance, implanted a new C-loop IOL. In these cases, the anterior capsule is placed in the lens at the 6-o’clock position and followed by placements at the 9-, 12-, and 3-o’clock positions. All capsulotomy edges remained within the IOL optic rim. No patients reported glare sensitivity or light sensations. An earlier and more predictable refractive outcome, stable sufficient IOL centration, and less IOL rotation seem possible with the described fixation.2

Less and Less Ultrasound Power:
Lens Fragmentation

Phacoemulsification has been the mainstay of cataract surgery for more than a quarter of a century. But applying ultrasound (US) energy within the confines of the eye is not without risk. US energy can harm intraocular structures, most of all the corneal endothelium. Endothelial cell loss, sometimes excessive loss, has been reported after phacoemulsification in healthy eyes with no previous risk factors.3 US energy has also been implicated in the pathogenesis of cystoid macular edema. Since the introduction of phacoemulsification, surgeons have been looking for a way to prevent these hazards of US energy.

The solution has arrived: it is fragmenting the lens with the femtosecond laser. After LCS was introduced in our clinic, some phacoemulsification was needed by 59% of patients 200 to 400, by 38% of patients 700 to 900, and by 9% of patients 1200 to 1400.4 Among our most recent procedures, a mere 3% required any US energy at all. The protective effect on the endothelium was profound both 1 week and 3 months postoperatively. When 73 patients had one eye operated upon with the femtosecond laser lens fragmentation and the other eye with conventional phacoemulsification, the average endothelial cell loss after 1 week was less in the LCS compared to the conventional group. Average endothelial loss after 3 months was 8.1% in the LCS group.5

And Something Else That Can Be Reduced: OVD

Just like phacoemulsification, ophthalmic viscosurgical devices (OVD) in cataract surgery have advantages and some disadvantages. At the end of surgery, the complete removal of these substances can be manually demanding and residual OVDs might cause an increase in IOP. OVD-induced IOP increases often require antiglaucomatous therapy, and it has not been unusual that new OVDs were recommended based on their ability to raise the IOP only modestly.6 We used an OVD-free technique in 23 cases, in which the dimple-down technique was performed to confirm the free-floating capsulotomy and a gentle hydrodissection was performed if necessary. The anterior chamber was stabilized using the irrigation handpiece. No intra- or postoperative complications were observed. The IOP before surgery was 15.9 ± 4.2 mmHg (range: 7 to 23 mmHg), 12.8 ± 4.3 mm Hg (range: 6 to 20 mmHg) 4 days after surgery, and 12.0 ± 2.3 mm Hg (range: 8 to 15 mmHg) 1 week after surgery. Corneal thickness was 558 ± 33 μm (range: 502 to 621 μm) preoperatively and 598 ± 43 μm (range: 523 to 666 μm) 3 days after surgery. Mean central corneal thickness was 588 ± 40 μm (range: 503 to 647 μm) 1 week after surgery. OVD-free LCS has the potential to achieve comparable or even better clinical results achieved with standard cataract surgery using OVDs and US phacoemulsification.7

Save Time, and in the End Maybe Even Money

Cataract surgery today is almost always refractive surgery. The refinement and precision of the femtosecond laser will bear fruit not only in terms of patients with premium IOL who are extremely satisfied with their visual results immediately after the operation but also in the reduction of subsequent interventions—interventions no longer necessary because there is less tilt, less decentration, less endothelial loss, and (most importantly since this is the most common complication after cataract surgery) less posterior capsule opacification thanks to new techniques with the femtosecond laser.8

In experienced hands, in an adequate setting (yes, we strongly favor the laser platform and the operating table in the same sterile room), and with a well-trained team, current LCS is as time-
effective as the operations we have been performing over the last 10 years. There might be arguments against the femtosecond laser in cataract surgery, but it is hard to see a serious one arising from the realm of medicine, from surgeons who strive to provide their patients with the safest and most effective procedure. Instead we expect to face predominantly financial concerns. Yes, the femtosecond laser costs money, but so do intravitreal injections and so do drugs in many fields like oncology and immunology.

We’ve heard it all before. Or, as the (in the end victorious) candidate in that famed presidential debate remarked with a shrug and a smile. “There you go again!”

References


Laser Surgery Is More Efficient: Con

*Michael E Snyder MD*

**What Is Efficiency?**
- Time efficient?
- Cost efficient?
- Lines of visual improvement per unit time?
- Lines of visual improvement per dollar spent?

**Time**
How does the femtosecond laser impact surgery speed?
- How long does it take to create the wounds manually? With laser?
- How long does it take to do the capsulorrhexis manually? With laser?
- How long does phaco and I/A take with versus without nuclear pretreatment?

How long does it take the surgeon to:
- Call the time-out in the laser suite?
- Dock the laser?
- Get to and from the laser suite?

**Money**
Does femto have extra cost? You bet!
- Cost to patient
- Cost to doc
- Cost to facility

**Visual Results**
No relative difference in outcomes or lines of vision between femto and manual phaco

**Selected Readings**
Laser Surgery Is Safer: Pro

Kevin M Miller MD

I. Femtosecond laser-assisted cataract surgery (FLACS) turns mediocre surgeons into good surgeons.
   A. It takes several critical steps out of their hands.
   B. They only have to position the patient, align with the eye, and dock.
   C. How would you like the incisions, capsulorrhexis, and lens fragmentation to be done on your cataract surgery?
      1. By one of your colleagues or trainees
      2. By a femtosecond laser
   D. FLACS produces consistent and reproducible results.
   E. Best practices of leading surgeons can easily be shared.

II. The relaxing incisions are more predictable.
   A. There is a consistent optical zone.
   B. There is consistent arc length.
   C. There is consistent depth with less chance of inadvertent perforation.

III. Cataract incision architecture is more precise.
   A. External incisions are still problematic in areas of pannus, arcus, and haze.
   B. Internal incisions are much more precise.
      1. Internal wound architecture is much better on OCT.
      2. This reduces the likelihood of wound leakage during surgery.
      3. It improves chamber stability.
   C. No significant corneal higher order aberrations (HOAs) are induced.

IV. The capsulorrhexis is rounder and more predictable.
   A. This reduces the likelihood of tear-out or radialization in a beginner’s hands.
      1. Incomplete capsulorrhexis increases the likelihood of:
         a. Posterior capsule rupture
         b. Vitreous loss
      2. A capsulorrhexis that is too small increases the likelihood of:
         a. Difficulty removing subincisional cortex
         b. Nighttime glare from anterior capsule opacification (ACO)
   B. More consistent optic overlap
      1. Reduces the incidence of posterior capsule opacification
      2. Reduces the odds of IOL decentration
   C. The capsulorrhexis is stronger when created by a femtosecond laser.
   D. Femtosecond lasers will ultimately enable the design of newer lenses that take advantage of a consistent capsulorrhexis diameter.
   E. It will enable the successful completion of a capsulorrhexis in difficult cases, including:
      1. Mature white cataracts
      2. Dense brunescent cataracts
      3. Eyes with decentered cataracts because of weak or broken zonules
      4. Infants and children
   F. A femtosecond laser capsulorrhexis does not require the use of ophthalmic viscosurgical devices (OVDs) or capsule stains.
   G. It can be fashioned in small pupil cases after the insertion of a pupil expansion device.

V. The lens nucleus is prefragmented and softened before the application of ultrasound energy.
   A. This reduces the phacoemulsification time needed to remove the nucleus.
   B. It results in reduced cumulative dissipated energy (CDE) or effective phaco time (EPT) and produces:
      1. Less corneal swelling
      2. Similar or reduced endothelial cell trauma and loss as compared to standard phaco
      3. Similar or less postoperative anterior segment inflammation
      4. Quicker visual recoveries
      5. Less zonular stress
      6. Less need for dispersive OVD, which is harder to remove than cohesive OVD
      7. Reduced intraoperative surgical time
      8. No evidence of increased macular edema

VI. The safety of FLACS is gradually increasing.
   A. The IOP rises are far lower.
   B. Patient interface devices are gentler on the external ocular surface.
C. Many steps have been automated, including:
   1. Detection of the limbus
   2. Placement of the incisions
   3. Placement of the capsulorrhexis
D. Trapped gas within the capsular bag is no longer a problem.17
E. Cortex removal is no longer a problem.18
F. Inadvertent grid pattern treatment of the cornea during suction breaks does not affect acuity.19
H. Docking time is being reduced.
I. Improved imaging is making detection of the posterior capsule better.
J. There are far fewer cases of posterior capsule rupture and dropped nucleus today.
K. Results continue to improve with surgeon experience.20
VII. We are just at the beginning of this technology.
   A. It is similar to the early days of phacoemulsification.
   B. It will only get better.

References
Laser Surgery Is Safer: Con

Shahzad I Mian MD

I. Laser Refractive Lens Surgery
   A. Cataract surgery with IOL: most common ophthalmic surgery worldwide
      1. 19 million/year
      2. 3 million/year in United States
   B. Phacoemulsification: > 90% of procedures

II. History
   A. 2001: Femtosecond for refractive surgery

III. Steps in Cataract Surgery
   A. Capsulotomy
   B. Lens fragmentation
   C. Wound construction

IV. Four Femtosecond Laser Systems Available
   A. LenSx (Alcon LenSx; Fort Worth, Texas, USA)
   B. Catalysis (Optimedica Catalysis; Santa Clara, Calif., USA)
   C. Victus (Technolas Perfect Vision and Bausch + Lomb; Rochester, NY, USA)
   D. LensAR (LensAR, Inc.; Orlando, Fla., USA)

V. Selection of Patients
   A. Pupil not dilate to 5 mm
   B. Corneal opacity
   C. Advanced glaucoma
   D. Functioning bleb, tube, or valve
   E. Uncooperative or overly anxious patients
   F. Small interpalpebral fissures / deep-set orbits
   G. Excessive blepharospasm
   H. Conjunctivochalasis
   I. Severe neck and back problems

VI. Surgeon
   A. Learning curve
   B. Dock the eye to the laser
   C. Interpret the anatomical image
   D. Adjust the laser parameters
   E. Deliver energy safely

VII. Intraoperative Complications
   A. Suction loss
   B. Conjunctival redness or hemorrhage
   C. Incomplete capsulotomy
   D. Imprecise corneal incisions
   E. Damage to the iris
   F. Posterior capsule rupture
   G. System/computer failure

VIII. Literature Review
   A. No significant differences for corrected distance visual acuity outcomes and effective phacoemulsification time
   B. Femtosecond laser is associated with an increase in IOP.
   C. No evidence on measures of safety and effectiveness
   D. Adverse event risks were similar.
   E. No studies reporting quality-of-life outcomes
   F. No cost-effectiveness

IX. Considerations
   A. Little is known regarding the medium- and long-term outcomes.
   B. Skilled surgeons to deal with any complications that may arise
   C. Large, randomized, controlled trials are required.
Laser Surgery Yields Better Visual Outcomes: Pro

Zoltan Nagy MD
Laser Surgery Yields Better Visual Outcomes: Con

Bonnie A Henderson MD

I. Background
A. Cataract surgery technology continues to evolve.
   1. Intracapsular to extracapsular cataract surgery
   2. Extracapsular to phacoemulsification
   3. Phacoemulsification to femtosecond laser-assisted surgery
      a. Current femtosecond laser platforms for cataract surgery
      b. Surgical steps in which femtosecond lasers are used

II. Advantages
A. Precision for corneal incisions for astigmatism
B. Continuous circular capsule opening
C. Lens softening/fragmentation
D. Centration and stabilization of IOL
E. Enhanced safety
F. Improved reproducibility of outcomes

III. Disadvantages
A. Cost
B. Inefficiency/flow
C. Learning curve
D. Additional time for surgery
E. Subconjunctival hemorrhages
F. Increase risk of anterior capsular tears
G. Insufficient studies to prove improved outcomes

IV. Peer-Reviewed Studies on Visual Outcomes

References
Section V: Interactive Consultations: Lens Refractive Surgery
Optical Problem of Multifocal Corneas

Pablo Artal MD PhD

Introduction

One of the current frontiers in LASIK applications is the ability to induce extended depth of focus or multifocality to correct for presbyopia. This approach has some physical limitations that clearly affect the quality of vision after surgery. There is a compromise among the degree of near vision achieved and the reduction of contrast for distance objects.

Different ablation profiles have been tested in the past: inferior off-center ablations, a peripheral near zone (concentric ring for near vision), or a central near zone. But many recent LASIK techniques are based on corneal asphericity and the related induction of spherical aberration to increase the depth of field. These techniques present an unsatisfactory predictability concerning the induced depth of field and consequently affect patient satisfaction.

Bilateral interventions are common, and they are useful for patients, combining different types of profiles in each eye. In any case, due to the delicate balance between quality of vision and the induced optical profiles, it would be very advisable to test them in advance, and noninvasively.

Adaptive Optics Instruments for Visual Testing

After many years of continuous development, adaptive optics (AO) is now a mature technology, aiming to obtain better images by correcting optical aberrations. Perhaps the most popular AO application is in astronomical telescopes, to remove the image degradation induced by atmospheric turbulence. The optical problems involved in the human eye are similar to those in the astronomical case, although with different spatial and temporal scales.

If the aberrations of the eye are known, it is possible to correct them using a wavefront correcting device that compensates for the eye’s aberrations. In the ideal case, the system of “corrector + eye” becomes aberration-free, producing perfect (diffraction-limited) retinal images. The main application in the early days of AO for the eye was to improve the resolution and quality of retinal fundus images recorded through the corrected eye optics in ophthalmoscopes. However, once AO instruments were operative for the eye, we soon realized that not only could ocular aberrations be corrected, but that any desired aberration pattern could also be added to the eye in a controlled manner. By using an additional optical path, visual stimuli were projected to the eye’s subject to perform visual testing for a variety of optical conditions.

This is the basis of the concept of the AO vision analyzer. This instrument consists of a wavefront sensor to measure the eye’s aberrations and a correcting device to modify the eye’s optics. A Hartmann-Shack wavefront sensor (HSS) measures the eye’s aberrations and residual defocus. The correcting / manipulating device is placed in the system conjugated both with the subject’s pupil plane and the wavefront sensor, by using appropriate sets of lenses in a telescope configuration. Subjects view a stimulus (letters or any visual scene) produced either by a pico-projector or an OLED microdisplay. Figure 1 presents a schematic diagram of a typical AO instrument.

As an example of application, Figure 2 shows the visual acuity as a function of the object vergence measured in a patient after induction of negative spherical aberration. Due to the extended depth of focus, visual acuity is nearly independent of object position, although the value for distance is compromised. The adequate magnitude of the required spherical aberration could be optimized for the specific requirements of each patient.

The potential for applications of this type of AO instrument in refractive surgery is enormous, in presbyLASIK in particular. This approach would allow for optimizing the optical correction for different visual tasks and conditions—for example, by inducing asphericity to provide extra depth of focus in presbyopic eyes. In this type of invasive procedure, before a definitive ablation of the cornea is performed, the optical profile to be induced could be optimized for each patient. This will open the door to an era of truly customized eye treatments.
Evolution of Bi-aspheric Presbyopic Correction
Over 2K Treatments
To Report the Evolution of a Bi-aspheric Presbyopic Correction Through 4 Years and 2000 Treatments

Pierre Baudu MD, Franck Penin, Samuel Arba Mosquera

Introduction

There has recently been a tremendous increase in interest in surgical presbyopic correction. The effective treatment of presbyopia combined with any refractive error has proven to be a significant challenge for refractive surgeons. Refractive corrections for presbyopia by means of excimer laser systems are as old as laser refractive surgery itself. Moreira et al in 1993 said, “After multifocal ablations, a greater spread of surface powers is observed, often with a bimodal distribution, indicative of an apparent multifocal effect. These observations suggest that in some patients undergoing photorefractive keratectomy for myopia, it may be possible to reduce symptoms of presbyopia.”

The term “presbyLASIK” indicates a corneal surgical procedure based on traditional LASIK to create a multifocal surface able to correct any visual defect for distance while simultaneously reducing the near spectacle dependency in presbyopic patients. Little literature is found concerning monocular distance-corrected performance after presbyLASIK (ie, best achievable distance vision combined with the pseudoaccommodation contribution for near).

In a previous report it was stated, “PresbyLASIK is certainly a promising technology, but it has not yet reached the level of maturity of monovision. In our opinion, a combination of micro–monovision and presbyLASIK (ie, both eyes multifocally corrected but with a focus shift between eyes, with distance eye closer to emmetropia and near eye more in myopia) will help provide better intermediate vision and stereoacuity expected from multifocal ablations together with the lower compromise in UDVA of the monovision and blended vision approaches.”

In another report it was found that there were statistically significant differences between myopia and hyperopia for postoperative SE (−0.19 D more residual myopia for preoperative myopes), binocular UNVA and DCNVA (both 0.2 lines better for preoperative myopes), and change in CDVA (1 letter better for preoperative myopes).

History of Development: Multifocal Ablations

Vinciguerra et al proposed a 10- to 17-micron deep semilunar-shaped zone immediately below the pupillary center, steepening the corneal curvature in that area, and reported promising results with this technique. Attempts for pseudo-accommodative cornea opened new concepts for correction of presbyopia, realized basically in the form of a peripheral near zone (concentric ring for near vision) or in the form of a central near zone (central disc for near vision).

Charman concluded that the main requirement in presbyopia is extended binocular depth of focus to yield adequate distance and near vision with good retinal contrast at lower spatial frequencies, rather than the highest levels of acuity and modulation transfer function at a single distance. He further suggested that, for many presbyopes, this can be achieved by aiming for residual high-order aberrations.

Artola et al found evidence for delayed presbyopia after photorefractive keratectomy for myopia due to the induced corneal aberrations, which may reduce the quality of the retinal image for distance but enhance near acuity by way of a multifocal effect that can delay the onset of age-related near vision symptoms. Dai was one of the first to propose the use of rigorous methodologies to theoretically optimize vision over the entire target range from near to distance.

Ortiz characterized the optical quality by the Strehl ratio, the spot size on the retina, and objective decimal visual acuity calculated based on measured corneal topography using Fresnel propagation algorithm based on a realistic eye model. They found that with a complete characterization of the eye and a complete propagation algorithm (that takes into account all refractive surfaces in the eye at the same time), it is possible to evaluate the optical quality in eyes of patients who have undergone central presbyLASIK treatment.

Reinstein et al successfully combined extended depth of focus with monovision in a micro-monovision protocol, whereas Epstein and Gurgos combined monocular peripheral presbyLASIK on the nondominant eye with monofocal distance correction on the dominant eye.

Results: PresbyMAX

Uthoff et al investigated the outcomes of simultaneous correction of presbyopia and ametropia by a biasepheric cornea modulation technique, based on the creation of a central area hyperpositive for near vision and leaving the pericentral cornea for far vision in 60 eyes of 30 patients treated with the PresbyMAX technique. The mean binocular distance of uncorrected visual acuity (DUCVA) improved in the hyperopic group from 0.28 ± 0.29 logMAR to −0.04 ± 0.07 logMAR, in the emmetropic group from 0.05 ± 0.07 logMAR to 0.02 ± 0.11 logMAR, and in the myopic group from 0.78 ± 0.27 logMAR to 0.09 ± 0.08 logMAR. The mean binocular near uncorrected visual acuity (NUCVA) increased in the hyperopic group from 0.86 ± 0.62 logRAD to 0.24 ± 0.23 logRAD, and in the emmetropic group from 0.48 ± 0.14 logRAD to 0.18 ± 0.11 logRAD. The myopic presbyopes showed a decrease of the mean binocular NUCVA from 0.04 ± 0.19 logRAD to 0.12 ± 0.18 logRAD. The mean postoperative spherical equivalent for distance refraction was −0.13 ± 0.61 D for the hyperopic presbyopia, −0.43 ± 0.35 D for the emmetropic presbyopia, and −0.68 ± 0.42 D for the myopic presbyopia group, whereas the software took aim at −0.50 D in all groups.
Discussion

The performance of different types of IOLs (refractive, diffractive, pseudoaccommodating, and multifocal) is constantly being improved, but the IOLs cause a decrease in near vision contrast sensitivity. Controversial viewpoints exist regarding where to center corneal refractive procedures to maximize the visual outcomes. A misplaced refractive ablation might result in undercorrection and other undesirable side effects. The coaxial light reflex seems to lie nearer to the corneal intercept of the visual axis than the pupil center (PC), and it is thus recommended that the corneal coaxial light reflex be centered during refractive surgery. Boxer Wachler et al identified the coaxial light reflex and used it as the center of the ablation. De Ortueta and Arba Mosquera used the corneal vertex (CV) measured by videokeratoscopy as the morphologic reference to center corneal refractive procedures.

The center of the pupil, assuming that the patient fixates properly, is the locus where the line of sight passes through, which is the reference axis recommended by the OSA for representing the wavefront aberration. Nevertheless, because the pupil center is unstable, a morphologic reference is more advisable. It is well known that the pupil center shifts with changes in the pupil size, moreover, because of the entrance pupil we see is a virtual image of the real one.

Due to the smaller angle kappa associated with myopes compared to hyperopes, centration issues are less apparent.

Literature suggests that marked anisometropia is uncommon, either in the magnitude of sphere or astigmatism, with few notable exceptions, concluding that the axis of astigmatism does not follow any particular rule (mirror or direct symmetry) across right and left eyes.

The development of specific patient reported outcome metrics has also advanced in the recent times. Buckhurst et al and Lévy et al developed well-designed questionnaires for the assessment of visual quality after presbyopic corrections. Oh et al preserved the central cornea (CST group) by amniotic membrane patching to protect the center of the cornea and encourage early wound healing in 22 eyes of 11 patients with emmetropia who were treated with the presbyopic excimer laser. The corneal wound healing time of the CST group was faster than that of the non-central preserved cornea NCST group. The time it took to achieve effective near and distance visual acuities were 1.2 ± 0.4 days and 2.3 ± 1.5 days in the CST group, whereas the same took 2.3 ± 1.2 days and 5.2 ± 2.1 days each for the NCST group. Statistically significant differences in both distance and near visual acuity were observed between the CST and NCST groups 2 years after the operation. The mean refractive error showed less regression in the CST group than in the NCST group within this same time period.

PresbyLASIK treatment constitutes a new modality in the correction of presbyopia after monovision LASIK. In several reports, Alió et al demonstrated the efficiency, predictability, stability, safety, and visual quality of central presbyLASIK in presbyopic patients with hyperopia. Controversial viewpoints exist regarding the reversibility of presbyLASIK procedures. This has been discussed by Luger et al. Baudu et al reported good results in retreatments, including reversals after presbyLASIK, whereas Luger et al demonstrated the use of a non-wavefront guided Presby-reversal treatment targeting a monofocal cornea after biaspheric ablation profile in a patient intolerant to multifocality.

Currently, several methods are combined together to benefit from their advantages and reduce the impact of their disadvantages. In a sense we can say that all corneal presbyopic correction methods have evolved to hybrid techniques combining their original approach in different powers for either eye, or combining their original approach with certain amount of monovision. These hybrid modifications include conductive keratoplasty (full correction in the distance eye combined with CK multifocality and monovision in the near eye), Supracor and PresbyMAX (reduced multifocality in the distance eye combined with full multifocality and monovision in the near eye), Intracor (full correction in the distance eye combined with Intracor multifocality and monovision in the near eye), Kamra (full correction in the distance eye combined with pinhole-based extended depth of focus and monovision in the near eye), as well as laser blended vision (moderate multifocality in both eyes combined with monovision in the near eye). A converging trend toward hybrid techniques is observed all across the corneal presbyopic correction spectrum.

References


Bilateral Hyperopic and Presbyopic LASIK

Andrea Ryan MBBS MRCS, Sarah Moran MRCOphth, Michael O’Keefe FRCOphth

The optimal correction of presbyopia remains elusive despite the existence of a variety of presbyopic corneal excimer laser, inlay, and IOL techniques. In this presentation, I will discuss a bilateral multifocal corneal excimer LASIK procedure for the simultaneous correction of hyperopia and presbyopia—Supracor™—developed by Technolas Perfect Vision GmbH and CE marked (Conformité Européenne) for use in Europe but not FDA approved in the United States.

Indications for Supracor Treatment

1. Age ≥ 47 years
2. Manifest refraction spherical equivalent (MRSE) +0.75 to +3.0 D
3. Astigmatism ≤ 2 D
4. Maximum 0.75 D and 0.50 D difference between cycloplegic and manifest refraction for sphere and cylinder
5. Mean keratometry reading 41-45 D
6. Angle kappa < 10 degrees
7. Able to tolerate a near addition of +1.75 D
8. Corrected distance visual acuity (CDVA) in both eyes ≥ 20/25 Snellen
9. Absence of usual LASIK restrictions
   – Minimum CCT (central corneal thickness) > 500 µm
   – No evidence of keratoconus on corneal topography
   – Absence of significant dry eyes / ocular surface disease

The Supracor Procedure

The procedure is designed for use with the Technolas 217P excimer workstation (Technolas Perfect Vision GmbH). Following creation of a standard LASIK flap of ≥ 9 mm diameter and 110-120 µm thickness, the stromal bed is ablated in a unique profile in a 6-mm optical zone centered on the pupil center. The near addition is created by 2000 pulses fired to create a central “bump” on the cornea. The target spherical equivalent refraction is −0.50 D in both eyes. The procedure is “aberration optimized” and causes a shift in spherical aberration in a negative direction to enhance depth of focus. Standard post-LASIK care is given postoperatively.

Clinical Results

We have previously published the results of our initial series of 43 eyes of 23 patients treated with Supracor at 6 months postoperatively.1 Our main findings were as follows:

1. Mean binocular uncorrected distance visual acuity (UDVA) 0.07 ± 0.12 logMAR
2. Binocular Snellen UDVA ≥ 20/20 in 48%, ≥ 20/32 in 91%
3. Mean MRSE −0.69 ± 0.71 D
4. Binocular uncorrected near vision N8 or better on Vocational Reading test in 91%
5. Reading ability is heavily dependent on incident light.
6. 22% retreatment rate to enhance UDVA – performed after 6 months
7. 7.4% loss of 2 or more lines of binocular CDVA, 100% maintained CDVA of 20/32 or better

We concluded that satisfactory spectacle independence for near and distance vision was achievable with the procedure, but there was a high retreatment rate to improve UDVA and the near vision is very dependent on good incident light. We proposed that nomogram adjustment and adopting an asymmetrical approach of targeting emmetropia in the dominant eye and −0.50 D in the nondominant eye may address some of the shortcomings of the treatment.

Subsequent to this initial patient series, we have an ongoing study evaluating near, intermediate, and distance vision in a new group of patients treated by Supracor, adopting a new nomogram and the asymmetrical approach. Two further nomogram adjustments have been necessary during the course of the study. To date, 56 eyes have been treated. Six eyes have been retreated and not included in this interim analysis. Visual acuity was measured with the Optec Vision tester 6500 (Stereo Optical).

Interim results at 3 months for 50 eyes are as follows:

1. Mean binocular UDVA 0.00 ± 0.09 logMAR
2. Binocular UDVA 20/20 or better in 60%, 20/32 or better in 95%
3. Mean MRSE -0.13 ± 0.85 D
4. Mean uncorrected near visual acuity 0.21 ± 0.2 logMAR
5. Binocular uncorrected near visual acuity 20/20 or better in 30%, 20/32 or better in 65%, 20/50 or better in 95%
6. 5.3% loss of 2 lines of binocular CDVA

Loss of lines of CDVA has also been a concern in a study by Cosar et al, with 10.6% of eyes losing 2 lines of CDVA.2

Conclusions

The Supracor procedure can provide a satisfactory level of spectacle independence for hyperopic presbyopes. However, careful patient selection is of paramount importance, with preoperative counselling with regard to the light dependency of the near vision and compromise in uncorrected distance vision with a 10%-20% possibility of requiring an enhancement. Patients with high occupational near visual demands should be avoided. Refraction may take 6 months to stabilize. The nomogram is still being refined.

References

Laser Blended Vision for Presbyopia Correction

Dan Z Reinstein MD

Introduction

There has recently been a tremendous increase in interest in surgical presbyopic correction. The effective treatment of presbyopia combined with any refractive error has proven to be a significant challenge for refractive surgeons. Traditionally, the principles used for monovision contact lenses have been applied to corneal refractive surgery. However, many of the same limitations found with monovision contact lenses have applied to monovision induced by refractive surgery, including loss of fusion and stereovision. Multifocal corneal ablation profiles have also been suggested; however, although an overall improvement in visual acuity has been recorded for both near and distance vision, the acuity has remained relatively low and safety and quality of vision have been compromised. A better solution, offering improved visual results and greater tolerance, is still required. In this section, we describe the use of corneal nonlinear aspheric ablation profiles to increase depth of field in both eyes, combined with micro-monovision, to treat presbyopia in emmetropic, myopic, and hyperopic patients.

Laser Blended Vision

To better understand the way laser blended vision works, instead of viewing presbyopia as the inability to accommodate, it is helpful to consider it as a decrease in depth of field. This decrease can be overcome, at least in part, by using an optimized ablation profile that increases the depth of field of each eye without significantly compromising visual quality, contrast sensitivity, or night vision. The optimization is based on the patient age, refraction, preoperative spherical aberration, tolerance for anisometropia, and treatment centered on the corneal vertex.

It is known that one way of increasing the depth of field is to increase the amount of corneal spherical aberration independent of the zonal power shift that would be created by calculating the sphere for a particular zone in a cornea with spherical aberration. Based on that knowledge, during early work, the initial aim was to be able to adjust depth of field enough to provide clear vision from distance through intermediate to near, creating an eye that could see 20/20 at distance and that would also see a computer screen and read J1. However, it was soon realized that while spherical aberration could be increased, visual quality and contrast sensitivity can be compromised by large amounts of spherical aberration. This implied that there is a tolerable level of spherical aberration within which is provided a beneficiary increase in depth of field.

It was discovered that with photopic pupil diameters, the depth of field could be safely increased to 1.50 D for any starting refractive error. Given a 1.50 D depth of field, it would not be possible to get full distance and full near vision monocularly; therefore, based on the time-tested concept of monovision, the nondominant eye was set up to be slightly myopic, so that the depth of field of the predominantly distant eye was able to see at distance down to intermediate, while the predominantly near (nondominant) eye was able to see in the near range and up to intermediate. In the intermediate region both eyes had similar acuity, an optimal situation for stereopsis, and this draws on the knowledge of binocular fusion processing: the horopter—a volume centered on the fixation point that contains all points in space are integrated in the conscious mind to create the perception of a single image. Monovision, or in this case, micro-monovision, draws on the inherent cortical processes of neuronal gating and blur-suppression (the ability for conscious attention to be directed to the specific area within the entire visual field of both eyes with the best image quality). This is in contrast to other attempts to treat presbyopia that try to induce a multifocal cornea with 2 distinct focal points.

A further component is the increase in depth of field afforded by pupil constriction during accommodation, a component that persists even in eyes that have lost the ability to change crystalline lens power during the accommodative effort. The combination of controlled induced corneal aberrations and pupil constriction gives a significant increase in depth of field on the retinal image, albeit not a perfect image. However, intraretinal and cortical processing and edge detection is the final component working in laser blended vision: the pure retinal image, which is modified by spherical aberration, is further enhanced by central processing to yield the perception of clear and well-defined edges.

In principle, enhanced depth of field can be achieved through the introduction of either positive corneal spherical aberration, in which corneal power increases with zonal diameter, or negative aberration, in which power decreases with distance from the corneal vertex. Most patients have some nascent positive spherical aberration before treatment. A standard myopic ablation induces positive spherical aberration, which will add to the pre-existing positive spherical aberration.

The important thing is to control the induction of spherical aberration to avoid increasing the spherical aberration above the tolerance threshold, which can cause night vision disturbances and loss of contrast sensitivity and can result in a topographic central island. To account for this, the nonlinear aspheric ablation profile includes a precompensation factor for the induction of spherical aberration. A standard hyperopic ablation induces negative spherical aberration, but it is unlikely that the spherical aberration will be increased above the tolerance threshold because most patients start with some positive spherical aberration and the range of hyperopic treatments is smaller than the range of myopic treatments.

In emmetropic patients, you cannot rely on the induction of spherical aberration by the ablation, so the spherical aberration component is increased, but this has an impact on the refractive accuracy. As emmetropic patients have high expectations and low tolerance to refractive inaccuracy, the best option is to increase the depth of field somewhat and make sure that the micro-monovision component is as accurate as possible. The range of aspheric profiles, which also take age and preop spherical aberration into account, are referred to as “nonlinear aspheric ablation profiles,” since the spherical aberration component is governed by a nonlinear function.
Table 1. Preoperative Demographic Data, Postoperative Binocular Efficacy, Accuracy of Spherical Equivalent and Safety in Terms of CDVA Lines Lost for the 3 Populations

<table>
<thead>
<tr>
<th></th>
<th>Myopia</th>
<th>Hyperopia</th>
<th>Emmetropia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patients (n)</td>
<td>136</td>
<td>111</td>
<td>148</td>
</tr>
<tr>
<td>Gender</td>
<td>43% male</td>
<td>34% male</td>
<td>45% male</td>
</tr>
<tr>
<td></td>
<td>57% female</td>
<td>66% female</td>
<td>55% female</td>
</tr>
<tr>
<td>Preop SEQ</td>
<td>-3.58 ± 1.80 D</td>
<td>+2.58 ± 1.17 D</td>
<td>+0.25 ± 0.43 D</td>
</tr>
<tr>
<td>up to -8.50 D</td>
<td>up to +5.75 D</td>
<td>up to +1.00 D</td>
<td></td>
</tr>
<tr>
<td>Preop cylinder</td>
<td>0.83 ± 0.64 D</td>
<td>0.49 ± 0.50 D</td>
<td>0.44 ± 0.31 D</td>
</tr>
<tr>
<td>up to 2.50 D</td>
<td>up to 3.25 D</td>
<td>up to 1.25 D</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>49 yrs</td>
<td>56 yrs</td>
<td>55 yrs</td>
</tr>
<tr>
<td>Median (range)</td>
<td>(43 to 63)</td>
<td>(44 to 66)</td>
<td>(44 to 65)</td>
</tr>
<tr>
<td>Preop CDVA 20/20</td>
<td>100%</td>
<td>94%</td>
<td>100%</td>
</tr>
<tr>
<td>(logMAR 0) or better</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preop CDVA 20/16</td>
<td>62%</td>
<td>46%</td>
<td>68%</td>
</tr>
<tr>
<td>(logMAR -0.1) or better</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Binoc UDVA 20/20 and UNVA J5</td>
<td>99%</td>
<td>95%</td>
<td>98%</td>
</tr>
<tr>
<td>Binoc UDVA 20/20 &amp; UNVA J2</td>
<td>95%</td>
<td>77%</td>
<td>95%</td>
</tr>
<tr>
<td>Postop SEQ within ± 0.50 D</td>
<td>92%</td>
<td>79%</td>
<td>91%</td>
</tr>
<tr>
<td>Postop SEQ within ± 1.00 D</td>
<td>99%</td>
<td>95%</td>
<td>100%</td>
</tr>
<tr>
<td>Lost 2 or more lines CDVA</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
<tr>
<td>Lost 1 line CDVA</td>
<td>8%</td>
<td>17%</td>
<td>13%</td>
</tr>
<tr>
<td>Retreatment rate</td>
<td>19%</td>
<td>22%</td>
<td>12%</td>
</tr>
<tr>
<td>Retreatment rate had 20/32 been used as criteria</td>
<td>5%</td>
<td>6%</td>
<td>4%</td>
</tr>
</tbody>
</table>

Abbreviations: SEQ indicates spherical equivalent refraction; CDVA, corrected distance visual acuity; UDVA, uncorrected distance visual acuity; UNVA, uncorrected near visual acuity.

Results

The outcomes using Presbyond Laser Blended Vision with the MEL 80 excimer laser (Carl Zeiss Meditec; Jena, Germany) have been published in myopic, hyperopic and emmetropic patients. All treatments were performed as bilateral, simultaneous LASIK. Inclusion criteria were: medically suitable for LASIK, presbyopic with corrected distance visual acuity no worse than 20/25 in either eye, and tolerance of at least −0.75 D anisometropia. The standard micro-monovision protocol corrected the dominant eye to plano and the nondominant eye to −1.50 D, irrespective of age. Results are reported with 1 year follow-up and include all retreatments.

The distance vision of the near eye was better than expected given the −1.50 D refraction, and approximately 80% of the near eyes were 20/63 or better. For a typical eye, 0.25 D of myopic defocus results in the loss of 1 logMAR line of UDVA. Therefore, an untreated eye with myopia of −1.50 D would only be expected to achieve a UDVA of 20/80, which is more than 2 lines worse than the mean UDVA of 20/39 for the 3 populations.

To demonstrate the effect of neural summation, when the relatively blurred nondominant eye was added for binocular distance vision, the percentage of patients with distance vision of 20/20 or better increased from 93.4% monocularly to 96.8% binocularly. In other words, the addition of a blurred nondominant eye to the distance eye resulted in even better distance vision, unlike contact lens monovision (for adds greater than 1.50 D), in which it is demonstrated that there is reduction of distance vision obtained monocularly when the nondominant blurred eye is added. The near efficacy outcomes were also better than might be expected.

A person 55 years of age would be expected to need a near spectacle addition in the range of −1.50 to −2.25 D, whereas excellent near vision was achieved with a −1.50 D anisometropia for these populations.

The safety in terms of CDVA and contrast sensitivity was the same as for standard LASIK with the MEL 80. Mean postoperative mesopic contrast sensitivity was either the same or slightly better than preoperatively at 3, 6, 12, and 18 cpd for all 3 populations, using the CSV-1000 (VectorVision). Studies with monovision have demonstrated that in a proportion of monovision...
patients, stereoacuity is lost and that once stereo acuity is lost, it does not come back. In comparison, results of our stereoacuity studies (using a random dot stereo test [Stereo Optical Co.]) confirmed that while postoperative uncorrected stereoacuity was lower than preoperative near corrected stereoacuity, a functional level of stereo acuity was maintained postoperatively; 68% of patients had stereoacuity of 100 secs or better, and 93% had stereoacuity of 200 secs or better. The study also found that near correction restored preoperative near corrected stereoacuity in the majority of patients; 5% of patients with 40-50 secs of stereoacuity preoperatively showed a 1-patch decrease in best corrected stereoacuity, while 100% of patients initially having 60 secs or less showed no loss at all.

Conclusion

In conclusion, the combination of micro-monovision with increased monocular depth of field through appropriate non-linear aspheric ablation profiles improves visual outcomes substantially in comparison with the conventional monovision approach. Trials show that laser blended vision is effective with presbyopic patients having refractive errors between +5.75 and −9.00 D, including emmetropic presbyopes. With the safety advantages of modern femtosecond LASIK, the rapid bilateral surgical procedure, and the recovery time of a few hours, patient satisfaction is extremely high. Laser blended vision benefits from all of the wow-factors of LASIK, with the ability to offer easy enhancement of vision if necessary in the future.

References

PresbyLASIK in Pseudophakia

Thomas Kohnen MD PhD FEBO, Oliver Klaproth

PresbyLASIK is a procedure currently under discussion in Germany. Recently, the KRC (the Kommission Refraktive Chirurgie, the German Commission for Refractive Surgery) has questioned its routine application and doubted whether it has proven its safety sufficiently yet. According to the KRC’s guidelines, presbyLASIK should not be used outside of prospective, ethics committee-approved clinical trials. Why is that?

How do we define PresbyLASIK?

Before discussing presbyLASIK in pseudophakia, one has to agree on the definition of the term “presbyLASIK.” In opposition to other excimer laser approaches like monovision, we define presbyLASIK as a multifocal method. However, it utilizes the same surgical approach as LASIK. There are several approaches to presbyLASIK ablation profiles, such as PresbyMAX by Schwind (Germany),2 Supracor by Technolas / Bausch + Lomb (Germany/USA),3 or Blended Vision by Zeiss (Germany).4 The precise method may differ, but all are based on monocular multifocality—either by creation of different refractive circular zones and/or modification of spherical aberration. Usually these multifocal approaches are combined with slight monovision. Per our definition, presbyLASIK always uses monocular multifocality and thus simultaneous imaging of 2 or more foci on the retina, similar, but not the same, as what multifocal contact lenses or IOLs do.

Shortcomings of PresbyLASIK

PresbyLASIK is, of course, appealing to patients and doctors. It offers a fast and well-known routine surgical procedure. However, presbyLASIK is not LASIK and has certain optical particularities, which need to be taken into consideration before treatment. These are, among others:

- PresbyLASIK is a static approach. Especially in younger presbyopic patients, surgeons have to plan higher addition powers to provide sufficient near visual acuity with progressing presbyopia. On the other hand it is known that higher addition powers lead to higher optical aberrations and are therefore less well-tolerated by patients.

- The dependency on pupil diameter might also play a role. This is an advantage in near tasks, where pupil constriction optimizes the use of the central near portion of the newly shaped cornea. For photopic distance tasks, however, the pupil is also small, which in this case might lead to limitations of distance visual acuity.

- PresbyLASIK procedures have thus proven to increase near visual acuity; however, due to the above-mentioned effects, they are also known to reduce corrected distance visual acuity (CDVA) and contrast sensitivity. Studies show that 6%-13% of eyes lose 2 or more lines of CDVA, 22%-58% lose 1 ore more line.2,3

- Furthermore, depending on the ablation profile, retreatments might prove difficult, and so might IOL calculation in case of later cataract surgery.

Why is it a problem to combine presbyLASIK with previous cataract surgery?

Pseudophakic patients who underwent uncomplicated cataract surgery are usually more or less emmetropic and always fully presbyopic. Therefore they require the full near addition power of about 2.5 D. This leads, as described above, to optical limitations. Furthermore, elderly pseudophakic patients usually have smaller pupils, which questions the entire principle of multifocal corneal multifocality, as only the central near add focus can be utilized. Therefore we think it is questionable whether pseudophakic patients should be treated with presbyLASIK, even though the problems of presbyopia progression and IOL calculation no longer occur.

What is the alternative?

First of all today’s multifocal—especially trifocal—IOLs offer a predictable, safe, and well-established method of avoiding the problem of pseudophakic presbyopia in the first place. If patients have been implanted with monofocal IOLs already, sulcus-fixed multifocal (toric) add-on IOLs offer an option for achieving independence from glasses in near and far. Multifocal add-ons offer predictable and precise optical outcomes, similar to those achieved with multifocal IOLs implanted in the capsular bag, with less pupil size dependency than presbyLASIK. Last but not least, the procedure is reversible, which also offers the option to implant those lenses at the same surgery session as the monofocal IOL. If the patient does not like the multifocal optics after some months, the lens can be removed from the sulcus.

Summary

We do not perform presbyLASIK in pseudophakic patients, so we do not have our own experience yet. Theoretically add-on IOL options seem to be superior for reasons of better optical quality, less pupil size dependency, and, last but not least, reversibility.

References


Applying and Avoiding PresbyLASIK

Ioannis Pallikaris MD

I. PresbyLASIK
   A. Less invasive and maybe with fewer potential complications than IOL implants.
      1. The use of LASIK is more adequate for presbyopia: more controllable technique for corneal multifocality, avoiding the plastic compensatory effect of the growing epithelium at surface ablation profiles.
      2. PresbyLASIK is better suited for young presbyopes (40-55 years of age) whose crystalline lens is still transparent and in whom intraocular surgery may be more risky than corneal refractive surgery.
   B. Potential refractive laser vision correction (LVC) approaches for near vision enhancements:
      1. Monovision
      2. Multifocal ablations
      3. Increase in depth of focus
      4. Combined approach

II. Monovision
   A. Binocular approach
      1. Typically considers eye dominance
      2. Correction: dominant eye emmetropic (for far) and the fellow eye slightly myopic (for near)
      3. Initially used with contact lenses (CL)
   B. Should consider patients’ needs and expectations (occupation, lifestyle, etc.)
   C. Relies on the neuronal adaptation of the overall sighting process within the brain: interocular blur suppression
   D. Tolerance to monovision is limited.
      2. 72%-97% success rate with LVC, but with pre-testing (Reilly CD, et al. Surgical monovision and monovision reversal in LASIK. Cornea 2006.)
      3. Best accepted anisometropia in the range from 1.00 to 1.50 D (Braun EH, et al. Monovision in LASIK. Ophthalmology 2008.)
      4. Tolerance should be tested in advance.
   E. Applying because:
      1. Simple
      2. Preop monovision trial possible
      3. No compromise in monocular image quality
      4. Attempted correction is precisely adjustable to patient’s needs and tolerance.
   F. Avoiding because:
      1. Not easily reversible compared to CL
      2. Not always accepted
      3. Patient motivation and cooperation necessary
      4. Potential compromises in:
         a. Night vision
         b. Stereopsis
         c. Contrast sensitivity

III. Multifocal Ablations
   A. Central distant with peripheral near
      1. Avalos, Rosakis, Agarval (PARM technique, 1998), G Tamayo, 2000, Telandro 2004
      4. Satisfaction (spectacle independence): 54% in hyperopes, 48% in myopes
   B. Central near with peripheral distant
      1. Ruiz LA, Jackson WB, Visx (Presbyopic LASIK, 2001)
      2. Bartoli F (Wavefront-guided PRK, 2002)
      3. Seok Won Jung (Multifocal corneal ablation for hyperopic presbyopes, 2008)
      4. Baudu P (Uncorrected binocular performance after biaspheric ablation profile for presbyopic cornea treatment using Amaris with the Presby-MAX module, 2013)
   C. Applying for center near because:
      1. Miosis: Pupil contraction during accommodation to near distance supports pseudoaccommodation.
      2. Prolate corneal shape: More refractive power in the pupil center
      3. Spherical aberration that occurs during accommodation: Typical trend for spherical aberration to be shifted toward negative values for near vision
      4. Less tissue ablation in depth and volume than other multifocal approaches
D. Avoiding because:
1. Amount of correction is limited.
2. May need nomogram adjustment
3. No preop trial for tolerance possible
4. Not easily reversible (customized treatment)
5. Induced aberrations cause decreased image quality at every distance.
6. Effect is reduced over time, with a gradual decline in near vision outcomes.

IV. Depth of Focus (DOF) Increase
A. For DOF control, the spherical aberration (SA) of the entire eye is important.
B. Preop corneal asphericity is not necessarily related to the SA of the entire eye due to internal aberrations (→ aging). When setting Q-values without having information on the preop ocular SA of the eye, which corneal Q-value to aim at in order to optimize SA for DOF control?
C. Increasing the prolate shape of the cornea is not a benefit in itself:
1. It can lead to central island-like postop condition.
2. It always increases ablation depth.

D. Applying because:
1. Profile is of progressive nature (“continuous multifocal”).
2. Contour changes are spread out over the complete optical zone. The spherical aberration (SA) shift does increase the depth of field.
3. Power shift through miosis supports pseudoaccommodation.

E. Avoiding because:
1. Amount of excess SA is limited.
2. Too small effect for daily life (max. approx. 1 D)
3. Decreased image quality at every distance
4. Effect is reduced over time.

V. Combined Methods
A. Laser blended vision/Micro-monovision
1. Combining increased depth of field with micro-monovision

B. Applying because:
1. Better acceptance than conventional monovision (97% tolerance)
2. Although depth of field effect may decrease over time, the monovision remains intact.

C. Avoiding because:
1. Both eyes need to be treated.
2. Potential decrease in image quality

VI. Conclusion
LASIK for presbyopia correction can provide high patient satisfaction when the following are fulfilled:
A. Considering patient’s needs and expectations
B. Preop tolerance test
C. Considering preoperative refractive status
D. Reliable laser algorithms
E. Analyzing near vision parameters such as:
1. Reading speed
2. Light conditions
3. Print size
F. The main limitations of presbyLASIK today:
1. Little scientific evidence through published data, although it is widely used.
2. The dispersion of the techniques
3. The lack of uniformity of the ablation profiles offered by different excimer laser technologies
4. The difficulty in reversing the result, especially for multifocal approaches (customization needed)
G. Further studies are necessary to implement the scientific evidence of these techniques. When available, such evidence could generalize this refractive surgery technique, which may offer a huge potential of application, useful for phakic presbyopes and pseudophakic patients.

References and Selected Readings
Nightmare Case of Recurrent Epithelial Ingrowth After LASIK

David R Hardten MD

Epithelial ingrowth occurs after LASIK in a small percentage of LASIK patients, with the risk factors of anterior basement membrane dystrophy and enhancements by lifting the flap. Most cases will spontaneously resolve through resorption of small areas of epithelium. Others may progress to where the central corneal irregularity is affected, leading to the need for removal of the epithelial ingrowth.

If removal is planned, then almost 50% of cases will have recurrence of the epithelial ingrowth, likely from many risk factors. One problem that occurs is that the epithelium grows under the flap before the flap is totally adherent to the stromal bed for the 300-degree area of the edge of the flap.

To aid in prevention of recurrence, in this series of short videos, the use of fibrin adhesive is shown to provide a barrier to the migration of epithelium until the flap has healed sufficiently to the stromal bed.
Complex Cataract Surgery on an Eye With an Opaque Cornea

BY MARK D. EWALD, MD; BENNIE H. JENG, MD; THOMAS “TJ” JOHN, MD; CLARK L. SPRINGS, MD; AND ALAN N. CARLSON, MD

A 52-year-old Hispanic man suffered a traumatic injury to his left eye from a piece of tile at a construction site in January 2013. He sought care locally during the subsequent month for an infection that worsened despite topical antibiotics.

The patient was referred to the Duke Eye Center with a descemetocele and worsening inflammation (Figure 1). His eye was cultured and aggressively treated with topical antibiotics. Cultures and Gram stain were not helpful, and his cornea perforated a week later. An eccentric keratoplasty (tectonic and therapeutic) was performed on an emergency basis. The patient did very well with the exception of a cataract that developed over the ensuing months. He was scheduled for cataract surgery.

On the day of surgery, the patient was noted to have an opaque cornea. The cost of the medication had contributed to his discontinuation of the corticosteroid drops, and he had unfortunately developed acute graft rejection since his last eye examination. Given the degree of corneal opacification, scarring, and vascularization as well as the extent of anterior and posterior synechiae, the patient was rescheduled for a full-thickness penetrating keratoplasty (PKP)—rather than Descemet stripping automated endothelial keratoplasty or Descemet membrane endothelial keratoplasty—in combination with cataract/IOL surgery. The center’s social worker became deeply involved to address the medical team’s concerns about noncompliance.

Regarding cataract surgery and the IOL’s insertion, what special precautions and techniques are used in an eye with a previous infection, extensive posterior synechiae, and poor visibility through an opaque cornea from scarring or, in this case, graft failure (Figure 2)?

—Case prepared by Alan N. Carlson, MD.
MARK D. EWALD, MD

We ophthalmologists concentrate our medical and surgical efforts on restoring vision. This vignette, however, highlights the potential complications—non-compliance due to economic factors in this case—that can occur outside a clinic or OR. I certainly agree with involving a social worker in this patient’s care. Also needed is a conversation between the surgeon and patient on the latter’s ability to care for the eye postoperatively. If the patient is unable or unwilling to adhere to the postoperative regimen, further surgical intervention should be postponed.

With respect to cataract surgery, careful management of the sequelae of the patient’s previous infection and resulting inflammation is needed. Posterior synechias can be performed with viscoelastic in the anterior chamber and an iridodialysis spatula passed through a paracentesis. If the pupil does not dilate after the iridolenticular adhesions are broken, the surgeon can consider placing iris retraction hooks or a Malyugin Ring (MicroSurgical Technology) to improve the view of the cataract.

Before creating the capsulorhexis, the surgeon must be prepared to apply capsular dye to the anterior capsule if the infectious and inflammatory process has created a white lens that is blocking the red reflex. Thorough hydrodissection will also be important; there may be additional capsular scarring and adhesions to the lens itself from the prior conditions.

Visualization of the anterior segment will be poor, given the failed corneal transplant. Assuming the patient will be able to care for his eye postoperatively, I would consider performing a repeat corneal transplant, open-sky removal of the cataract using the techniques described earlier, and placement of a three-piece IOL. Poor adherence to the postoperative drug regimen will result in a second failed corneal transplant, chronically poor vision, and little enthusiasm on an ophthalmologist’s part for performing a third surgery.

BENNIE H. JENG, MD

Is the cornea too opaque to allow phacoemulsification and the implantation of an IOL? If not, then I would try to stain the anterior capsule of the lens with trypan blue to facilitate visualization through the opaque cornea. I would perform phacoemulsification and IOL implantation per my usual technique. If the view proved challenging intraoperatively, a light pipe at the limbus or even in the eye could help with illumination. After closure of the wounds, a standard PKP could be performed.

If the cornea were too opaque to allow safe phacoemulsification and IOL implantation, I would plan to perform an open-sky extracapsular cataract extraction and IOL surgery. I would start by placing a Flieringa ring, lysing the iris-lens adhesions, and placing iris hooks. A Malyugin Ring in this setting would not be the best choice, because expression of the lens nucleus might not be possible through the device’s opening. At this point, trephination of the cornea could proceed, and I would stain the anterior capsule with trypan blue dye. Either a large continuous curvilinear capsulorhexis (CCC, my preference) or a can-opener capsulotomy could be performed. The lens nucleus could then be expressed through controlled hydrodissection. I would remove the cortex with a Simcoe manual irrigation/aspiration instrument. A three-piece IOL could be placed in the bag if a CCC were performed or implanted in the bag or the ciliary sulcus if a can-opener capsulotomy were used. The PKP could then be finished.

THOMAS “TJ” JOHN, MD

The infiltrate’s close proximity to the limbus complicates management. Based on the figure, the cloudy cornea appears to be due to both graft failure and possible infiltrates at the graft-host junction. The priority in this case is to address the corneal infection that appears to be present along the graft-host junction from the 5- to the 2-o’clock position (clockwise). A large, repeat
therapeutic graft may be indicated if the infiltrate is not responding to medical treatment.

Because cataract surgery is an elective procedure, I would avoid the operation until the infection has been eradicated and the eye is quiet. At that time, because of the compromised view of the anterior segment, I would consider performing an open-sky triple procedure with cataract extraction and in-the-bag implantation of a posterior chamber IOL in an osmotically and mechanically softened eye to prevent vitreous pressure during an open-sky procedure. This second graft would be well centered. All iris adhesions could be lysed at the time of the triple procedure.

Care should be taken during hydrodissection and the lens expressed out of the capsular bag with adequate visibility. I would create a large capsulorhexis for easy delivery of the cataractous lens, and I would use a viscoelastic agent to enhance safety. I would employ osmotic agents as needed. The potential for glaucoma-related issues postoperatively would have to be addressed.

CLARK L. SPRINGS, MD

The key for combined PKP and cataract/IOL surgery is successful in-the-bag fixation of the IOL. At the preoperative visit, I would take the patient to the minor room and inspect the anterior segment under the operative microscope to determine if there is any view of the anterior segment structures. If the view is adequate, I would plan for a closed-system capsulorhexis with trypan blue dye, exposure prolonged to ensure a deep blue stain. I would aim for a largish capsulorhexis (5 mm) so that I could prolapse the lens with hydrodissection and perform supracapsular phacoemulsification to protect the posterior capsule. After implanting the IOL, I would perform an intracameral injection of a miotic before proceeding with PKP.

If the view were too poor for any anterior segment maneuvers, then the cataract surgery would have to be performed under open-sky conditions. This approach would decrease the likelihood of achieving a CCC and stable, in-the-bag fixation of the IOL. After lysing the posterior synechiae, I would stretch the pupil to approximately 5 mm and use it to guide the capsulorhexis. I have found that a stretched pupil helps to bar a capsular tear from extending peripherally. Applying downward pressure on the lens with an iris spatula in my nondominant hand would simulate the effect of a pressurized anterior chamber.

The movement of a capsulorhexis forceps is centrally shearing, which will keep a tear from extending peripherally (as opposed to a standard technique in which the motion of the capsulorhexis forceps exerts a tearing force peripherally).

ALAN N. CARLSON, MD

These distinguished and expert contributors recognized the complexity and multitude of issues of this particular case. Medical compliance and follow-up care were my top priority before I agreed to perform additional surgery, and the center’s social worker was invaluable in this regard.

After complete resolution of all infection and active inflammation, the residual scar prevented a closed-system, limbal approach. Opting for an open-sky procedure, I wanted to use a speculum that would maximize the patient’s comfort but also not contribute to back pressure. I find that a wire lid speculum works well in highly cooperative patients who do not tend to squeeze their lids during surgery.

The original graft was intentionally eccentric due to the location of the infection and perforation. The repeat procedure used a full-thickness, centered graft. I prefer a controlled entry, which I accomplished by adding viscoelastic through a paracentesis prior to surgical entry of the cornea. I managed anterior and posterior synechiae with viscodissection, blunt dissection, and—when necessary—sharp dissection. An open-sky capsulorhexis can be particularly tricky, as Dr. Springs pointed out. Trypan blue ophthalmic solution (VisionBlue 0.06%; DORC International) improved my visualization of the open-sky capsulorhexis that was initiated centrally, spiraling out to the desired size. The optimal size is less than 5 mm to avoid prolapse of the IOL’s optic, which might occur with any back pressure.

I continued cortical cleaving hydrodissection after the first wave to cause a second wave of fluid that led to hydro-expression of the lens nucleus, which was easily extracted. I performed cortical removal using irrigation and aspiration with a high-flow state to keep the capsular bag open and essentially flush out the residual cortex. I primarily used viscoelastic as a lubricant for the IOL’s insertion, because the bag would not open as readily as it would in a closed system.

In my experience, a multipiece acrylic IOL is superior and less likely to prolapse or extrude than a plate or one-piece “Gumby” acrylic IOL design. The remainder of the procedure was fairly standard. With respect to the PKP, I used interrupted sutures rather than a single running suture due to the extent of corneal neovascularization.

A video of how I handled this case is available on Eyetube.net or at http://bit.ly/1unVPzF.
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Flap Complications
To Lift or Not to Lift

Natalie Afshari MD

Background
Although rare, postoperative LASIK flap complications may prove challenging even for the most experienced surgeon. Diffuse lamellar keratitis (DLK), first described by Smith and Maloney, is an uncommon inflammation of the flap interface. On the other hand, central toxic keratopathy is a rare noninflammatory complication of LASIK flap interface. These conditions can lead to central stromal haze and decreased postoperative visual acuity. Initial therapy for flap interface inflammation includes frequent use of topical steroids, with close follow-up. Clinicians must be quick in diagnosing each particular condition, as therapeutic options may vary. In particularly severe cases, many practitioners face the dilemma of whether to lift the LASIK flap. In this report we describe a case of severe flap interface inflammation where the decision was made to lift the LASIK flap in order to hasten recovery.

Case Report
A 31-year-old woman presented to Cornea and Refractive Surgery clinic with a history of high myopia, seeking refractive surgery. Her past medical and ocular histories were unremarkable. She underwent uncomplicated bilateral LASIK procedure with femtosecond flap creation. On postoperative Day 1, she was found to have DLK and was started on frequent (q1h) topical prednisolone acetate. She was stable on postoperative Day 2 and had improved vision on postoperative Day 3, with a visual acuity of 20/15. On postoperative Day 4, she had worsening of her vision and exam. The decision was made to lift the LASIK flap that same day. The patient's vision slowly improved over the next several weeks, and at the final encounter, her vision had improved to 20/20.

Discussion
Diffuse lamellar keratitis (DLK), although unusual, is still a significant complication of LASIK that may result in suboptimal visual acuity and, although less likely, significant corneal pathology. The complete etiology of DLK is still unknown, and it is believed to be noninfectious. Central toxic keratopathy (CTK) is a noninflammatory condition that can mimic DLK. The difference is that DLK is more diffuse and CTK is more central. CTK slowly resolves over several months after surgery and it is typically unresponsive to steroids. In most cases DLK will respond to steroids. Of particular difficulty is the decision and the timing to therapeutically lift the LASIK flap. Our patient's condition significantly improved after lifting the LASIK flap and the visual acuity improved over time.

References
Descemet Membrane Endothelial Keratoplasty 

Nuances

Francis W Price Jr MD

In the United States, endothelial keratoplasty (EK) has been the standard of care for endothelial dysfunction since 2007. Descemet-stripping endothelial keratoplasty (DSEK or DSAEK) has been the predominant form of EK; however, Descemet membrane endothelial keratoplasty (DMEK) has been slowly gaining traction and increased penetration because of improved vision, decreased wound size, and reduced rate of immunologic graft rejection reactions compared with either penetrating keratoplasty (PK) or DSEK/DSAEK.

Two main factors have limited widespread adoption of DMEK: perceived difficulties with donor tissue preparation and a steep learning curve for mastering surgical techniques. Multiple techniques have been developed to successfully harvest DMEK donor tissue, resulting in a 1% or less donor tissue loss rate during preparation. Multiple eye banks are also preparing DMEK donor tissue, so preparation is no longer an impediment to DMEK surgery. What remains an impediment is mastering the surgical skills to insert, unfold, and position the DMEK graft.

With due respect to songwriter Paul Simon, I present 15 ways to lose your donor tissue. You can:
1. Accept a 20-year-old donor lenticule
2. Smash the scroll
3. Not stain the roll
4. Prolapse the iris
5. Push on the eye
6. Flush the anterior chamber
7. Lose your cool
8. Wash away the stain
9. Place it upside down
10. Bleed the eye
11. Misplace the bubble
12. Not treat the detachment
13. Rub the eye
14. Rip the graft
15. Leave in the viscoelastic

Or you can take your time, slowly insert the donor tissue, partially unfold it, check the orientation, place air under it, center the tissue, and fill the eye with air, pushing the tissue gently against the recipient.

Surgery is best done under topical anesthesia so one can verify that the IOP is not too high and there is no vascular occlusion. Topical anesthesia does not cause swelling and inflammation in the orbital area, as does infiltrative anesthesia, and it does not pose the serious risks of general anesthesia. A big part of successful topical anesthesia is proper surgeon control and management of the patient’s anxiety.

During surgery, care must be taken not to push on the eye and raise back pressure, which can prolapse iris, donor, and vitreous. This is especially an issue in eyes with previous YAG capsulotomies.

Once the donor tissue is in the eye, one has to carefully manipulate it to partially unfold it and then verify the orientation of the endothelial side—we use a slit beam. Other strategies include marking the tissue or checking the orientation with intraoperative OCT.

Once orientation is verified, then continue unfolding the donor tissue, inject air, manipulate the tissue into place, and fill the anterior chamber about 90% with air or air with long-acting gas.

Selected Readings

Contact lens-assisted crosslinking (CA-CXL) is a new technique for crosslinking thin corneas where the thickness of the corneal stroma after epithelial removal is less than 400 microns. Standard crosslinking in such a cornea can lead to increased UV irradiance at the level of the endothelium, leading to endothelial damage.

CA-CXL works by utilizing the Beer-Lambert principle. It is performed in thin corneas by utilizing a soft contact lens soaked in riboflavin solution. This contact lens, when placed on the cornea, attenuates the UV irradiance to safe levels by increasing the functional thickness of the cornea. The contact lens that is used should not have an in-built UV filter. We used the Bausch + Lomb Hilafilcon B daily disposable soft contact lens, as this lens does not have an in-built UV barrier. A soft lens design has advantages of adding a thickness of 90 microns to the functional corneal thickness. This helps in extending the benefit of crosslinking to thinner corneas. It also has the advantage of following the shape of the cornea.

Intraoperative corneal dehydration that can occur because of the use of riboflavin in dextran should especially be avoided in thin corneas. Intraoperative dehydration can be avoided by the use of riboflavin in HPMC (Vibex Rapid, Avedro, Inc.). It may also be decreased by performing accelerated crosslinking (CLUVR Rapid, Appasamy Associates; Chennai, India). This can further decrease intraoperative dehydration by decreasing the duration of contact with dextran-containing solution.

To sum up, it is important to take extra precautions with thin corneas while crosslinking. An existing effective technique is hypotonic CXL. However, with all techniques, it is important to always verify that the functional corneal thickness exceeds 400 microns. This is done in CA-CXL by rechecking pachymetry after placing the contact lens. It is also important to remember that very thin corneas may continue to show progression despite crosslinking, and in such corneas, it may be preferable by far to perform a deep anterior lamellar keratoplasty. Hence, the urge to crosslink every cornea should be avoided, and crosslinking by any technique should be decided prudently.
Pseudophakic Corneal Edema

Sadeer B Hannush MD

Introduction

Pseudophakic corneal edema is a well-known short- or long-term complication of cataract extraction with IOL implantation. The common pathway to corneal edema involves corneal endothelial cell loss to a level below what is required to maintain corneal clarity. This complication is more frequently associated with anterior chamber IOLs. Cystoid macular edema may develop as a comorbid condition.

Video

The presentation describes a case of corneal edema with a subluxated posterior chamber IOL implant. After a pars plana anterior vitrectomy, the IOL is delivered into the anterior chamber (AC) and out of the eye atraumatically. This is followed by the insertion of an intrasclerally fixated/glued 3-piece foldable posterior chamber IOL. The corneal pathology is addressed with endothelial keratoplasty.
Mitomycin C: Uses and Abuses

Randy J Epstein MD, Parag A Majmudar MD, Rachel H Epstein MD

This talk discusses off-label uses of an FDA-approved medication. No authors have any relevant financial conflicts to disclose.

I. History of Mitomycin C (MMC) Use on the Cornea and External Eye
   A. Pterygium surgery
   B. Corneal neoplasia and corneal intraepithelial neoplasia
   C. Refractive surgery (the principal focus of this talk)
      1. Basic science studies
      2. Clinical studies: 15 years of follow-up
      3. American Society of Cataract and Refractive Surgery survey, 2009: 88% of member surgeons use MMC.

II. Our Technique for the Use of MMC in Refractive Surgery
   A. For “routine” (high-risk) surface ablation
      1. Dosing
      2. Application technique
      3. Nomogram adjustment
   B. Over prior RK, complicated flaps or scars
   C. Post-penetrating keratoplasty
   D. For other indications (Salzmann nodular degeneration, etc.)

III. Toxicity of MMC
   A. Ocular surface
   B. Keratocytes
   C. Endothelium?

IV. Safety of MMC
   A. Short-term studies
   B. Long-term studies

V. “Creative” Uses of MMC
   A. Intrastromal
   B. Conjunctival hyperemia

VI. Current Recommendations for the Use of MMC in Corneal and Refractive Surgery

Reference and Selected Readings


12. Kim B-H. Regional conjunctivectomy with postoperative mitomycin C to treat chronic hyperemic conjunctiva. *Cornea* 2012; 31:236-244.


Section VIII: Interactive Consultations—
Corneal Refractive Surgery

NOTES
Traditional Methods for Astigmatism Magnitude Selection and Axis Alignment

Douglas D Koch MD

I. Prevalence of Corneal Astigmatism in Cataract Patients

Two large studies:


<table>
<thead>
<tr>
<th>Astigmatism (D)</th>
<th>Hoffer Study</th>
<th>Ferrer-Blasco, et al. Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 0.50</td>
<td>40.2%</td>
<td>58.8%</td>
</tr>
<tr>
<td>0.75-1.00</td>
<td>26.7%</td>
<td>12.1%</td>
</tr>
<tr>
<td>1.25-1.50</td>
<td>14.1%</td>
<td>12.6%</td>
</tr>
<tr>
<td>1.75-2.00</td>
<td>8.1%</td>
<td>7.2%</td>
</tr>
<tr>
<td>2.25-2.50</td>
<td>3.9%</td>
<td>3.6%</td>
</tr>
<tr>
<td>2.75-3.00</td>
<td>2.6%</td>
<td>2.3%</td>
</tr>
<tr>
<td>3.25-3.50</td>
<td>1.6%</td>
<td>1.6%</td>
</tr>
<tr>
<td>&gt; 3.50</td>
<td>2.9%</td>
<td>1.7%</td>
</tr>
</tbody>
</table>

II. Issues

A. Minimal astigmatism required for good UCVA. Especially important in patients receiving multifocal IOLs.

B. Target for optimal clarity is less than 0.75 D for monofocals and 0.5 D for multifocals.

C. In my practice, over 25% of eyes undergoing cataract surgery require astigmatism management.

III. Cataract incision induces minimal astigmatism on average.

A. Depending, of course, on several parameters

B. In my patients, a 2.4-mm temporal clear corneal incision induces around 0.20 D on average with moderate variability, but some get over 0.5 D change.

IV. Preoperative Planning

A. Quantifying astigmatism

1. Manual keratometry is the traditional standard and is still advocated by some.

2. An advantage is the ability to visualize the quality of the keratometric mires.

B. Automated keratometry is performed by the IOL-Master or LenStar.

Points measured are 6 for the IOLMaster and 32 for the LenStar, indicating a presumed advantage for the latter.

C. Corneal topography: Multiple indications, including evaluation of corneal epithelial irregularities by examination of mires, ruling out corneal ectatic disorders.

1. Critical role in confirming the overall meridian of the astigmatism.

2. The accuracy is sometimes questionable, particularly for “SimK” values.

V. Why do we need to mark or image eyes?

A. From sitting to lying down, many eyes rotate.

B. One study showed a mean of 4.1 ± 3.7 degrees, with 8% rotating greater than 10 degrees.

1. 10 degrees of rotation produces a 34 reduction with induced astigmatism at an oblique axis.

2. So misalignment undercorrects at the intended meridian and induces new astigmatism at a new meridian: a doubly adverse outcome.

VI. Methods of Alignment

A. Marking

1. Sitting the patient up and free-hand marking

2. Using one of a variety of markers that utilize a level

3. Technology using smart phones

B. Aligning the steep meridian to anatomical features

1. A preoperative drawing

2. Automated devices as will be discussed

VII. Traditional methods provide acceptable results.

A. LASIK study: No difference in outcomes with manual marking vs. iris registration

B. Study comparing standard marking, slitlamp marking, and alignment with photographic images

Errors were 3.69 ± 1.49, 3.14 ± 1.64° and 2.29 ± 1.06°, respectively, showing some benefit of “mapping” to photographic images.

C. Comparison of 4 marking approaches: all < 10-degree error
VIII. Conclusion

Studies are needed to validate the benefits of more expensive approaches, which nevertheless are very promising, especially for narrowing the range of errors.

References


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Slitlamp</th>
<th>Pendular Marker</th>
<th>Bubble Marker</th>
<th>Tonometer Marker</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAE ± SD</td>
<td>2.3 ± 1.8</td>
<td>1.8 ± 2.2</td>
<td>2.9 ± 1.9</td>
<td>4.7 ± 2.9</td>
</tr>
<tr>
<td>Maximum</td>
<td>6.8</td>
<td>7.8</td>
<td>5.6</td>
<td>9.3</td>
</tr>
</tbody>
</table>

Table 2. Rotational Misalignment for Each Marking Method
Photographic/Topographic Iris Registration

Jonathan D Solomon MD

Cassini Corneal Shape Analyzer: Novel Diagnostic Technology From i-Optics:

I. Instantaneous Multicolor LED Measurement
   A. Ray Tracing Elevation Map
   B. Approximately 700 red, yellow, green LEDs
   C. Allows complete coverage centrally and wide peripheral capture
   D. Instantaneous point-to-point measurement, eliminates time delay errors
   E. Asymmetric multicolor design to increase measurement precision vs. monochromatic light data point overlap
   F. Overcomes axial asymmetry limits of Placido. What does this mean?

II. Design fundamentals allow high precision and measurement repeatability.
   A. Axis of astigmatism
      1. Cassini error: < 3.5°
      2. Scheimpflug: > 30°
      3. Placido: > 15°
   B. Magnitude of astigmatism
      1. Cassini error: < 2%
      2. Scheimpflug: = 0%
      3. Placido: > 5%
   C. Instantaneous capture
      1. Cassini: 0 seconds
      2. Scheimpflug: 1-2 seconds
      3. Placido: 0 seconds
   D. Submicron accuracy elevation mapping
      1. Cassini error: < 0.8 µm
      2. Scheimpflug: < 1 µm
      3. Placido: > 2 µm
III. Corneal Shape and Aberration Analysis

Figure 3. (2.65 X 4.24): Cassini corneal analysis.

IV. Cassini Clinical Applications

A. Anterior/posterior corneal astigmatism analysis
B. Toric IOL planning
C. Refractive surgery preop/postop analysis
D. Corneal wavefront matching to aspheric IOLs

V. Surgical Guidance Integration: LENSAR with Cassini

A. Preplace laser arcuate incisions are predicated on accurate axis identification.
B. Arcuate incision architecture (depth/ chord length/ diameter) based on magnitude of cylinder
C. Axis identification is predicated on reference identification (stackable error).

Figure 4. (2.47 X 4.8) Traditional reference marks.

1. i-Optics Cassini enables accurate data from the office suite and image generation for surgical planning in the laser suite.
3. Obtains keratometry, white-to-white, and high quality iris/pupil image for autoregistration.
4. Instant acquisition and seamless data flow to the LENSAR surgical system.
VI. Arcuate Incision Guidance

Unique iris registration algorithm on the LENSAR surgical system deduces cyclotorsion by comparing unwrapped iris images. Example: Manual registration based on 2 particular features yield a cyclotorsion estimate of 13 degrees. In comparison, LENSAR algorithm deduced cyclotorsion of 12 degrees by looking at the entire unwrapped images.

Figure 5. (1.93 X 3) Cassini eye image.

Figure 6. (1.93 X3) LENSAR infrared iris image.

Table 1. Cyclotorsion Statistics (in degrees as computed by algorithm) for 29 Eyes. Absolute Value Cyclotorsion (Abs.)

<table>
<thead>
<tr>
<th></th>
<th>O.D.</th>
<th>O.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg.</td>
<td>0.272727</td>
<td>1.972222</td>
</tr>
<tr>
<td>Abs. avg.</td>
<td>4.272727</td>
<td>4.972222</td>
</tr>
<tr>
<td>Median</td>
<td>1.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Abs. median</td>
<td>4</td>
<td>4.25</td>
</tr>
<tr>
<td>Min.</td>
<td>-10.5</td>
<td>-12</td>
</tr>
<tr>
<td>Max.</td>
<td>8</td>
<td>10.5</td>
</tr>
<tr>
<td>Abs. min.</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Abs. max.</td>
<td>10.5</td>
<td>12</td>
</tr>
</tbody>
</table>

Selected Readings


3-D Video Registration

Robert J Weinstock MD

Key Discussion Concepts

1. 3-D visualization in ophthalmic surgery came to market in 2008 with the TrueVision 3D Surgical System, which is a full stereoscopic surgical camera platform that is compatible with any existing surgical microscope. 3-D image registration and surgical guidance for corneal and cataract procedures came to market in 2010 with the 510(k) cleared TrueGuide software (formerly known as the Refractive Cataract Toolset). The system utilizes preoperative images and diagnostic data to generate dynamic surgical guidance templates that are tracked in real time on the eye during live surgery for incision positioning, toric IOL alignment, and multifocal IOL positioning. Several key technical partnerships have enabled recent system advancements, including diagnostic integration with the i-Optics Cassini corneal analyzer, the first fully integrated Leica TrueVision 3-D surgical microscope, iris registration integration with the Lensar femtosecond laser system.

2. The 3-D registration and imaging method of the TrueVision system features the unique Dynamic Optimization functionality, which acts as a real-time IOL and incision calculator on the eye during live surgery. A surgeon-specific software profile allows the software engine to tie the predicted effects of surgically induced astigmatism (SIA) that is unique to the surgeon directly to the astigmatism correction using toric IOL positioning and corneal incisions. The surgeon can change the planned correction preoperatively or intraoperatively, which the software will automatically recalculate for each case.

3. 3-D visualization with dynamic surgical guidance software allows the surgeon to maintain focus on the operative field as registration images and information are presented within the surgical field as needed during live surgery. High-resolution full 3-D imaging and guidance overlays are matched in the desired plane of view without parallax error that can result from 2-D viewing.

TrueGuide 3-D Software Features

- Accurate diagnostics
  - Integration with the i-Optics Cassini diagnostic device
  - TrueCapture software suggests treatment and IOL choice.

- Advanced data flow
  - TrueGuide preoperative and intraoperative software link
  - Seamless transfer of patient data and surgical planning

- Dynamic optimization
  - Software engine provides real-time calculations.
  - Links primary incision location and IOL positioning
  - Drives lowest residual astigmatism based upon multiple variables

- Precision surgical guidance
  - Surgical templates powered by TrueVision Smart 3D
  - Customized individual surgeon profiles
  - Auto-registration and eye tracking

- Clinical outcomes analysis
  - Postoperative diagnostics with Cassini to drive nomogram analysis
  - CE Mark and FDA clearance
Intraoperative Automated Cyclorotation Adjustment (Verion)

Robert J Cionni MD
Intraoperative Automated Cyclorotation Adjustment (Zeiss Calisto)

Roger F Steinert MD

This presentation will demonstrate the intraoperative automated cyclorotation adjustment of the Zeiss Calisto system. The surgeon can plan preoperatively the placement and length of incisions and astigmatic keratotomies and program these parameters into the system. The landmarks used for tracking are captured at the time of performing the preoperative partial coherence tomography measurements for IOL power calculation. In the operating room, the surgeon visualizes these surgical parameters through the heads-up display inside the operating microscope, with the tracking system automatically compensating for any cyclorotation.
Intraoperative Aberrometry (Talbot Moire)

Alan R Faulkner MD

I. Talbot Moire Interferometry (Marketed as ORA or Optiwave Refractive Analysis by WaveTec)
   A. Provides streaming refractive information that assists in intraoperative decision making
   B. High-resolution and large dynamic range of −5 D to +20 D provides broad application.
   C. Enables real-time surgical course correction
   D. Tells the surgeon when the eye is stable prior to the refractive measurement being taken
   E. Compatible with and attaches directly to existing microscope
   F. Workstation interface guides alignment and data processing.
   G. Cloud-based data analysis system allows entry of pre- and postop data to facilitate optimization.

II. Video Demonstration of Live Measurement, Data Analysis, and IOL Power Selection

III. Real-time Data Streaming
   A. Provides streaming data to assess stability of eye prior to measurement
   B. Results in greater consistency and accuracy in IOL power recommendations and astigmatic guidance
   C. Short measurement times and faster processors result in 2 seconds for measurement and 3 second processing time.

IV. Clinical Applications
   A. Intraoperative aphakic refraction for IOL calculations
   B. Optimized proprietary IOL calculation formulas that are optimized based on axial length and for normal eyes as well as post-refractive eye
   C. Surgeon optimization with entry of postop data
   D. Analytical tools for evaluation of outcomes and comparison with aggregate global data
   E. Intraoperative guidance for more precise toric IOL outcomes
      1. Intraoperative aphakic refraction for spherical and toric power and cylinder
      2. Based on whole eye refraction, accounts for additive effect of both anterior and posterior corneal power
      3. Pseudophakic refraction provides guidance for proper axis orientation
      4. Provides information for performance and management of LRIs

V. Outcome Data
   A. Outcomes analysis: prediction error and distribution (See Figure 1.)

Global Outcomes Analysis:
Prediction Error and Distribution

Figure 1.

B. My data for non-refractive eyes is very similar (see Figure 2).

My Outcomes-Non Post Refractive Absolute Prediction Error

Figure 2.

C. ORA influenced the surgeon’s choice 60% of the time. The majority of the changes were ≤ 0.5 D. (See Figure 3.)

D. ORA compared favorably against the Holladay 2 formula (see Figure 4).

E. Improved accuracy with refractive IOLs (See Figure 5.)
Intra-operative Decision

Figure 3.

*Comparison:
Optimized Holladay 2 vs. ORA System*

Figure 4.

Improved Refractive Accuracy for Presbyopic IOLs

Figure 5.
F. Management of astigmatism with toric IOLs (See Figure 6.)

G. Post-hyperopic LASIK (See Figure 7.)

H. Post-myopic LASIK compared to popular formulas (See Figure 8.)

VI. Summary

A. Through streaming refractive information, intraoperative aberrometry can provide more refined measurements to assist with IOL selection and alignment.

B. Live data streaming allows monitoring of the eye status.
   1. Alignment/readiness of the eye and IOL
   2. No interference for lid/speculum
   3. Tear film
   4. IOP
   5. IOL unfolding and tilt
Intraoperative Aberrometry (Sequentially Shifting)

HOLOS Intraoperative Aberrometry

Jay S Pepose MD PhD

I. Use of Wavefront Aberrometry in Ophthalmology
   A. Shack-Hartmann (commonly used to drive LASIK treatments): Generally a static acquisition with extensive processing; lateral resolution several hundred microns; sensitive to ambient lighting
   B. Talbot-Moiré (WaveTec): Intraoperative aberrometer based upon interferometry
   C. HOLOS (Clarity Medical): Dynamic, real time, intraoperative sequential wavefront sensor

II. Need for Aberrometry in Cataract Surgery
   A. Cataract outcomes vs. LASIK outcomes
         a. The mean absolute biometry prediction error was 0.402 ± 0.388 D of 17,056 cataract surgeries.
         b. Of the predicted value, 8049 cases (47%) were within ±0.25 D; 12,175 cases (71%) were within ±0.50 D, and 15,809 cases (93%) were within ±1.00 D.
         c. Only 55% of eyes were emmetropic (as defined by ±0.5 D and < 1 D of astigmatism.) Roughly, 33% had ≥ 1 D residual cylinder.
         d. These results excluded post-refractive surgery eyes, where outcomes are more variable.
         a. Mean MRSE at 1-month follow-up was 0.03 ± 0.29 D
         b. Mean defocus equivalent was +0.27 D ± 0.31 D.
         c. MRSE was within 0.50 D of target for 93.7% of eyes and within 1.00 D for 99.3% of eyes.
         d. Of 32,569 eyes, 49 eyes (0.15%) were overcorrected by 1.00 D MSE, and 176 eyes (0.54%) were undercorrected by 1.00 D.
   B. Sources of error in IOL calculations
      1. Errors in axial measurement (axial length, anterior chamber depth, lens thickness)
      2. Keratometry (including impact of posterior cornea)
      3. Rhexis size, position, shape
      4. Effective lens position (ELP) of the theoretical formulas
      5. Tolerance of IOL manufacturing
      6. SIA reliability
      7. Impact of corneal asphericity on calculating best focus
      8. Assessing pupil size for specific functions, like driving and pupil-dependent focus shifts
      9. Impact of errors in refraction (also impacted by tear film instability, pupil size)

III. Limitations of Legacy Technology (see J Refract Surg. 2013; 29(9):630-635.)
   A. Use of charge-coupled device (CCD) or complementary metal-oxide semiconductor (CMOS) image sensors requiring transfer of hundreds of thousands of pixels/frame and extensive processing
   B. Lateral resolution of several hundred microns
   C. Sensitivity to ambient light

IV. Components of HOLOS Real-Time, Sequential Wavefront Aberrometer
   A. Light source: 830-nm super-luminescent diode collimated light source focused onto retina to create returned wavefront
   B. Variable aperture: Intercepts a portion of the incident wavefront
   C. Detector: A position sensing device to indicate 2-dimensional displacement from a reference position
   D. Focusing element: Focuses the aperture-selected portion of the shifted wavefront onto the detector

V. Comparison of HOLOS to Other Aberrometry Systems (See Table 1)
<table>
<thead>
<tr>
<th></th>
<th><strong>HOLOS IntraOp</strong></th>
<th><strong>Legacy</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology</strong></td>
<td>Continuous real-time wavefront acquisition and display</td>
<td>Talbot Moiré and Shack-Hartman, snapshots of processed wavefront then display</td>
</tr>
<tr>
<td></td>
<td>Large dynamic range and ambient light immunity due to lock-in amplification and detection; no grids</td>
<td>Limited dynamic range and ambient light immunity; CCD/CMOS sensor based; grids reduce return wavefront intensity</td>
</tr>
<tr>
<td></td>
<td>Instantaneous wavefront detection and display; minimal algorithm overhead and processing</td>
<td>Multiple frames (samples) and time averaging required for convergence; algorithm and overhead intensive</td>
</tr>
<tr>
<td><strong>Working distance</strong></td>
<td>150 mm, 175 mm, 200 mm</td>
<td>200 mm</td>
</tr>
<tr>
<td><strong>Diopter range</strong></td>
<td>-10 D to +30 D</td>
<td>-5 D to +20 D</td>
</tr>
<tr>
<td></td>
<td>Dynamic selectable region of interest</td>
<td>Fixed grid array</td>
</tr>
<tr>
<td><strong>User interaction</strong></td>
<td>Hands free; No user interaction required to acquire refractions</td>
<td>User selects surgical phase (pseudophakic / aphakic) and selects when to accept data/reading; turn down lights, adjust for Z-axis (vertex distance)</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td>Record and playback capability (DVR) of wavefront data synchronized to video of patient’s eye</td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Customization</strong></td>
<td>Surgeon configurable for visualization, feedback, confidence levels / indications</td>
<td>Unknown</td>
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<tr>
<td><strong>Calibration</strong></td>
<td>Automatic internal calibration</td>
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</table>
Posterior Elevation Tomography for Keratoconus Screening

Mitchell P Weikert MD

I. Background
A. Historically, ectasia risk assessment was based on features of and indices developed from anterior surface measurements.
   1. Curvature: absolute, symmetric vs. asymmetric
   2. Astigmatism: absolute, regular vs. irregular
   3. Elevation: relative to reference surface
B. Posterior corneal measurements were incorporated when imaging technologies permitted:
   1. Slit-scanning ± Placido-based topography
   2. Posterior elevation and curvature, pachymetry distribution
C. Evolution of new imaging techniques allowed for expansion of potential screening tools:
   1. Scheimpflug imaging
   2. Combined Placido-Scheimpflug imaging
   3. OCT
   4. High resolution, repeatable, accurate

II. Additional Information Provided by the Posterior Cornea
A. Pachymetry distribution
B. Curvature and total corneal power (when combined with anterior surface information)
C. Aberrations
D. Elevation

III. Elevation Measurement
A. Compare measured surface to reference surface
B. Best-fit sphere (BFS) most common
C. Best-fit toric asphere (BFTA) – astigmatic surface
D. Interpretation highly dependent on:
   1. Fitting region/diameter
   2. Repeatability
   3. Radius of BFS
   4. Asphericities of BFTA

IV. Goals of Ectasia Screening
A. Most indices designed to separate normal eyes from keratoconus (KCN); relatively easy
B. Ideal indices would separate normal eyes from forme fruste keratoconus (FF-KCN); much more difficult
   1. Some studies define FF-KCN as no clinical signs, but some topographic signs.
   2. Other studies define FF-KCN as no clinical or topographic signs.

V. Potential Applications of Posterior Corneal Elevation in Ectasia Screening (Normal vs. FF-KCN)
A. Combined slit scanning and Placido topography (early work)
   1. Mean posterior elevation in keratoconus suspects > normal controls
   2. Posterior elevation > 40 μm recommended cutoff
B. Combined slit scanning and Placido topography (later work)
   1. No difference in maximum posterior central elevation in FF-KCN vs. normal corneas
   2. Mean posterior elevation at thinnest pachymetry in FF-KCN > normal corneas (26.3 μm vs. 19.7 μm, respectively)
   3. Discriminant function (34 total variables) increases ability to differentiate FF-KCN from normal corneas (AUROC 0.98, sensitivity 93%, specificity 92%, accuracy 92%).
C. Scheimpflug imaging (single camera)
   1. Keratometric asymmetry and topometric indices better than elevation differences (max − min) at differentiating normal from FF-KCN corneas
   2. All methods with suboptimal statistical results (best AUROC 0.81, sensitivity 57%, specificity 91%)
D. Scheimpflug imaging (single camera)
   1. Back difference elevation (via Belin-Ambrósio display) better than posterior elevation at differentiating normal from FF-KCN corneas (AUROC 0.755 vs. 0.683), but still suboptimal (sensitivity 74% and 65%, specificity 67% and 59%, respectively).
   2. Pachymetry indices performed better.

E. Combined Scheimpflug (single camera) and Placido topography
   1. Support vector machine (SVM): Supervised learning technique for pattern classification to maximize the margin of separation between the closest data points of 2 separate classes
2. Combines 8 indices, 3 of which use elevation data from the posterior cornea

3. Discrimination between FF-KCN corneas and normal corneas improved with inclusion of posterior elevation data (accuracy 97%, sensitivity 92%, specificity 98% for all data; accuracy 93%, sensitivity 75%, specificity 95% for anterior data only).

F. Combined Scheimpflug (single camera) and Placido topography

1. Elevation analysis with a BFTA was better than analysis with a BFS in differentiating FF-KCN corneas from normal corneas.

2. Maximum posterior elevation (MPE) was better than maximum anterior elevation (MAE) for the BFTA (AUROC 0.88 and 0.80, sensitivity 82% and 66%, specificity 80% and 86%, respectively).

3. Single parameters still suboptimal

VI. Conclusions

A. Additional information provided by the posterior cornea is valuable in keratoconus screening.

B. No single measurement or device is sufficient (at this time) to fully assess ectasia risk.

1. Combination of variables much more effective than single variables

2. KCN and FF-KCN have a wide spectrum of presentations.

C. Inherent weakness in all measurements derived from topography and tomography; use of a secondary measure (shape) to try to identify a primarily biomechanical process (corneal weakness)

References


Clinical Correlation of Topography, Tomography, and OCT in Cornea Imaging

Current Principles in Cornea Diagnostics and Possible Need to Revisit Keratoconus Criteria

Costas H Karabatsas MD, A John Kanellopoulos MD, and G Asimellis

Most ophthalmologists are familiar with computerized corneal topography maps and have been using them as a diagnostic tool in everyday practice in cataract and refractive surgery for nearly two decades. Because it is easy to assess corneal data in a map format instead of using numbers or written axes, topography maps have become very popular in ophthalmology. When it comes to using topography maps in laser corneal ablation, all these parameters are considered under a much more meticulous and critical perspective.

Placido-disc topography is probably still the most widely used form of corneal imaging today. It uses the simple principle of reflection keratometry, in which an instrument with a concentric ring pattern is allowed to illuminate the cornea with the patient’s eyes fixating in the center. This system has been used for many, many years to ascertain a qualitative measurement of the corneal curvature. That is, circular mires appear compressed on the steep axis of corneal astigmatism and appear to bunch up at the keratoconus and/or pellucid marginal degeneration apex. There is a catch, however. This type of imaging requires an almost-perfect tear film and an unobstructed (by eyebrows, lashes, nose) view of the entire corneal surface.

Computerized Placido-based topography goes a step further. It is able to analyze the deviation, or note, of each subsequent circle or Placido mire reflection in reference to the first central one. In this manner, if the subsequent mire is closer, there is steepening, and if it is further away in relation to the standard pattern, there is flattening. This is how topographic maps derive by analyzing the data provided by the corneal (tear film) reflection image of the Placido discs. A potential advantage of computerized Placido-based topography is that the image is not affected by corneal opacities, as long as they do not interfere with the tear film. This is a major limitation for tomography devices, such as scanning-slit (Orbscan), Scheimpflug (Pentacam), and OCT corneal imaging.

A major limitation, however, for Placido-based topography is the lack of central 2- to 2.5-mm data at the center of the cornea, as this area is not evaluated because the data processing starts from the position of the second Placido circular mire in regard to the first central one. It is therefore possible that Placido-based computed topography can completely miss a sharp, even very steep elevation (commonly named “island”) of depression (“divid or pit”).

When the clinician quickly overviews the Placido tear film image on the top left of the Topolyzer report, along with the underlying iris, pupillary (defined even better with a dotted circle), and sometimes limbal and scleral structures, an immediate angle kappa assessment can be made. If the dark pupillary aperture image is centered with the central mire, there is little or no angle 2 kappa. If there is an obvious mismatch of the pupillary aperture captured and the central mire (assuming that the patient was fixating correctly), we have a mismatch of the geometrical center of the pupil and corneal apex, thus significant angle kappa. This is actually routine in hyperopic patients, but watch for myopic or myopic astigmatic patients who would otherwise raise low suspicion, but nevertheless can be diagnosed immediately in this simple fashion. In a patient with significant angle kappa, if the laser vision correction is centered just on the pupillary center, it may be grossly decentered.

Topography, Tomography, and OCT in Keratoconus Imaging

Various keratoconus diagnosis, staging, and progression criteria are currently in clinical use, and some of them may have limited value. Among them, there are clinical evaluation data, and topography / topometry-derived indicators. Clinical data include visual acuity (uncorrected distance visual acuity, UDVA, and best-spectacle corrected distance visual acuity, CDVA), as well as manifest refractive spherical equivalent (MRSE). Topographic / topometric measurements (quantitative and qualitative) include corneal keratometry, anterior / posterior elevation, curvature asymmetry, corneal pachymetry, etc.

Our long clinical experience with keratoconus screening and management indicates, for example, that corneal pachymetry and visual acuity may not always be very reliable indicators of ectasia or keratoconus progression assessment. Reduced visual acuity per se may not correlate with the severity of keratoconus, and may only manifest in very advanced stages of the disease. The assessment of keratoconus severity and visual function has yielded poor results when compared to a number of anterior surface-derived topographic parameters (including keratometry, pachymetry, surface-asymmetry indices) in keratoconic eyes. Published reports from other investigators also indicate the limitations in specificity and sensitivity of the traditionally employed keratoconus criteria in clinical use.

Despite the use of several topographic / topometric diagnostic criteria, ophthalmologists in everyday practice often face cases that cannot be fully fitted either in the keratoconus or in the “normal cornea” groups. These suspect cases present a real diagnostic and management challenge for the clinician. This further emphasizes the need for research to explore possible improvements in the keratoconus diagnosis.

Keratoconus diagnosis employs either clinical or topographic / topometric-measurement based criteria. Among them is keratometry, either obtained with topography and/or topometry based computer-derived measurements. Topography system principles may be Placido-disk, slit-scan, or Scheimpflug tomography, providing anterior curvature data. Additionally, pachymetry measurements are used, obtained either by ultrasound, slit-scan tomography, or Scheimpflug imaging. Limitations, however, do exist, for example in relation to the curvature measurement accuracy of Placido-disk topographers, which may be compounded by tear film insufficiency or corneal warpage in rigid contact lens wearers, as well as pachymetry measurements by Scheimpflug imaging, which may be suspect to error if corneal clarity is compromised.
Some of the established criteria for keratoconus progression in comparison to baseline measurement used in contemporary clinical evaluation of keratoconus include the following:\(^8\text{--}^{10}\)

- K-max (steepest keratometry) ≥ 1 D increase
- K-mean – K-min ≥ 1 D increase (K-min, flattest keratometry)
- Kmean ≥ 0.75 D increase (Kmean = average of K-max K-min)
- Pachymetry ≥ 2% decrease in central corneal thickness (CCT)
- Corneal apex power ≥ 1 D increase (measured with cone location and magnitude index)
- MRSE change ≥ 0.5 D
- Several established decision trees exist based on combinations of the above, such as the Klyce indices of Surface Asymmetry Index (SAI) and Surface Regularity Index (SRI) and the KISA\% index.\(^1\)

The following equipment will be presented:

1. **Placido-disk topography** (KeratoGraph 5, Oculus; Germany)
   The KeratoGraph 5 is a late-generation Placido-disc based corneal topographer, reporting, in addition to standard keratometry and topography, specific anterior-surface irregularity indices that describe cornea irregularity (ISV and IHD).

2. **High-resolution Scheimpflug imaging** (Pentacam HR, Oculus; Germany)
   The Pentacam HR is a high-resolution rotating Scheimpflug camera system. It measures corneal thickness, anterior and posterior corneal topography and elevation maps, total corneal refractive power, and corneal power distribution, as well as corneal optical opacities. Specific to keratoconus investigation, the device reports values for anterior corneal curvature asymmetry indices such as the ISV and IHD.

3. **Novel color-spot reflection topography** (Cassini, i-Optics; the Netherlands)
   The Cassini is a newly introduced elevation-based topographer operating on the principle of multicolored (LED) spot-reflection topography. In addition to the standard topometric maps and anterior surface aberrations, it may offer posterior curvature and elevation data—a unique feature among reflection topographers. Moreover, keratoconus-specific data are included, such as the Klyce indices of Surface Asymmetry Index (SAI) and Surface Regularity Index (SRI).

4. **Anterior segment OCT** (RtVue-100, OptoVue; USA)
   The RtVue-100, a Fourier-domain anterior segment OCT device, is unique among similar devices for offering not only corneal thickness maps but also epithelial thickness maps and total (calculating anterior and posterior) corneal refractive power.

   Detailed, yet clinically accessible indicators (provided by systems like the KeratoGraph and/or the Pentacam) such as the index of surface variance (ISV) and the index of height decetration (IHD) may offer a more dependable description of the anterior surface asymmetry in most keratoconic eyes.\(^1\) Our initial investigation indicates that there is a significant correlation between the two anterior-surface irregularity indices and keratoconus classification.

   Additionally, the indices derived from anterior segment OCT (S-I, SN-IT, Min-Med, Min-Max, epithelial thickness, epithelial thickness asymmetry) may also provide more sensitive and specific data. Our team has investigated these parameters prior to the advent of OCT in the realm of epithelial thickness imaging by another unique device, based on very-high frequency scanning ultrasound, the Artemis (UltraLink LLC; Canada).\(^1\) In this study, for the first time, our group showed that an overall thicker epithelium is observed in a specific age group of young keratoconic patients, in addition to the accentuated epithelial thickness range and topographic variability differences.

### References

Dynamic Scheimpflug Imaging

Cynthia Roberts PhD

I. Confounding Issue for Biomechanical Assessment
A. As IOP increases, wall tension increases (LaPlace's law).
B. As wall tension increases in the cornea, it stiffens due to nonlinear properties, shown below.
C. Therefore, as IOP increases, cornea and sclera will stiffen.
D. A soft cornea with higher IOP may exhibit stiffer behavior than a stiff cornea with lower IOP.

II. Dynamic Scheimpflug imaging is achieved with the Oculus CorVis ST.
A. Ultrahigh-speed (UHS) Scheimpflug camera with air puff-induced corneal deformation
   1. 4330 frames per second
   2. ~140 images over a 30-ms airpuff
B. 8-mm horizontal coverage
C. Constant metered collimated air pulse
D. Currently FDA approved for tonometry and pachymetry only

III. Corneal Deformation With Dynamic Scheimpflug Imaging

Figure 2. 3.435 ms (top image): Convex cornea predeformation; 14.656 ms (second image from top): Inward movement becomes concave after first applanation event; 16.030 ms (third image): Continued inward movement; 19.465 ms: Outward movement after maximum deformation; 22.671 ms (fourth image): Near second applanation event; 30.915 ms (bottom image): Cornea recovers convex shape.

IV. What influences deformation?
A. IOP is the strongest influence, by far, and then, in the following order:
B. Corneal biomechanical properties
C. Corneal thickness
D. Corneal curvature
V. Standard Deformation Parameters (see Figure 3)

VI. Parameter Definitions
   A. First applanation (see Figure 4, top)
   B. Second applanation (see Figure 4, bottom)

VII. What deformation parameters correspond to corneal stiffness?
   A. Increasing pachymetry correlates with increasing “stiffness.”
   B. “Stiffer” corneas have lower velocities (more force is required to reach velocity).
      1. Initiate deformation later (requires more force to initiate movement)
      2. Recover quicker due to lower depths traversed
   C. “Stiffer” corneas have greater applanation lengths (wider and shallower at applanation).
   D. “Stiffer” corneas have flatter curvatures at highest concavity.

VIII. IOP vs. Stiffness and the Influence of the Scleral Shell
   A. Paired human donor corneas
      1. One cornea mounted as a whole globe
      2. Corneal-scleral rim excised from fellow eye and mounted in an artificial anterior chamber
   B. Internal pressure varied from 10 to 50 mmHg

E. “Stiffer” corneas have narrower displacement at depth (peak distance is shorter at highest concavity).
   1. Threshold phenomenon is due to spatially distributed source with highest pressure in center.
   2. Insufficient pressure to displace a stiffer cornea near the edges of the air puff

Figure 3.

Figure 4. Highest concavity (left = stiffer, less curved; right = softer, more curved).
IX. IOP and Deformation Parameters

Table 1

<table>
<thead>
<tr>
<th></th>
<th>IOPcc</th>
<th>Pachy</th>
<th>1st App Time</th>
<th>HC Time</th>
<th>2nd App Time</th>
<th>1st App Length</th>
<th>2nd App Length</th>
<th>Def. Amp</th>
<th>W-Dist</th>
<th>Curv Rad HC</th>
<th>V-in</th>
<th>V-out</th>
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</thead>
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<tr>
<td>KCN</td>
<td>19.6</td>
<td>489</td>
<td>8.0</td>
<td>17.9</td>
<td>23.8</td>
<td>1.3</td>
<td>1.5</td>
<td>0.91</td>
<td>4.77</td>
<td>8.98</td>
<td>0.18</td>
<td>−0.32</td>
</tr>
<tr>
<td>NL1</td>
<td>10.4</td>
<td>517</td>
<td>8.4</td>
<td>20.6</td>
<td>24.1</td>
<td>2.2</td>
<td>2.3</td>
<td>1.13</td>
<td>4.61</td>
<td>11.74</td>
<td>0.23</td>
<td>−0.37</td>
</tr>
<tr>
<td>NL2</td>
<td>19.6</td>
<td>564</td>
<td>9.5</td>
<td>17.63</td>
<td>23.2</td>
<td>2.9</td>
<td>2.6</td>
<td>0.89</td>
<td>4.39</td>
<td>13.13</td>
<td>0.16</td>
<td>−0.23</td>
</tr>
</tbody>
</table>

Abbreviations: Pachy indicates pachymetry; App, applanation; HC, highest concavity; Def. Amp, deformation amplitude; W-Dist, width of deformation at highest concavity; Curv Rad, radius of curvature at highest concavity; V-in, inward velocity; V-out, outward velocity; KCN indicates keratoconic cornea; NL1, normal cornea 1; NL2, normal cornea 2.

X. Biomechanics Basics (Pearls)

A. Biomechanics = response to an applied force
   1. Dynamic Seyempihlug imaging uses and air puff as the applied force.
   2. Biomechanics is assessed with deformation parameters extracted from images
B. For eyes, stress is a function of IOP.
C. Stiffer eyes require greater force for similar deformation, deflection, displacement, velocity, etc.
D. Eyes become stiffer with increasing IOP.

XI. Important Take-Home Messages

A. One value of stiffness will be insufficient to characterize the cornea biomechanically!
B. Changes in IOP will modify properties!
XII. Biomechanical Assessment in 2-D
   A. Softer eye with higher IOP may exhibit stiffer behavior than stiffer eye at lower IOP.
   B. Biomechanical properties should be plotted on 2-D plot to determine which is appropriate curve.

XIII. Proposed Standard Color Scheme for Reporting Biomechanical Properties
   A. Softer, higher strain is RED.
      1. Will correlate with higher curvature
      2. Will correlate with lower thickness
   B. Stiffer, lower strain is BLUE.

XIV. Biomechanics will be the Next Generation of corneal assessment.
   A. The influence of biomechanics on disease development and progression
   B. Biomechanical screening
   C. Biomechanical evaluation of response to intervention

Selected Readings
Corneal Collagen Crosslinking With and Without Epithelial Removal: Contralateral Study With 0.5% Hypotonic Riboflavin Solution

Aleksandar Stojanovic MD

I. Corneal Collagen Crosslinking (CXL)
A. Mechanism of CXL and the dual role of riboflavin1-4
B. “Classic CXL”: “epithelial-off” CXL
1. The standard protocol of epithelial-off CXL3
2. Safety and efficacy of epithelial-off CXL2,5,6
C. “Epithelial-on” CXL
1. Advantages of epithelial-on CXL over epithelial-off CXL: Avoiding complications caused by epithelial removal7-9
2. The major limitation: an inadequate and inhomogeneous riboflavin penetration10
3. Approaches that have been pursued to solve the major limitation.
4. Contradictory results of epithelial-on CXL reported by previous studies11-17

II. Study: Epithelial-on CXL vs. Epithelial-off CXL
A. Patients and methods
1. Patients: 20 patients; one eye of the patient was randomly chosen to be treated with epithelium-on CXL and the fellow eye was treated with epithelium-off CXL.
2. Inclusion and exclusion criteria
3. Surgical technique
4. The multifactorial approach that was utilized to enhance the riboflavin penetration13
   a. BAC-containing local preoperative medication
   b. Hypotonic riboflavin solution without dextran
   c. Increased concentration of riboflavin (0.5%)
   d. Prolongation of the riboflavin-induction time until objective verification of the stromal saturation is confirmed
B. Results
1. Pain evaluation (see Table 1)
2. Visual acuity and refraction (see Figures 1-5 and Table 2)

Figure 1. Uncorrected distance visual acuity 12 months after epithelium-on and epithelium-off CXL.

Table 1. Pain Evaluation

<table>
<thead>
<tr>
<th></th>
<th>Pain Score</th>
<th>Time Point of the Most Intense Pain (hour)</th>
<th>Pain Length (hour)</th>
<th>Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epithelium-on CXL</td>
<td>3.03 ± 0.73</td>
<td>3.78 ± 1.67</td>
<td>11.63 ± 5.89</td>
<td>13</td>
</tr>
<tr>
<td>Epithelium-off CXL</td>
<td>3.33 ± 0.38</td>
<td>6.25 ± 3.38</td>
<td>33.90 ± 23.76</td>
<td>5</td>
</tr>
<tr>
<td>P-value</td>
<td>0.3765</td>
<td>0.002</td>
<td>0.000</td>
<td>-</td>
</tr>
</tbody>
</table>
Figure 2. Development in uncorrected distance visual acuity pre- and 1-12 months postoperatively.

Figure 3. Change in Snellen lines in corrected distance visual acuity 12 months after epithelium-on and epithelium-off CXL.

Figure 4. Development in corrected distance visual acuity pre- and 1-12 months postoperatively.

Figure 5. Stability of spherical equivalent refraction 1-12 months after epithelium-on and epithelium-off CXL.

Figure 6. Stability of refractive cylinder 1-12 months after epithelium-on and epithelium-off CXL.
3. Corneal topography and wavefront aberrations (see Figure 7 and Table 3)

![Figure 7](image-url)

4. Endothelial cell count

III. Discussion

A. Why used hypotonic riboflavin solution?

1. To increase the permeability of the corneal epithelium\(^\text{18}\)

2. To increase riboflavin penetration into the stroma\(^\text{19}\)

B. Why used 0.5% riboflavin solution?

To increase the concentration gradient across the epithelium, with an aim to enhance its penetration and achieve higher UVA absorption\(^\text{19-22}\)

C. Why were the corneal topography and wavefront aberrometry changes lower than previously reported?

1. Higher concentration of riboflavin in the stroma may have led to quicker oxygen consumption and therefore a reduction in the efficiency of CXL\(^\text{23}\)

2. Corneal hydration caused by the hypotonic solution may have led to slower oxygen transporta-\(^\text{24}\)

D. Interpretation of epithelial absorption / filtering of UVA radiation\(^\text{10,25}\)

IV. Conclusion

A. The current study showed no difference in safety and efficacy between the “epithelium-on” and the “epithelium-off” CXL using a protocol that ensures corneal saturation with 0.5% hypotonic riboflavin solution.

B. Efficacy in reversing topography features of keratoconus with use of 0.5% hypotonic riboflavin seems to be lower compared to the reported results with “standard” 0.1% riboflavin.

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### Table 2. Changes in Visual Acuity and Refraction During 12-Month Follow-up

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CXL</th>
<th>Preoperative</th>
<th>1 Month</th>
<th>6 Months</th>
<th>12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>UDVA (logMAR)</td>
<td>Epithelium-on</td>
<td>0.77 ± 0.39</td>
<td>0.62 ± 0.36(^a)</td>
<td>0.54 ± 0.37(^a)</td>
<td>0.62 ± 0.37(^a)</td>
</tr>
<tr>
<td></td>
<td>Epithelium-off</td>
<td>0.67 ± 0.44</td>
<td>0.62 ± 0.45</td>
<td>0.54 ± 0.43(^a)</td>
<td>0.50 ± 0.44(^a)</td>
</tr>
<tr>
<td>P-value</td>
<td>0.394</td>
<td>0.962</td>
<td>0.991</td>
<td>0.289</td>
<td></td>
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<tr>
<td>CDVA (logMAR)</td>
<td>Epithelium-on</td>
<td>0.20 ± 0.19</td>
<td>0.11 ± 0.14(^a)</td>
<td>0.06 ± 0.12(^a)</td>
<td>0.02 ± 0.89(^a)</td>
</tr>
<tr>
<td></td>
<td>Epithelium-off</td>
<td>0.16 ± 0.13</td>
<td>0.13 ± 0.18</td>
<td>0.09 ± 0.15(^a)</td>
<td>0.05 ± 0.12(^a)</td>
</tr>
<tr>
<td>P-value</td>
<td>0.402</td>
<td>0.633</td>
<td>0.424</td>
<td>0.239</td>
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<tr>
<td>SE(D)</td>
<td>Epithelium-on</td>
<td>-1.58 ± 3.00</td>
<td>-1.32 ± 2.97</td>
<td>-1.97 ± 3.10</td>
<td>-1.73 ± 2.66</td>
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<tr>
<td></td>
<td>Epithelium-off</td>
<td>-1.81 ± 2.48</td>
<td>-2.06 ± 3.39</td>
<td>-1.61 ± 2.24</td>
<td>-1.68 ± 2.32</td>
</tr>
<tr>
<td>P-value</td>
<td>0.746</td>
<td>0.436</td>
<td>0.619</td>
<td>0.945</td>
<td></td>
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<tr>
<td>Cylinder (D)</td>
<td>Epithelium-on</td>
<td>-3.19 ± 2.49</td>
<td>-2.58 ± 2.11</td>
<td>-2.64 ± 2.35</td>
<td>-2.66 ± 2.34</td>
</tr>
<tr>
<td></td>
<td>Epithelium-off</td>
<td>-3.54 ± 2.10</td>
<td>-3.26 ± 2.07</td>
<td>-3.09 ± 2.33</td>
<td>-2.79 ± 2.25</td>
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<tr>
<td>P-value</td>
<td>0.543</td>
<td>0.167</td>
<td>0.453</td>
<td>0.852</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) The difference between pre- and postoperative data was statistically significant (\(P < .05\)).

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This document contains text and tables discussing corneal topography, wavefront aberrations, endothelial cell count, and various factors influencing the outcomes of corneal cross-linking (CXL) procedures, including the use of hypotonic riboflavin solutions.
Table 3. Changes in Topography Features and Wavefront Aberrations During 12-Month Follow-up

<table>
<thead>
<tr>
<th>Parameter</th>
<th>CXL</th>
<th>Preoperative</th>
<th>1 Month</th>
<th>6 Months</th>
<th>12 Months</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pachymetry (μm)</td>
<td>Epithelium-on</td>
<td>459.50 ± 39.24</td>
<td>445.50 ± 48.92&lt;sup&gt;a&lt;/sup&gt;</td>
<td>453.50 ± 47.02</td>
<td>458.25 ± 41.09</td>
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<tr>
<td></td>
<td>Epithelium-off</td>
<td>463.05 ± 31.34</td>
<td>434.35 ± 33.90&lt;sup&gt;a&lt;/sup&gt;</td>
<td>434.65 ± 31.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>450.55 ± 32.14&lt;sup&gt;a&lt;/sup&gt;</td>
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<tr>
<td></td>
<td>P-value</td>
<td>0.625</td>
<td>0.286</td>
<td>0.051</td>
<td>0.273</td>
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<td>IRI (μm)</td>
<td>Epithelium-on</td>
<td>34.25 ± 18.57</td>
<td>34.35 ± 18.66</td>
<td>33.65 ± 20.16</td>
<td>35.30 ± 20.09</td>
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<tr>
<td></td>
<td>Epithelium-off</td>
<td>36.40 ± 13.10</td>
<td>38.05 ± 14.41</td>
<td>34.30 ± 13.91</td>
<td>33.15 ± 13.75</td>
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<tr>
<td></td>
<td>P-value</td>
<td>0.658</td>
<td>0.400</td>
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<td>PE (μm)</td>
<td>Epithelium-on</td>
<td>61.80 ± 24.90</td>
<td>62.25 ± 28.22</td>
<td>60.80 ± 24.11</td>
<td>63.00 ± 31.67</td>
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<tr>
<td></td>
<td>Epithelium-off</td>
<td>60.65 ± 27.01</td>
<td>59.55 ± 27.30</td>
<td>63.90 ± 25.57</td>
<td>67.35 ± 28.60</td>
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<tr>
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<td>P-value</td>
<td>0.865</td>
<td>0.717</td>
<td>0.611</td>
<td>0.486</td>
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<td>Sim K1 (D)</td>
<td>Epithelium-on</td>
<td>47.89 ± 4.46</td>
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<tr>
<td></td>
<td>Epithelium-off</td>
<td>47.51±2.98</td>
<td>47.52 ± 4.29</td>
<td>47.74 ± 4.43</td>
<td>47.25 ± 3.91</td>
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<tr>
<td></td>
<td>P-value</td>
<td>0.695</td>
<td>0.758</td>
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<td>Sim K2 (D)</td>
<td>Epithelium-on</td>
<td>44.29 ± 2.77</td>
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<td>44.34 ± 2.77</td>
<td>44.47 ± 2.80</td>
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<tr>
<td></td>
<td>Epithelium-off</td>
<td>44.71 ± 2.98</td>
<td>44.17 ± 3.25</td>
<td>44.17 ± 3.14</td>
<td>44.01 ± 2.97</td>
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<tr>
<td></td>
<td>P-value</td>
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<td>K-max (D)</td>
<td>Epithelium-on</td>
<td>52.68 ± 5.35</td>
<td>52.95 ± 5.38</td>
<td>52.40 ± 5.74</td>
<td>52.78 ± 5.55</td>
</tr>
<tr>
<td></td>
<td>Epithelium-off</td>
<td>53.59 ± 4.72</td>
<td>53.40 ± 5.03</td>
<td>53.58 ± 5.59</td>
<td>53.28 ± 5.18</td>
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<td></td>
<td>P-value</td>
<td>0.525</td>
<td>0.555</td>
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<td>RMS: HOAs</td>
<td>Epithelium-on</td>
<td>1.18 ± 0.67</td>
<td>1.20 ± 0.60</td>
<td>1.20 ± 0.71</td>
<td>1.20 ± 0.77</td>
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<tr>
<td></td>
<td>Epithelium-off</td>
<td>1.15 ± 0.55</td>
<td>1.15 ± 0.51</td>
<td>1.12 ± 0.57</td>
<td>1.07 ± 0.58</td>
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<td></td>
<td>P-value</td>
<td>0.980</td>
<td>0.496</td>
<td>0.714</td>
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<tr>
<td>RMS: S3+5+7</td>
<td>Epithelium-on</td>
<td>1.15 ± 0.65</td>
<td>1.16 ± 0.59</td>
<td>1.12 ± 0.71</td>
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<td></td>
<td>Epithelium-off</td>
<td>1.11 ± 0.55</td>
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<td>P-value</td>
<td>0.953</td>
<td>0.545</td>
<td>0.769</td>
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</tbody>
</table>

<sup>a</sup> The difference between pre- and postoperative data was statistically significant (P < .05).

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Corneal Densitometry and Ocular/Corneal Scatter Measurements

Roger Zaldivar MD

As an eye specialist can never really know how a patient sees a given image, we must rely on patient dissatisfaction as a key indicator of suboptimal vision. But given that patients often struggle to clearly articulate visual quality problems, the utility of this method of identifying visual problems is somewhat limited.

The problem of accurately determining the presence of suboptimal visual quality is further compounded by the way in which numerous factors, such as refractive power, ocular dynamics, and brain-based image interpretation, contribute to the final image a patient sees. And as these are factors that can fluctuate, so can a patient’s appreciation of visual quality.

The Benefits of Objectivity

A simple solution to this problem is to measure visual quality objectively rather than subjectively, and this is something that we’ve been doing with the HD Analyzer (Visiometrics; Terrassa, Spain) at our clinic in Mendoza. This device is a next-generation optical quality analysis system (OQAS) that assesses visual quality whenever such a measure is needed, be that among refractive or cataract patients. As the process is purely objective, it removes from the patient the responsibility of recognizing and describing suboptimal vision. Instead it measures the presence of light scatter that arises from any disturbance in light’s path, such as corneal disease, tear film imperfections, opacities in the crystalline lens, and this measurement indicates image quality. As tear film structure, higher-order aberrations, light diffraction, and light scattering all influence the quality of a final retinal image, the HD Analyzer integrates them in a measurement called OSI, or objective scattering index.

The concept of measuring visual quality when attempting to optimize vision is by no means new. Devices such as corneal topographers and wavefront aberrometers have been used for this purpose for many years. But as they produce difficult-to-interpret results and don’t take into account important information such as scattering, their clinical usefulness remains limited.

The Science Behind the Device

The HD Analyzer, developed by Prof. Pablo Artal from the University of Murcia, is based on the double-pass technique and offers a simple approach to visual quality assessment. It involves the analysis of a punctual light source imaged on the retina after passing twice through the eye’s structures. Measures of point spread function (PSF), objective scatter index (OSI), modulation transfer function (MTF), and tear film quality are captured by the device and are used to provide an image and a score that reflect a patient’s visual quality. The measure of OSI is particularly important in determining visual quality as it quantifies the extent to which light scatters once inside the eye. The HD Analyzer quantifies light scatter by assessing the intensity of light distribution in the outer parts of the image obtained after the double pass process. OSI values can range from 0 to 25, where increasing OSI indicates worsening visual quality. In general, average visual quality is reflected by an OSI of around 1, whereas OSI values over 5 indicate high levels of light scattering and poor visual quality.

The measurement of OSI by the HD Analyzer also aids early detection of cataracts and assists the monitoring of cataract progression because light scatter increases as cataracts mature. And as the measurements captured by the HD Analyzer also reflect tear film dynamics, the device can be used to complement conventional dry eye diagnosis and treatment response monitoring methods.

Addressing Post-Refractive Surgery Visual Quality Myths

We recently conducted a small study to determine the true level of visual quality achieved by patients after different refractive procedures. In the study, 7 refractive patients were implanted with an implantable collamer lens (ICL) and 7 underwent LASIK (Intralase Femtosecond Laser, Abbott Medical Optics; Santa Ana, Calif.). The OQAS-based assessments were performed with the HD Analyzer at 4 hours and 1 day postintervention. The findings revealed that, contrary to popular belief, better visual quality was achieved with ICL implantation than with LASIK, and this visual quality was established more quickly with ICL than with LASIK. Patients in the ICL group displayed OSI measurements of approximately 0.5 at postintervention Day 1, and this measurement did not fluctuate with time. In contrast, those in the LASIK group had OSI measurements ranging between 1.4 and 2.0 by Day 1.

As our clinic offers LASIK procedures, we often come across the opinion that because LASIK is a fast and noninvasive procedure, the results achieved are better than those obtained with the more time-consuming process of implanting an ICL. However, research has long suggested that a much better quality of vision can be achieved with ICL implantation because it is a procedure that doesn’t destabilize or diminish the tear film. And given that the tear film has an important role in decreasing corneal irregularities, the absence of tear film alteration in ICL implantation ensures that new aberrations are not induced by the procedure. With LASIK, the study results showed very high OSI measurements at 4 hours following intervention (ranging from 4.4 to 5.7), which improved over the course of Day 1. This accurate reflection of how visual quality changes with time following LASIK demonstrates just how precise the HD Analyzer is at capturing visual quality. The steady fall in OSI measured by the HD Analyzer echoed this pattern of events.

This small study with the HD Analyzer demonstrates that although LASIK does improve visual acuity immediately after the surgery, the dramatic effects often reported after the procedure may have little to do with exceptional visual quality and more to do with the sudden improvement in acuity. Many patients who present for LASIK are used to seeing very little without glasses or contact lenses. Suddenly seeing clearly without glasses can trigger much excitement that can be misinterpreted as exceptional visual quality. The HD Analyzer sheds light on such misconceptions, and in doing so, helps guide eye physicians on the best approaches for maximizing the visual quality of all their patients.
Moving Forward

The system, which provides a unique objective measure of visual quality in only 5 minutes, is already being used in the daily management of refractive patients in clinics across Europe. At present its common uses include diagnosing eye disease, demonstrating the effect of higher-order aberrations and accommodation on a patient’s visual acuity, and performing pre- and post-refractive and cataract surgery assessments. In all of these everyday eye clinic scenarios, achieving the best vision for a patient requires maximizing visual acuity as well as quality. Given the variation in patient understanding and vocalization of visual quality, it is clear that an objective method of determining visual quality is needed in today’s ophthalmology market. And as more and more physicians grow acquainted with the capabilities of the HD Analyzer, it is our hope that this device will help to boost visual standards among ophthalmic patients.

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Brillouin Corneal Imaging and Biomechanical Assessment

Roberto Pineda MD

I. Introduction
   A. Why are corneal biomechanics important?
      1. Keratoconus identification
      2. Refractive surgery screening
   B. How are we measuring corneal biomechanics today?
      1. Ex vivo techniques
      2. In vivo techniques
         a. Ocular Response Analyzer
         b. Corvis ST

II. Brillouin Optical Microscopy
   A. What is Brillouin scattering?
   B. How is Brillouin scattering measured?
      1. Spectroscopy
      2. Limitations of Brillouin microscopy
   C. What can Brillouin scattering measure?
      1. Corneal elasticity
      2. Corneal viscosity
      3. Lens elasticity
   D. Brillouin microscopy and keratoconus: Focal and regional maps
   E. Brillouin microscopy and corneal crosslinking
      1. Epi-off
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   F. Human studies and Brillouin microscopy
Interferometry a Quantitative Measure for Corneal Biomechanics: Recent Advances

John Marshall PhD
Comparative Study of Cornea and Anterior Segment Biometric Features Between Scanning Slit Beam Technology, Placido Disk Topography, and a Scheimpflug Imaging System

**Presenting Author:** Juan Carlos Serna MD  
**Coauthors:** Arturo J Ramirez-Miranda MD, Aida Jimenez, Alejandro Navas MD, Enrique O Graue Hernandez MD

**Purpose:** To compare 3 anterior segment biometric features (K-readings, white-to-white, and anterior chamber depth) by 3 different topography systems.  
**Methods:** Thirty-four eyes were examined with scanning-slit technology (Orbscan II), Scheimpflug imaging system (Pentacam), and Placido disk (Aladdin), and the intraclass correlation coefficient (ICC) was calculated with Bland-Altman analysis.  
**Results:** A high ICC and agreement between Aladdin and Orbscan for K-min \( r = 0.93 \), K-max \( r = 0.98 \), and white-to-white \( r = 0.72 \) and between Aladdin and Pentacam for K-min \( r = 0.96 \) and K-max \( r = 0.97 \) was observed. A weak correlation for anterior chamber was noted in all comparisons.  
**Conclusion:** Ks and white-to-white measurements with several systems can be used interchangeably in normal corneas.

Quantitative Evaluation of the Natural Progression of Keratoconus With 3-D Anterior Segment OCT

**Presenting Author:** Naoyuki Maeda MD  
**Coauthors:** Hisataka Fujimoto MD, Hayato Mitamura MD, Yoshinori Oie MD, Takeshi Soma MD, Shizuka Koh MD, Motoyuki Tsujikawa**, Kohji Nishida MD, Satoshi Kawasaki MD

**Purpose:** To evaluate the progression of keratoconus quantitatively.  
**Methods:** We followed 119 eyes with keratoconus, keratoconus suspect, and forme fruste keratoconus for up to 5 years using swept-source OCT. Age-related changes (19-78 years) in corneal thickness, curvature, and asymmetry were investigated.  
**Results:** We observed significant progression in thinnest corneal thickness (-7.3 ± 17.0 mm, \( P = .0001 \)) and anterior best-fit sphere (-0.05 ± 0.11 mm, \( P = .0001 \)) without changes in the location of the thinnest point.  
**Conclusion:** Sequential measurements of corneal thickness and steepening with OCT are promising methods for considering and monitoring surgical interventions for keratoconus.

Enhanced Ectasia Susceptibility Screening Based on Clinical Data and Pentacam

**Presenting Author:** Isaac O Ramos MD  
**Coauthors:** Fernando António Faria-Correia**, Allan Luz MD**, Bernardo Teixeira Lopes MD**, Livia Jordao, Rosane Oliveira Correa MD, Marcela Salomao MD**, Renato Ambrósio Jr MD

**Purpose:** To test a described criterion based on clinical and tomography data to identify preoperative risk for ectasia.  
**Methods:** The preoperative clinical and tomographic data from 46 eyes from 38 patients who developed ectasia after LASIK (Group 1) and 266 control eyes from 141 patients with stable LASIK (Group 2) were analyzed. The Enhanced Ectasia Susceptibility Screening (EES) was used to distinguish the groups.  
**Results:** The EES obtained 90% of sensitivity and 92% of specificity, with AUC = 0.936 to distinguish the groups.  
**Conclusion:** The ESS is a valid and effective method for detecting eyes at risk for ectasia after LASIK. This combined parameter represents a significant improvement over previously utilized screening strategies.

Comparison of Metrics Obtained With Discriminant Analysis and Decision Trees for the Detection of Subclinical Keratoconus

**Presenting Author:** Jens Buehren MD  
**Coauthors:** Sonja Kleinhans**, Eva Herrmann PhD**, Thomas Kohnen MD PhD FEBO

**Purpose:** To compare the ability of discriminants and decision trees for building metrics to detect subclinical keratoconus.  
**Methods:** Scheimpflug tomography was performed in 32 normal eyes with keratoconus in the fellow eye and 245 control eyes. Single value metrics from tomography input data were built with discriminant analysis and decision trees.  
**Results:** Accuracy was higher for metrics based on decision trees (89.2%-92.4%) than for metrics based on discriminant analysis (75.5%-90.7%). Decision trees showed also higher specificity (93.5%-98.4%), while sensitivity was lower (21.9%-78.1%).  
**Conclusions:** Decision trees achieved a slightly higher accuracy and specificity than discriminant functions but did not provide a clinically acceptable sensitivity.

**The co-author has not submitted financial interest disclosure information as of press date.**
Biological and Biomechanical Responses to Traditional Epithelium-off and Transepithelial Riboflavin-UVA CXL Techniques in Rabbits

Brian Armstrong MD


Purpose
To compare the biological effects of riboflavin ultraviolet A (UVA) corneal cross-linking (CXL) performed with a traditional epithelium-off method to several transepithelial methods in a rabbit model. Preliminary experiments on biomechanical rigidity were also performed.

Methods
Four treatment groups were included: (1) standard epithelium-off, (2) tetracaine transepithelial, (3) benzalkonium chloride-ethylenediaminetetraacetic acid (BKC-EDTA) transepithelial, and (4) femtosecond laser-assisted transepithelial riboflavin-UVA CXL. Six eyes from each treatment group and the untreated control group were analyzed at 24 hours and 2 months after treatment in wound healing studies. The TUNEL assay was performed to detect the extent of stromal cell death. Optical density was measured with a Scheimpflug analyzer. The corneal stiffening effect was quantitated in 3 eyes from each group using optical coherence elastography performed 2 months after treatments.

Results
Twenty-four hours after CXL, stromal cell death extended full corneal thickness with both standard epithelium-off CXL and femtosecond laser-assisted CXL, but only approximately one-third stromal depth after BKC-EDTA transepithelial CXL. Negligible stromal cell death was detected with tetracaine transepithelial CXL. Cell death results were statistically different between the BKC-EDTA transepithelial CXL and standard epithelium-off CXL groups ($P < .0001$). Significant corneal opacity differences were noted. Standard epithelium-off CXL had the greatest density and tetracaine transepithelial CXL had the least density compared to the control group after treatment. As measured with optical coherence elastography, a trend toward greater mean stiffening was observed with BKC-EDTA transepithelial CXL than with epithelium-off CXL, femtosecond laser-assisted CXL, or tetracaine transepithelial CXL, but the result did not reach statistical significance. All of the CXL treatment groups exhibited significantly smaller variance of stiffness compared to the control group.

Conclusion
In the rabbit model, BKC-EDTA transepithelial CXL produced less stromal cell death and less risk of endothelial cell damage than standard epithelium-off CXL or femtosecond laser-assisted CXL. Additional study is needed to determine whether biomechanical stiffness is significantly different between the epithelium-off CXL and transepithelial CXL groups.
Keratoconus Management: Long-term Stability of Topography-Guided Normalization Combined With High-Fluence Crosslinking Stabilization (The Athens Protocol)

A John Kanellopoulos MD

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OCT Combined With Videokeratography to Differentiate Mild Keratoconus Subtypes

Yaron S Rabinowitz MD
Femtosecond Cataract Innovations

Burkhard Dick MD

It took approximately 200 years from Jacques Daviel’s introduction of extracapsular lens extraction to Harold Ridley’s IOL and a further 40 years to phacoemulsification. The femtosecond laser is a symbol of an ever-faster evolution of medical technology. Within just a short period of time, its potential has been explored by clinicians utilizing the innovations that come with the laser and developing new techniques in their daily work with a technology that by no means has yet reached its limits.

The advent of the femtosecond laser in cataract surgery is not just a step toward more precision, a few better functional results here, some higher patient satisfaction there. The femtosecond laser opens the door to something completely new—to procedures that have not been possible up to now. This concerns pediatric cataract surgery, it leads to the development of new IOL types implanted with a completely new mode of fixation. And in probably the most important leap forward: we can employ the laser after surgery actually is over, on an eye that is not open any longer—and with the posterior laser-assisted capsulotomy thus performed (see below), we will probably reduce the most common undesired side effect of lens surgery, posterior capsule opacification, or after-cataract. These are things that have not been done before!

Pioneering in Pediatric Cataract Surgery

A precise intervention with the best visual results, the highest chances to prevent amblyopia, and optimal safety margins are particularly desirable in patients who will live with the results of cataract surgery for the next 80 or 90 years: children with congenital cataract. We have used the femtosecond laser off-label in more than 28 interventions so far, all under general anesthesia. Since none of the laser systems were created for the treatment of small children, placing the fluid-filled interface between the laser and the globe sometimes required a small lateral cantholysis; this now in most cases is no longer necessary in operating centers equipped with a femtosecond laser that uses a special interface for narrow lid margins and small eye (LOI 12). Treatment time was very short. In most cases, the anterior and posterior capsule discs were easy to remove. No capsular tears occurred. No significant intra- or postoperative complications were observed. This technique has great potential to increase the predictability, accuracy, and safety of congenital cataract surgery. The posterior capsulotomy can be precisely centered relative to the anterior capsulotomy. Aphakic correction with contact lenses and later secondary IOL implantation is reasonable because the rate of axial growth is especially high in the first year. An IOL should be implanted in a secondary intervention before school enrollment, ie, before the age of 6.1

The Femto-IOL: Stable and Permanent Positioning

Having a good and intraoperatively fixed position and centration is essential for toric, multifocal, and aspherical IOLs. Femtosecond lasers make it technically possible to cut an anterior capsulotomy with preset size, circularity, and sufficient strength. The system’s 3-D spectral domain OCT visualizes both the curvature of the anterior and of the posterior capsule as well as the lens equator plane for creating a treatment plan. Less aligned with the center of the pupil and more with the line of sight, the optic of certain IOLs can be fixated within the anterior capsulotomy. There are a number of advantages that can be expected from these new foldable acrylate IOLs, its fixation in the anterior capsulotomy and from centering the anterior capsulotomy on the scanned capsule rather than centering the capsulotomy on the pupil:

- A permanent and close-to-perfect centration of the IOL, which is not guaranteed by the more conventional 360-degree overlap—this reliable centration is essential for special implants like multifocal IOL, aspheric IOL, etc.
- An excellent predictability of the IOL position that is not threatened by capsular bag shrinkage (which, on the contrary, will rather strengthen the Femto-IOL fixation)
- A faster visual rehabilitation
- No IOL rotation, which is made impossible by this type of suspension

We have recently gained our first experience using the anterior laser capsulotomy in combination with a new IOL. The 90F IOL (Morcher GmbH; Stuttgart, Germany) has the design of a C-loop IOL with an additional flank. The anterior capsule can be fixated in this groove, which is comparable to the in-the-bag lens technique. The anterior capsule is placed in the lens at the 6-o’clock position and followed by placements at the 9-, 12-, and 3-o’clock positions. It was possible in all 6 eyes that had this type of IOL implanted to position the anterior capsule in the 90F IOL optic in all cases. All patients achieved a significant increase in visual acuity. The spherical equivalent was not statistically different between 1 week (−0.56 ± 0.53 D) and 1 month (−0.66 ± 0.54 D) postoperatively (P = .10). In this time period, the average individual anterior chamber depth differed by 0.01 ± 0.05 mm (range: −0.06 to 0.04 mm; P = .70). At the 1-month follow-up, no complications (eg, increased inflammation, fibrin reaction, tilt, optic or haptic degradation, pigment dispersion, iris capture, or macular edema) were observed.2

Special Femto-IOLs have been developed (Lenti Laser Lens by Oculetis, 90F, as well as the Masket ND IOL, both from Morcher) and are currently being introduced into the market. Another interesting option with this technique is an individually adjusted capsulotomy shape, not completely circular and with markings in its rim zone to adjust an IOL to an individual optical alignment.

Preventing Posterior Capsule Opacification With Posterior Primary Laser-Assisted Capsulotomy

It is not an exaggeration to quip that while cataract surgery is the most frequent surgical intervention of our time in the industrialized world, treating a consequence of that intervention—posterior capsule opacification (PCO)—by Nd:YAG capsulotomy is the second-most frequent intervention in modern medicine.

The Berger space is a tiny anatomical void between the posterior capsule and the anterior hyaloid membrane. At the
end of cataract surgery (ie, after IOL implantation), this small lacuna usually turns out to be larger than before, and larger than expected: up to the advent of femtosecond laser systems with imaging systems like, for instance, a full volume 3-dimensional spectral-domain OCT of the Catalys Precision Laser System, there was no way for the surgeon to intraoperatively visualize these structures. Now performing a primary posterior laser-assisted capsulotomy (PLC) is relatively easy. After the cataract surgery case is finished, the eye is redocked to the laser and the surgeon uses the OCT treatment screen to place the inferior third of the cylindrical capsulotomy treatment zone on the posterior capsule. Depending on the size of the Berger space, an incision depth between 400 and 800 μm is programmed to stay within the Berger space. The pulse energy is set to 9 to 10 μJ, and the capsulotomy diameter is usually 3.5 mm or greater. After confirmation of the treatment zones, the laser delivers pulses moving in an anterior direction. Because of the now relatively large Berger space—probably because the IOL is so much thinner than the natural lens—the laser is not firing in potentially dangerously close proximity to the vitreous when creating the PLC. Even if that would happen, the damage can be expected to be minimal. The extremely thin posterior capsule button forms a tiny scroll and drops out of view within just a short time. After undocking, the patient is rotated under the operating microscope for inspection. In our case series, the OCT succeeded in visualizing the posterior capsule after laser cataract surgery and IOL implantation in 53 of 55 patients (96%), and thus enabled us to cut a PLC. In 2 eyes (4%), no posterior PLC was performed because the anterior and posterior surfaces of the IOL were visible, but a certain identification of the posterior capsule for a safe and successful PLC was not possible. Further trials might help to identify preoperative feasibility factors.

This additional procedure has proved to be safe in all cases. No complications have occurred. This suggests that cataract surgeons could more easily adopt the PLC procedure than the manual posterior capsulorrhexis. Primary PLC has an immense potential to reduce PCO, the most common long-term complication of cataract surgery.  

Evolving Techniques for Challenging Cases: Pupil Expansion, Dimple-Down

Intraoperative small pupils, for cataract surgeons traditionally a challenge and for the patient a higher risk of complications, can be overcome by iris hooks or insertion of the Malyugin ring. These devices make a perfectly circular, perfectly centered anterior capsulotomy created by the femtosecond laser possible even in these difficult cases. The Malyugin ring, for instance, is implanted after homogenous filling of the anterior chamber with ophthalmic viscosurgical device (OVD). After stabilizing the anterior chamber with BSS and careful hydration of the paracenteses and the main incision, the docking of the laser system’s interface is performed and laser treatment commenced as usual. All the necessary steps like capsulotomy and lens fragmentation can be performed conveniently while the ring is in place.

Whether using the Malyugin ring or iris retractors, or operating on eyes with a regularly dilated pupil, the dimple-down technique, developed while exploring the possibilities of operating with the femtosecond laser, has proved valuable in verifying whether a free-floating capsulotomy has been achieved. The paracentesis is opened with a blunt cannula attached to a BSS or an OVD syringe. We then instill OVD to maintain the anterior chamber (if desired), advance the cannula to the middle of the lens capsule coming from the opposite AC angle, and press downward with the tip of the cannula at the center of the capsule. This downward motion indents the capsule disc, pulls it gently centrally, separates the free edge from the surrounding peripheral capsule, and confirms that there is a continuous 360-degree cut with a free disk. If a tag is present, this maneuver will identify its location and usually “pop” it free without causing a radial tear. We have not seen any capsule tears resulting from femtosecond laser capsule tags using this dimple-down technique in more than 800 cases.  

Outlook

Further innovations are being developed to overcome challenging situations. One of numerous improvements based on clinical experience is the newly developed smaller patient interface, with a diameter of 12 mm, conceived for patients with a narrow lid margin. Just recently a new hardware and software version has been introduced that in the case of suction loss will stop treatment immediately. These are further refinements of a technology that has already proven to be extremely safe, particularly after climbing the learning curve. In the center that introduced the femtosecond laser into cataract surgery, whatever minor complications the surgeons encountered over the first 4 years happened only in the first 100 cases.  

Cataract surgery has just started to explore new ways to make the most frequent surgical intervention in modern medicine even safer, even more effective. With the femtosecond laser ever more firmly established, the future looks bright indeed.

References

Photo-Activated Chromophore for Infectious Keratitis Crosslinking and the Impact of Fluorescein on the Antimicrobial Efficacy of Photoactivated Riboflavin in Corneal Crosslinking

Farhad Hafezi MD PhD

Introduction
Severe visual impairment due to corneal infection (corneal ulcers) represents a major cause of global blindness. Studies from defined geographical areas like the Indian subcontinent report an estimate of 2 million new cases/year in India alone. In developing countries, corneal infections are most often due to a minor trauma to the cornea that is not taken care of correctly and in a timely manner. In the developed countries, extended wear of soft contact lenses is the most common cause for corneal ulcers. The most common pathogens that cause corneal ulcers on a global level are bacteria and fungi (and mixed infections), followed by Acanthamoeba ulcers (a parasite), and, lastly, viral keratitis (herpes simplex and others).

The problems in corneal infections are multiple:

- Diagnostic dilemma: Corneal infections may be caused by a multitude of organisms, including bacteria, fungi, parasites, and viruses. Often, the clinical picture does not allow for an easy identification of the underlying pathogen and corneal swabs remain negative.
- Therapeutic dilemma: These circumstances make the choice of an appropriate therapy difficult in many cases. Current therapies include antibiotic, antifungal, and antiviral medications and, in the case of Acanthamoeba keratitis, even disinfecting agents. On top of this, the emerging resistance to fluoroquinolones might increase over the years.
- Economical considerations: Treatment costs for corneal ulcers may range from several hundreds to several thousands of U.S. dollars. Costs relate to medication and visits with the treating ophthalmologist, and, in severe cases, hospitalization and 24-hour instillation of medication. These costs cannot be handled in most developing countries.

Background Information
In 2008, a new concept was taken from transfusion medicine and transferred to ophthalmology: the reduction of pathogen load in platelet concentrates is achieved by treatment of concentrates with riboflavin (Vit B2 as a chromophore and UV-A light). In analogy, a research group in Zurich, Switzerland, which the author of this abstract was part of, showed that this application could be also applied in human corneal infection. The proof-of-principle study included 5 corneas that were therapy-resistant to any conventional type of treatment. In all 5 cases, the corneal infection calmed down within days to weeks and all eyes could be saved.

In the same year, the effect of riboflavin/UV-A irradiation was shown in vitro on several bacteria and fungi, with a killing rate of almost 98% within 30 minutes for the most common strains responsible for bacterial keratitis, like methicillin-resistant Staphylococcus aureus and Pseudomonas aeruginosa.

A case series and a clinical Phase I study performed by Makdoumi et al showed the beneficial effect of PACK-CXL (photoactivated chromophore for the treatment of infectious keratitis-corneal crosslinking) in 15 eyes of 15 patients with early onset corneal ulcers. Here, PACK-CXL was even used as the primary therapy, whereas controls received maximal conventional therapy (medication). Again, PACK-CXL alone was beneficial in the outcome in all eyes investigated. Between 2010 and 2013, our group performed a randomized prospective clinical trial examining the effect of adjuvant PACK-CXL therapy in advanced corneal ulcers with associated melting. Even in these far advanced cases with impending perforation, the additional effect of PACK-CXL was significant, with a drop in the ulcer-related complication rate from 23% (controls) to 0%. A number of smaller reports and case series have shown the effect of PACK-CXL on other bacterial, and also fungal infections.

Taken all current evidence together, PACK-CXL might be highly beneficial in early infiltrates and small ulcers, where the process has not exceeded a depth of 300 μm. On a side note, the pre-crosslinking application of fluorescein to detect the size of the ulcer should be avoided, since it competes with riboflavin for the energy of the UV light.

References


IOL Power Calculation in Keratoconus

**Presenting Author:** David T Truong MD  
**Coauthors:** R Wayne Bowman MD**

**Purpose:** To review the results of cataract surgery in keratoconus (KCN) and evaluate modern lens power formulas in KCN.  
**Methods:** Noncomparative case series of patients with KCN undergoing cataract surgery. Clinical data used to calculate predicted refraction and prediction errors using modern lens power formulas.  
**Results:** Surgeon-specific algorithms delivered manifest refractive spherical equivalence of −1.63 D and a prediction error of +1.0 D. Corneal power errors linearly correlated with refractive prediction errors \( r^2 = 0.92 \). Average absolute prediction error of Holladay II, Holladay II KK, Holladay I, Hoffer Q, and SRKT were 0.89 D, 0.53 D, 0.85 D, 0.68 D, and 0.88 D.  
**Conclusion:** Lens power formulas and adjustments with less sensitivity to corneal power variation result in better IOL prediction in KCN patients.

Results for an Advanced Nomogram for Nonpenetrating Intrastromal Femtosecond Laser Astigmatic Keratotomy During Laser-Assisted Cataract Surgery

**Presenting Author:** Julian D Stevens DO  
**Coauthors:** Nicola M Lau MBBS**, Alexander C Day MBBCHIR

**Purpose:** To report results of an advanced nomogram for intrastromal femtosecond laser astigmatic keratotomy during cataract surgery.  
**Methods:** A Catalys laser was programmed for arcuate incisions 20% to 80% depth, 8.0-mm optical zone. The arc lengths were varied. Sixty-seven eyes were analyzed. The intended correction was for 0.87 up to 2.50 D. Age, cylinder magnitude, and angle were included in the nomogram v3.  
**Results:** Cylinder 2.0 to 2.50 D mean vector achieved was 70% of intended \((n = 5)\), 1.0 to 1.90 D, 73% of intended \((n = 47)\); 0.75 to 0.90 D, 78% \((n = 15)\). The rotation of postop residual cylinder and vector analysis revealed angle error is a major source of undercorrection.  
**Conclusion:** Intrastromal femtosecond astigmatic keratotomy is effective in reducing pre-existing cylinder up to 2.50 D, with angle error being a significant reason for undercorrection.

Efficacy of Techniques for Performing Femtosecond Laser-Assisted Cataract Surgery in the Presence of Small Pupils

**Presenting Author:** William W Culbertson MD  
**Purpose:** To evaluate methods for femtosecond laser-assisted cataract surgery (FLACS) in spite of small pupils.  
**Methods:** The effects and results of 4 techniques for enlarging the pupil—Shugarcaine injection (22), pupil stretching (4), Malyugin ring (4), and visco mydriasis (5)—were performed prior to laser treatment, and the safety and efficacy were recorded for all 35 cases.  
**Results:** In every case, the laser treatment of the capsule and lens was safely and effectively performed, with all capsulotomies 4.2 mm or greater and no incomplete treatments or capsulotomies.  
**Conclusion:** FLACS may be safely performed in patients with preoperatively small pupils by employing prelaser modifications.

Evolution Profiles of Different Corneal Parameters in Progressive Keratoconus

**Presenting Author:** David Smadja MD  
**Coauthors:** Marcony R Santihago MD, Glaucio H Reggiani Mello MD

**Purpose:** To evaluate the safety and efficacy of small-incision lenticule extraction (SMILE) on follow-up of more than 1 year and up to 3 years. A multicenter study.  
**Methods:** Prospective noncomparative case series carried out on 1936 eyes of 1013 myopic patients treated with femtosecond laser SMILE from 2010. UCVA, BSCVA, and manifest refraction were measured in all cases.  
**Results:** Mean preoperative UCVA, BSCVA, and spherical equivalent were 0.1, 0.8, and −4.93, respectively. All these parameters showed statistically significant change in the postoperative period \((P < .01)\). Mean postoperative UCVA, BSCVA, and spherical equivalent were 0.88, 0.98, and −0.38, respectively. A fewer operative and postoperative complications were reported.  
**Conclusion:** SMILE is a safe and effective procedure with long-term refractive stability.

Small-Incision Lenticule Extraction for Postkeratoplasty Myopia and Astigmatism

**Presenting Author:** Moones Fathi Abdalla MD  
**Coauthors:** Osama I Ibrahim MD PhD, Tamer Hamdy Massoud MD, Ahmed A K El-Massry MD

**Purpose:** To evaluate the safety and efficacy of small-incision lenticule extraction (SMILE) in postkeratoplasty eyes.  
**Methods:** The SMILE procedure was performed for patients with previous keratoplasty. The preoperative refractive errors, UCVA, and BCVA were recorded. The residual refractive error, UCVA, and BCVA were recorded 6 months postoperatively.  
**Results:** Eleven eyes of 11 patients underwent the SMILE procedure. Mean follow-up was 6 months. The mean UCVA (Snellen decimal) changed from 0.14 (range: 0.05-0.3) preoperatively to 0.68 (range: 0.4-0.8) postoperatively. The mean BCVA changed from 0.73 (range: 0.5-0.9) preoperatively to 0.8 (range: 0.6-0.9) 8 at 6 months postoperatively.  
**Conclusion:** The SMILE procedure for the correction of postkeratoplasty myopia and astigmatism is a reproducible procedure with good visual outcomes.

**Note:** The co-author has not submitted financial interest disclosure information as of press date.
Corneal Coupling—Its Importance in Incisional and Ablative Procedures

**Presenting Author: Noel A Alpins MD FACS**

**Coauthors: George Stamatelatos OD, James Ong**

**Purpose:** To present corneal coupling, and its importance in cataract and laser procedures.

**Methods:** Retrospective incisional and ablative data was analyzed to demonstrate how newly defined coupling terms can be applied.

**Results:** Compound myopic and hyperopic astigmatism excimer laser treatments (3818 eyes) showed a coupling ratio close to 0.0, a coupling constant close to 0.5, and a coupling adjustment close to 0.0. Incisional limbal relaxing incisions (74 eyes) demonstrated a coupling ratio close to 1.0, and a coupling constant close to 0.0.

**Conclusion:** The revised definitions of coupling ratio and coupling constant can be used with both incisional and ablative surgery. Coupling adjustment can be used to improve surgical outcomes.

**The co-author has not submitted financial interest disclosure information as of press date.**
### E-poster Index

E-posters will be available for viewing during the meeting in the Lakeside Lobby, Level 3, and after the meeting on the Academy’s website: [www.aao.org/2014](http://www.aao.org/2014)

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E-poster Abstracts

Corneal Crosslinking

Corneal Crosslinking With Verteporfin Nonthermal Laser Therapy
Abstract #: RP30040725

**Presenting Author: Saleh Aziz Alageel MD**

**Purpose:** To test if corneas treated with combined verteporfin with nonthermal laser (NTL) increased corneal mechanical stiffness and increased resistance to enzymatic degradation. **Methods:** Corneas treated with verteporfin alone, irradiation with nonthermal laser (NTL), without verteporfin, and combined treatment verteporfin with non-thermal laser therapy for 1 treatment sequence (V+NTL1) and 6 sequences protocol (V+NTL6). Others were pretreated with 0.1% riboflavin/20% dextran (R+UVA). The biomechanical properties were measured. **Results:** Crosslinked corneas with (R+UVA) and (V+NTL6) demonstrated a slower rate of dissolution ($P < .005$). The stress-strain tests showed stiffer than control ($P < .005$). **Conclusion:** We report for the first time that verteporfin non-thermal photodynamic laser increases corneal mechanical stiffness.

Objective Assessment of Corneal Haze Following Corneal Collagen Crosslinking for Keratoconus: The Double-Pass System Corneal Haze Score
Abstract #: RP30040754

**Presenting Author: Ali Fadlallah Yahya MD**

**Coauthors:** Chadi Mehanna MD, Geoffrey Dethorey MD**, Margaux Guillard MD**, Amari Belkacem DO**, Jean-Marc Legeais**

**Purpose:** To assess corneal haze level following corneal collagen crosslinking (CXL) for keratoconus (KC) by measuring ocular light scattering with a double-pass system (DPS). **Methods:** Thirty-eight eyes referred for CXL for stage 1 and 2 KC were enrolled in a prospective study. Patients with lens or retinal anomalies were excluded. Corneal haze was graded using the system described by Fantes. HD Analyser System measurements provided Objective Scatter Index (OSI). **Results:** We found correlations between OSI and haze grade ($P < .01$). The OSI was between 0.9 and 2.5 in 9 eyes with grade 0 haze; 2.5 and 5.0 in 16 eyes with grade +0.5; 5.1 and 10 in 8 eyes with grade 1+; >10 in 3 eyes with grade 2+; and nonmeasurable in 2 eyes with grade 3+ haze. **Conclusions:** OSI DPS may be an objective tool in the postoperative evaluation of corneal haze following CXL in patients with keratoconus.

Keratoconus: Refractive Results of Intracorneal Rings and Spot® Corneoscleral Lenses Without Corneal Crosslinking
Abstract #: RP30040775

**Presenting Author: Solange Leroux Les Jardins MD**

**Coauthor: Guillaume Leroux Les Jardins MD**

**Purpose:** Refractive outcome study of 92 keratoconus (KC) eyes operated on with intracorneal ring (ICR). Out of these 92 eyes, 31 eyes have been adapted with a corneoscleral contact lens (CSCL) to complete the result. None had corneal crosslinking (CXL). **Methods:** Retrospective study. Mean age 31 years. Not stabilized KC and corneoscleral intolerant KC. Mean preoperative uncorrected best visual acuity (UCBVA) and corrected best visual acuity (CBVA) were 1.3 and 0.32 logMAR. Mean spherical equivalent (SEQ) was −5.5 D. 5-mm ICRs, Spot CSCL. Follow-up was 1 year minimum. **Results:** With ICRs, 92 eyes, UCBVA, CBVA, and SEQ were improved ($P < .0001$, Student). With ICRs and CSCL (31 eyes), improvement was impressive ($P < .0005$). For all the eyes, KC stabilization, no complications. **Conclusion:** ICRs improve and stabilize KC eyes. Results can be completed with CSCL if necessary. None of these eyes had CXL.

Refractive Outcomes of Topography-Guided PRK With Simultaneous Crosslinking for Keratoconus
Abstract #: RP30040784

**Presenting Author: David T Lin MD**

**Coauthors:** Simon P Holland MD, Choon Hwai Johnson Tan MBBS, Gregory Moloney MD**, Christian R Diaz MD**

**Purpose:** To evaluate topography-guided PRK with collagen crosslinking (TG PRK/CXL) for keratoconus (KC) with contact lens intolerance (CLI). **Methods:** TG PRK/CXL was performed with Allegretto WaveLight laser and Dresden protocol. Safety and efficacy were evaluated at 1 year. **Results:** 218 of 442 treated eyes met follow-up criteria. Forty-six percent had UCVA ≥ 20/40; 54% improved BCVA, 20% gained ≥ 2 lines, 5% lost ≥ 2 lines. Mean reduction in astigmatism 1.69 ± 1.78 D. Mean spherical equivalent (SE) reduced from −2.74 ± 2.81 D to −1.24 ± 2.18 D. Seven had hyperopic progression, 4 had SE > 1.50 D. **Complications:** 1 herpetic keratitis, 7 delayed epithelialization, 5 reduced vision for haze; 3 required PK. **Conclusion:** 1-year outcomes of a large series of TG PRK/CXL showed satisfactory efficacy and safety. It can be an alternative to CLI patients with KC.

**The co-author has not submitted financial interest disclosure information as of press date.**
Early Results of Topography-Guided PRK Performed With Schwind Laser With Simultaneous Crosslinking for Keratoconus and Post-LASIK Ectasia

Abstract #: RP30040788

Presenting Author: Simon P Holland MD
Coauthors: David T Lin MD, Choon Hwai Johnson Tan MBBS, Christian R Diaz MD**, Gregory Moloney MD**

Purpose: To evaluate topography-guided PRK with collagen crosslinking (TG PRK/CXL) for keratoconus (KC) and post-LASIK ectasia. Methods: KC and post-LASIK ectasia eyes underwent TG PRK performed with Schwind laser with maximum tissue sparing followed by CXL. Safety and efficacy were evaluated at 6 months. Results: Twenty-one of 53 eyes met follow-up criteria. Seventy-nine percent had UCVA ≥ 20/40; 64% had improved BCVA; 49% gained ≥ 2 lines; none lost ≥ 2 lines. Mean reduction in astigmatism was 2.30 ± 1.76 D. Mean spherical equivalent was −3.54 ± 4.45 D preop, −1.02 ± 2.31 D postop. Conclusion: Early results of TG PRK/CXL using a Schwind laser for KC and ectasia showed good efficacy and safety, with half gaining ≥ 2 lines BSCVA and 80% having ≥ 20/40 UCVA. Potential advantages include excellent image capture, tracking, and tissue sparing.

Ex Vivo Objective Corneal Biomechanical Evaluation of Very High Fluence and Higher Riboflavin Concentration Corneal Crosslinking

Abstract #: RP30040792

Presenting Author: A John Kanellopoulos MD

Purpose: To evaluate ex-vivo biomechanical strengthening of intrastromal very high fluence and higher riboflavin concentration corneal crosslinking (vhF-CXL). Methods: Eight human donor corneas had femtosecond-assisted interlamellar 80-μm tissue removal through a 3.5-mm channel and pocket creation followed by 0.25% riboflavin solution insertion and vhF-CXL. Automated transverse biaxial resistance measurements were employed to investigate the corneal strength of the central 5 x 5-mm button in vhF-CXL and control groups. Results: Shear modulus in vhF-CXL was 1.6 ± 0.1 (1.5 to 1.7) kPa, and in the control group, 1.2 ± 0.03 (1.24 to 1.14) kPa, corresponding to a 35% increase in rigidity (P < .023). Conclusion: Adjunct intrastromal corneal vhF-CXL appears to significantly enhance biomechanical stability.

Combined (SMILE) and Intrastromal Crosslinking in Mild Keratoconus: Refractive and Biomechanical Outcomes

Abstract #: RP30040802

Presenting Author: Moones Fathi Abdalla MD
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Purpose: To report visual, refractive, topographic, and biomechanical outcomes of simultaneous (SMILE) and intrastromal crosslinking in eyes with abnormal topography and forme fruste keratoconus (FFKC). Methods: Prospective case series of 39 eyes of 21 patients. Inclusion criteria were topographic diagnosis of FFKC, stable refraction and topographic findings for at least 1 year, BCVA > 0.7, central corneal thickness > 460 μm, and patient age > 21 years. Results: SMILE performed in all cases had a 100-μm cap and 300-μm residual stromal bed, followed by intrapocket injection of isotonic riboflavin 3 times with a 5-min interval, then 5 min. 18 mw/cm² UV crosslinking. Biomechanical stability was assessed using the Corvis ST Oculus. Conclusion: Combined SMILE and crosslinking might be a safe, predictable, and stable treatment option for FFKC.

Simultaneous Topography-Guided PRK Followed by Corneal Collagen Crosslinking vs. CXL: A Long-term Comparative Clinical and In Vivo Confocal Microscopy Study

Abstract #: RP30040851

Presenting Author: Georgios Kontodakis MD
Coauthors: George D Kymionis MD PhD, Vardhaman P Kankaria MD**, Argyro Plaka MBCB**, Kostas Tsoulnaras MD, Ioannis G Pallikaris MD

Purpose: To compare corneal collagen crosslinking (CXL) with simultaneous topo-guided PRK and CXL (t-CXL) for progressive keratoconus. Methods: Prospective comparative case series. Thirty eyes received t-PRK (maximum ablation 50 μm) followed by CXL, and 30 eyes received CXL. Results: Mean follow-up was 31.8 ± 9.2 months. Preoperatively corrected distance visual acuity (CDVA) was 0.26 ± 0.17 (logMAR) in the t-CXL group and 0.24 ± 0.18 in the CXL group. At last follow-up CDVA was 0.09 ± 0.10 in t-CXL group and 0.15 ± 0.12 in the CXL group (P < .05). No patient lost more than 1 CDVA line. In the t-CXL group 19 eyes and in the CXL group 8 eyes gained 2 or more lines. Keratometry and uncorrected distance visual acuity (UDVA) were also significantly better in the t-CXL group. Depth of CXL treatment, by confocal microscopy, was 26.9 ± 31.8 μm in the CXL group and 299.7 ± 29.8 in the t-PRK-CXL group (P < .001). Conclusion: Visual function was improved significantly more with t-CXL than with CXL.

Quantitative Assessment of Corneal Epithelial Permeability and Stromal Riboflavin Concentration With Enhanced Riboflavin Solution

Abstract #: RP30040860

Presenting Author: Miguel J Maldonado MD PhD

Purpose: To assess corneal epithelial permeability (CEP) and stromal riboflavin concentration (SRC) with transepithelial enhanced riboflavin solution (ERS) and compare it with the standard epi-off technique (SEOT). Methods: Rabbit eyes (18) received either transepithelial ERS (with trometamol and EDTA) or normal riboflavin after de-epithelialization, CEP was measured before and after the instillation protocol (every 2 min. for 30 min.) with a bioimpedance method in transepithelial eyes. SRC was quantitated with high-performance liquid chromatography. Results: No significant difference in CEP was detected before or after instillation protocol (P > .05). Mean SRC in transepithelial ERS was 20.4% of that in SEOT. Conclusion: The enhancers herein used appear to produce ephemeral changes in CEP. The transepithelial SRC thus achieved is 5 times lower than in the standard epi-off technique.

**The co-author has not submitted financial interest disclosure information as of press date.
Safety, Efficacy, and Pachymetry Variation in Collagen Crosslinking in Thin Keratoconic Corneas With Different Protocols

Abstract #: RP30040861

Presenting Author: Mukesh Taneja MD
Coauthors: Somasheila I Murthy, MD, Pravin Vaddavalli MD, Bhupesh Bogga FRCS MBBS MD

Purpose: To study corneal pachymetry variation, safety, and efficacy for collagen crosslinking (CXL) with different protocols for keratoconus patients with thin corneas. Methods: We used different protocols of CXL in 28 eyes using riboflavin of the Montreal protocol) with 5-minute accelerated study of a new treatment protocol for adjusting the TCAT ablation treatment (TCAT) combined with accelerated collagen crosslinking (CXL). This correlated well with transient corneal edema seen in 4 patients. Efficacy of the CXL procedure was seen to be maintained in all the protocols but was equivocal in transepithelial CXL and when pachymetry crossed 600 μ intraoperatively. Conclusion: Intraoperative pachymetry has a bearing on the safety and efficacy of the CXL procedure.

Accelerated Transepithelial Corneal Collagen Crosslinking for Keratoconus in a Pediatric Population

Abstract #: RP30040865

Presenting Author: Andrew Olivo MD
Coauthors: Arturo J Ramirez-Miranda MD, Alejandro Navas MD, Jasmin L. Pedro, Enrique O Graue Hernandez MD

Purpose: To evaluate the effectiveness of accelerated corneal collagen crosslinking (CXL) in children with keratoconus. Methods: Retrospective review of consecutive clinical case series. Results: Twenty-three eyes of 14 patients underwent accelerated CXL with a mean follow-up of 12 months. Topographic and refractive changes were analyzed; the improvement in mean uncorrected distance visual acuity was 0.19 ± 0.15 logMAR. The mean keratometry decreased 1.2 D. Pachymetry remained unchanged at 433 ± 39 microns to 431 ± 41 microns. Conclusion: Preliminary results of accelerated CXL in a pediatric population were encouraging, with no evidence of progression in 12 months.

Topography-Guided Customized Ablation Treatment and Accelerated Collagen Crosslinking for Keratoconus and Post-LASIK Ectasia: The Montreal Protocol

Abstract #: RP30040869

Presenting Author: Avi Wallerstein MD
Coauthors: Eser Adiguzel PhD, Tenley N Bower MD, Salim Korban BSc, Mark J Cohen MD

Purpose: To determine outcomes of topography-guided customized ablation treatment (TCAT) combined with accelerated collagen crosslinking (CXL) for keratoconus (KC) and post-LASIK ectasia with a new treatment protocol. Methods: Prospective study of a new treatment protocol for adjusting the TCAT ablation profile (the Montreal protocol) with 5-minute accelerated CXL. Results: 232 eyes (178 KC, 54 ectasia), 62 with 12-month follow-up. There was significant uncorrected distance visual acuity (UDVA) and corrected distance VA (CDVA) improvement (0.8 ± 0.6 vs. 0.6 ± 0.5 logMAR, P < .001; 0.2 ± 0.2 vs. 0.1 ± 0.2 logMAR, P = .04), and 2 D cyl and K-max reduction (P < .001). Postop UDVA 20/20, 20/30, and 20/40 in 5%, 29%, and 41%, vs. preop 0%, 7%, and 15%. Loss of ≥ 2 CDVA: 6%, 1 line: 3%, no change: 35%, gain ≥ 1: 55%. Conclusion: The Montreal protocol showed a significant reduction in cylinder/K-max and improvement in UDVA/CDVA.

A Comparative Evaluation of Subjective Point Spread Function Refraction Results With Subjective Phoropter Results on Keratoconus Patients

Abstract #: RP30040878

Presenting Author: William B Trattler MD
Coauthors: Shui T Lai PhD, Rohin Vij BS MA

Purpose: To evaluate the accuracy and reliability of point spread function (PSF) refraction on keratoconus patients. Methods: A comparative study of 14 patients (28 eyes), refactoring patients first with a standard phoropter, and then using a PSF digital refractor. Visual acuity was recorded using EDTRS eye charts. Results: Mean SE was −4.38 ± 5.55 D (range: −16.25 to +2.00 D) with the phoropter, and −4.55 ± 6.64 D (range: −18.63 to +2.46 D) with the PSF. Of 26 eyes, 18 eyes (69%) achieved a higher level of BCVA using the PSF refraction than with the phoropter. The 8 remaining eyes (31%) achieved an equal level of BCVA. Conclusion: The PSF refraction method produces a highly reliable and accurate refraction outcome in keratoconus patients and can provide patients with improved BCVA when compared to a standard phoropter.

Treatment of Coma Aberration With Intracorneal Ring Segments in Patients With Inferiorly Placed Keratoconus

Abstract #: RP30040895

Presenting Author: Orkun Muftuoglu MD

Purpose: To evaluate results of intracorneal ring segment (ICRS) implantations in patients with inferiorly placed keratoconus. Methods: Twenty-six eyes of 13 patients with keratoconus with its steepest part located in the peripheral cornea with significant coma (more than 0.90 mm) underwent inferiorly placed 220-degree ICRS implantation. All patients were evaluated with Scheimpflug-Placido disk corneal analyzer for 6 months. Results: The mean preoperative UCVA increased from 0.4 ± 0.3 (Snellen) to 0.7 ± 0.2 (P < .05). The mean total coma decreased from 1.21 ± 0.48 mm to 0.42 ± 0.29 mm at 6 months (P < .05). Conclusion: ICRS implantation in inferiorly placed keratoconus patients with significant coma seems to be effective in treating coma and to increase UCVA.
New Technology in Corneal Diagnostics

Effect of a Surgical Safety Checklist for Refractive Procedures
Abstract #: RP30040742
Presenting Author: Marie-Claude Robert MD
Coauthors: Catherine J Choi MD, Richard Urman, Fred E Shapiro DO**, Samir A Melki MD PhD
Purpose: To measure the effect of implementing a surgical safety checklist on the prevention of medical errors during laser vision correction (LVC). Methods: A safety checklist incorporating 28 sources of error was designed and implemented at the Boston Eye Group. The rate of “never events” was compared between consecutive patient cohorts before and after the safety checklist. Results: A total of 2951 consecutive patients were included in this study. There were 2.0 (0.14%) never events in the pre-checklist cohort and 0.0 (0%) following implementation of the checklist. Conclusion: A new surgical safety checklist seems to be effective in preventing “never events.”

Predictability of Postop Day 1 Aberrometric Refraction of Final Refractive Outcome at 1 Year After Myopic LASIK
Abstract #: RP30040759
Presenting Author: Edward E Manche MD
Coauthors: Charles Q Yu MD
Purpose: To determine if objective wavefront aberrometric refraction 1 day after myopic LASIK is predictive of final refractive outcomes 1 year after LASIK. Methods: Ninety-four myopic eyes underwent wavefront-guided LASIK. Aberrometric refraction was recorded on postop Day 1 and Year 1. Manifest refraction was done at 1 year. Results: There was a 0.30 D (SEQ) myopic shift between postop Day 1 and postop Year 1 as measured by aberrometric refraction. There was a correlation of R = 0.66 (P < .0001) when comparing aberrometric (SEQ) refraction at Day 1 and Year 1. There was a correlation of r = 0.53 (P < .0001) when aberrometric (SEQ) refraction at Day 1 with subjective manifest (SEQ) refraction at Year 1. Conclusion: Postop Day 1 aberrometric refraction correlates well with objective aberrometric refraction and subjective manifest refraction at 1 year.

The Incidence and Natural History of Subjectively and Objectively Determined Metrics of Light Scattering in Femtosecond LASIK
Abstract #: RP30040780
Presenting Author: Karoline M Rocha MD
Coauthors: Adam Weber MD**, William J Dupps MD PhD, Ronald R Krueger MD
Purpose: To assess the incidence and long-term outcomes of rainbow glare and stray light measurement in femtosecond-LASIK. Methods: Fifty eyes underwent LASIK (Allegretto, IntraLase FS60 vs. WaveLight FS200). Rainbow glare and stray light measurement (C-Quant) were obtained preoperatively and at 1 week and 1, 3, and 9 months postoperatively. Results: Light scattering peaked at 1 week in both IL and FS groups (log1.28 ± 0.16, P = .02), with statistically significant improvement at 3 and 9 months (log1.10 ± 0.16, P = .008 and log1.14 ± 0.13, P = .01).

Wavefront-Optimized vs. Topography-Guided Myopic LASIK: A Contralateral Eye Study in 31 Patients
Abstract #: RP30040794
Presenting Author: George Asimellis PhD
Coauthor: A John Kanellopoulos MD
Purpose: To comparatively evaluate safety and efficacy of wavefront-optimized (WFO) vs. topography-guided (TG) myopic LASIK. Methods: Of 31 patients, an eye was randomly assigned to WFO LASIK, the other to TG. Visual acuity, refraction, Placido topography, Scheimpflug topometry, Tscherning aberrometry, and anterior segment OCT were investigated perioperatively for 1 year. Results: Mean postoperative values WFO vs. TG: MSRSE from −5.29 ± 2.39 D and −4.96 ± 2.45 D to −0.29 ± 0.1 and 0.25 ± 0.1, UDVA: 20/22 and 20/15, CDVA 20/18 and 20/15, achieved optical zone (aOZ) 6.4 mm vs 6.8 mm. Total higher-order aberrations (RMSH) was 0.35 μm vs. 0.18 μm (P < .0001) when comparing aberrometric (SEQ) refraction during wavefront-guided LASIK acuity, wavefront, and aOZ results appear statistically superior to WFO.

Over 40% of patients reported rainbow glare at 1 week, 20% at 3 months, and 19% at 9 months in both groups. Conclusion: Rainbow glare and stray light measurement, as subjective and objective metrics of light scatter, are mild optical side effects of femtosecond-LASIK that gradually improve with time.
Multicenter Objective Digital Assessment of Opaque Bubble Layer and Femtosecond LASIK Flap
Abstract #: RP30040817
Presenting Author: Vance Michael Thompson MD
Coauthor: A John Kanellopoulos MD
Purpose: To assess opaque bubble layer (OBL) occurrence and flap diameter (ID) in a 2-center consecutive series of myopic patients having femtosecond LASIK (fLASIK).

Methods: Two parallel prospective studies of 118 (Center A) and 70 (Center B) eyes. DA of OBL occurrence and extent, and ID in myopic fLASIK using the FS200 and EX500 lasers. Results: For Center A and Center B, respectively: OBL occurrence: 5 eyes and 8 eyes, OBL extent: 7% (2%-13%) and 10% (4%-18%), ID for intended 8.00 mm: Achieved 7.85 mm (±0.04) and 7.83 mm (±0.04), ID for intended 8.50 mm: 8.38 mm (±0.03) and 8.39 mm (±0.03), respectively. Conclusion: fLASIK offers superior ID accuracy and minimal OBL occurrence, documented by objective means.

Advanced Tomographic Analysis for Enhancing Ectasia Detection
Abstract #: RP30040824
Presenting Author: Renato Ambrósio Jr MD
Purpose: To test and improve detection of subclinical ectatic disease.

Methods: Preop Pentacam HR data from 266 eyes with stable LASIK (1 year follow-up) was compared to 211 forme fruste keratoconus (FFKC) cases, defined as the eye with no clinical signs of ectasia from patients with keratoconus in the fellow eye. Novel linear regression analysis was developed and tested by ROC curve analysis. Results: BAD-D had highest AUC (0.892; cut off: 1.22; sensitivity: 73%; and specificity: 88.35%), followed by ART-Max (0.877). A new linear regression analysis, adding age to topo-tomographic parameters, enhanced AUC to 0.951. Conclusion: The integration of Pentacam parameters with age, a surrogate of biomechanical properties, significantly enhances ectasia detection. Some cases classified as FFKC may be unilateral ectasia.

Evaluation of Corneal Deformation With Scheimpflug Camera After Myopic PRK
Abstract #: RP30040834
Presenting Author: Michele Lanza MD
Coauthors: Raffaele Piscopo MD, Miguel M Rechichi MD, Gennarfrancesco Iaccarino MD**, Michele Rinaldi MD**
Purpose: To study corneal deformation after PRK with a Scheimpflug camera device.

Methods: A complete eye visit, Corvis ST (CST) and Pentacam (Oculus, Germany) scans were performed in 17 eyes of 17 patients before myopic PRK and at 1 year follow-up. Correlations among refractive data, corneal morphological data and corneal deformation data, were run. Results: CTS applanation time 1 (AT1) and applanation time 2 (AT2) differences showed a good correlation with corneal curvature (KM) changes (R: 0.65 and R: 0.68, respectively); AT1 changes were well correlated with central corneal thickness (CCT) changes (R: 0.54); AT2 variations were poorly correlated with CCT ones (R: 0.17). Conclusion: Corneal deformability changes after myopic PRK could be due more to KM changes more than CCT changes.

Corneal Astigmatism Evolution With Age: 350 Cases Evaluated With a Color Light Emitting Diode Reflection Topographer
Abstract #: RP30040843
Presenting Author: Ioanna Kontari MD
Coauthors: Costas H Karabatsas MD, George Asimellis PhD, A John Kanellopoulos MD
Purpose: To evaluate age and magnitude measurement repeatability in various groups with a novel topographer.

Methods: Two hundred eyes were measured 3 times consecutively and their data was correlated. Results: Flat K repeatability was 0.74 ± 0.89 D in the normal, 0.88 ± 1.45 D in the keratoconus (KCN), and 0.36 ± 0.46 D in the post-refractive surgery (LASIK) group. Steep K repeatability was 0.64 ± 0.82 D in the normal, 0.89 ± 1.22 D in the KCN, and 0.93 ± 1.12 D in the post-LASIK group. Axis repeatability was 3.45 ± 1.62° in the control, 4.12 ± 3.17° in the KCN, and 3.20 ± 1.99° in the post-LASIK group. Conclusion: The color light emitting diode reflection topographer appears to offer high repeatability of astigmatism magnitude and axis measurements in a wide clinical spectrum.

Color Light Emitting Diode Reflection Topography: Astigmatic Axis Repeatability in Normal, Keratoconus, and LASIK Eyes
Abstract #: RP30040845
Presenting Author: Costas H Karabatsas MD
Coauthors: Ioanna Kontari MD, George Asimellis PhD, A John Kanellopoulos MD
Purpose: To investigate distribution of axis and astigmatism magnitude in healthy younger and older eyes.

Methods: 350 consecutive eyes were imaged with the color light emitting diode reflection topographer (CLRT). Results: Group A (age 35.7 years) had with-the-rule mean astigmatism. Precataraocl older Group B (age 73.6 years) had on average against-the-rule astigmatism. In Group A, the average axis repeatability was from 2.49° (astigmatism < 3.00 D) to 1.14° (astigmatism ≥ 3.00 D) and magnitude repeatability from 0.25 D to 0.59 D. In Group B, it was 3.03° to 0.62° and 0.35 D to 0.61 D, respectively. Conclusions: Astigmatism shifts with age from with-the-rule to against-the-rule. The CLRT appears to offer high specificity in documenting corneal astigmatism.

Independent Verification of UVA Irradiation Levels of 4 Corneal Collagen Crosslinking Devices
Abstract #: RP30040846
Presenting Author: Costas H Karabatsas MD
Coauthors: Georgios Chatzilou MD, A John Kanellopoulos MD
Purpose: To evaluate the safety and consistency of clinical UVA irradiation devices.

Methods: Three laboratory-graded UVA digital light radiometers were employed to measure suggested UVA (peak 365 nm) levels in 4 CXL devices: KXL-I and KXL-II (Avedro), Vega (CSO), and UVX 2000 (IROC). Temporal variations during measurement and comparison of averages between different sessions were recorded. Results: Average fluence measured and suggested were KXL I, 29.5 ± 1.3 mW/cm² (30 mW/cm²); KXL II, 43.5 ± 0.9 mW/cm² (45 mW/cm²); Vega, 2.8 ± 0.3 mW/cm²; and UVX, 2.7 ± 0.7 mW/cm² (both 3 mW/cm²). Conclusion: All devices appeared stable and consistent, with minimal fluctuations noted.

** The co-author has not submitted financial interest disclosure information as of press date.
Dependability of Thinnest and Midperipheral Pachymetry After Myopic Photoablation Using a Dual Scheimpflug System
Abstract #: RP30040849
Presenting Author: Miguel J Maldonado MD PhD
Purpose: To assess the consistency of thinnest and midperipheral (6-mm radius) pachymetry after keratorefractive surgery. Methods: Fifty patients who underwent myopic surface photoablation with no biomicroscopically detectable corneal haze were subjected to 5 consecutive tomographic measurements (Galilei). The within-subject standard deviation (Sw), the repeatability, and the intraclass correlation coefficient (ICC) were calculated. Results: The repeatability (and ICCs) for thinnest and midperipheral superior, inferior, nasal, and temporal locations were 4.4 (0.99), 11.1 (0.97), 7.0 (0.99), 11.3 (0.96), and 9.9 µm (0.96), respectively. Conclusions: These estimates will help clinicians to discriminate real pachymetry change occurring in postoperative ectasia from pachymetry measurement noise.

Comparison of Manual Caliper vs. Anterior Segment Imaging for Sizing of Posterior Chamber Phakic IOL Implants
Abstract #: RP30040855
Presenting Author: Mujtaba A Qazi MD
Coauthors: Jay R Patel MD, Jay Stuart Pepose MD PhD
Purpose: To compare predictability of white-to-white (w-w) or sulcus measurements for horizontal sizing of posterior chamber phakic (Visian ICL) IOLs. Methods: Postoperative ICL vault and angle dimensions were retrospectively used to predict sizing of ICL (rICL) diameters, which were then statistically compared to values predicted by manual caliper and imaging (Orbscan, IOLMaster, Visante) techniques. Results: There was no statistical difference between caliper w-w (mean: 11.9 mm) and Visante sulcus readings (12.0, P > .07). Correspondingly, planned ICL size differed significantly from rICL for Orbscan or IOLMaster w-w (P < .02), but not for caliper and Visante measurements (P > .2). Conclusions: Anterior segment OCT sulcus measurements may be used as an alternative to manual caliper w-w readings for purposes of ICL sizing.

Comparison of Alcon and Holladay Toric IOL Calculator Recommendations in Patients With Toric IOL Implantation
Abstract #: RP30040879
Presenting Author: James Conner Lockwood BA
Coauthor: J Bradley Randleman MD
Purpose: To compare predictive outcomes from 2 toric IOL (T-IOL) calculators. Methods: Retrospective review of 72 eyes (44 patients) with T-IOL implantation (AcrySof IQ Toric). T-IOL calculations were performed using the Alcon and Holladay IOL Consultant Software (HCS) calculators. Results: At 1 month, average uncorrected distance visual acuity (UDVA) was 20/27 (20/20 to 20/60), average residual astigmatism was 0.57 D (0 to 1.75 D), and 57% of eyes were ≤ 0.5 D. Overall, Alcon and HCS calculators agreed on predicted T-IOL in 39% of cases. Among eyes with ≤ 0.5 D, 24% matched Alcon, 38% matched HCS, 30% matched both, and 8% matched neither. Conclusion: Outcomes with T-IOL were good; however, neither calculator was optimal in isolation for choosing the most appropriate T-IOL. Using multiple calculators improves T-IOL outcomes.

The Effect of Soft Contact Lens Materials on Corneal Epithelial Thickness as Determined by OCT
Abstract #: RP30040899
Presenting Author: Arthur B Cummings MD
Coauthors: Aoife Lloyd McKernan OD**, Ann-Marie Masterson**
Purpose: Epithelial thickness is reduced in soft contact lens (SCL) wear, reportedly because of hypoxia from low oxygen permeability (DK/t) SCLs. The purpose of this study was to explore the influence of modern SCL materials (Hydrogel: H, silicone hydrogel: SiH, generation 1, 2, 3) on epithelial thickness. Methods: Anterior segment OCT epithelial thickness measurements were compared for a SCL (n = 40) and a NCL control group (n = 20). Results: Central epithelial thickness was significantly different between the groups tested (NCL: 58.67 ± 5.18 µm, H: 59.13 ± 6.47 µm, SiH1: 49.50 ± 6.86 µm, SiH2: 61.00 ± 2.83 µm, SiH3: 67.50 ± 6.36 µm; P = .01). Conclusion: SCL modulus has a greater impact on epithelial thickness compared to DK/t.

Presbyopia—Lasers vs. IOLs
Prospective Evaluation of a Polyfocal Hydrogel IOL Used in Cataract Surgery
Abstract #: RP30040724
Presenting Author: Robert Edward T Ang MD
Purpose: To evaluate the distance, intermediate, and near vision outcomes of patients implanted with a polyfocal IOL made of hydrogel material. Methods: Ten patients underwent femtosecond laser-assisted cataract surgery and were bilaterally implanted with a polyfocal IOL. Results: At 1 month, the mean sphere was +0.52 D, mean cylinder was −0.59 D, and mean spherical equivalent was +0.22 D. Monocularly, 68% of eyes had uncorrected distance visual acuity (UDVA) of 20/25 or better, 94% had uncorrected intermediate visual acuity (UIVA) of 20/25 or better, and 82% had uncorrected near visual acuity (UNVA) of J3 or better. Conclusions: Outcomes at 1 month show that patients achieve good uncorrected distance, intermediate, and near vision.

**The co-author has not submitted financial interest disclosure information as of press date.
**Two-Year Outcomes of Small-Aperture Corneal Inlay Treatment for Post-LASIK Presbyopes, and Influence of Pupil Size**

**Presenting Author: Minoru Tomita MD PhD**

Purpose: To evaluate the efficacy of and influence of pupil size in implanting a small-aperture intracorneal inlay for the treatment of presbyopia in post-LASIK presbyopes. Methods: 5369 post-LASIK patients had an inlay implanted in their nondominant eye. Two groups were classified, 1 small-pupil group and 1 large-pupil group for both mesopic and photopic pupil size parameters. Results: Uncorrected distance visual acuity had a 1-line decline to 20/20, and uncorrected near visual acuity improved 3 lines to J2; both remained stable throughout the 2-year follow-up period. There was no correlation between the pupil size and the visual acuity either pre- or postoperatively for either mesopic or photopic pupil groups. Conclusion: The 24-month results demonstrate that implantation of a small-aperture corneal inlay in post-LASIK patients can be an effective treatment option for their presbyopia.

**High Toric IOL Implantation for Elevated Astigmatism**

**Abstract #: RP30040747**

**Presenting Author: Alexandra Abdala Figuerola MD**

**Coauthors: Arturo J Ramirez-Miranda MD, Karla P Lopez Dorantes MD, Alejandro Navas MD, Enrique O Graue Hernandez MD**

Purpose: To describe the outcomes of toric IOL in high astigmatism. Methods: Patients older than 45 years with astigmatism ≥ 3.0 D underwent cataract surgery with high toric IOL implantation (AT TORBI 709M or AT LISA toric 909M; Carl Zeiss Meditec). Results: Fourteen eyes of 9 patients (mean age: 50.21 ± 7.86 years). Preoperative cylinder was −6.17 ± 2.63 D, decreasing to −1.82 ± 2.11 D postoperatively. Preoperative sphere was −7.18 ± 6.26 D, and postoperatively +1.12 ± 0.71 D. Preoperative and postoperative spherical equivalents were −9.94 ± 6.23 D and 0.21 ± 1.19 D, respectively. Preoperative mean uncorrected distance visual acuity was 1.39 ± 0.65, improving to 0.30 ± 0.16. Conclusion: High toric IOLs may provide excellent visual and refractive outcomes.

**Evaluation of a Bi-toric, Trifocal Multifocal IOL**

**Abstract #: RP30040755**

**Presenting Author: Florian T A Kretz MD**

**Coauthors: Katharina Linz MD, Mary Attia MBBCH, Ramin Khoramnia MD, Tamer Tandogan MD, Gerd U Auffarth MD**

Purpose: Clinical evaluation of functional visual acuity (VA) of a toric, trifocal multifocal IOL (MIOL) in astigmatic eyes. Methods: A prospective study to evaluate functional outcomes after implantation of a bi-toric, trifocal MIOL (AT LISA MP939) 2-4 postop. Examinations: Uncorrected distance VA (UDVA), uncorrected intermediate VA (UIVA), uncorrected near VA (UNVA), corrected distance VA (CDVA), distance-corrected intermediate VA (DCIVA), distance-corrected near VA (DCNVA), and VA testings in individual distances (uncorrected and distance corrected) with the Salzburg Reading Desk (SRD). Results: Median binocular UDVA was −0.08, UIVA was −0.12, and UNVA 0.00, compared to a CDVA of −0.10, a DCIVA of −0.12, and a DCNVA of −0.06 (logMAR). SRD binocular, objective UNVA (39.4 cm) of 0.11 similar to a subjective UNVA (38.9 cm), and an objective UIVA of 0.09 (80.0 cm) compared to a subjective UIVA of 0.03 (78.2 cm). Conclusion: The toric, trifocal MIOL offers a high amount of spectacle independence for daily tasks.

**Implantation of a Hydrogel Corneal Inlay for the Correction of Presbyopia in Emmetropes: Single Center Experience**

**Abstract #: RP30040765**

**Presenting Author: Paul J Dougherty MD**

Purpose: To investigate my cohort of subjects implanted with Raindrop Inlay in emmetropic presbyopes as part of a multicenter prospective FDA IDE study. Methods: The Raindrop was implanted in 45 subjects (MRSE −0.50 D to +1.00 D) in the nondominant eye under a femtosecond flap. Results: At 6 months, all subjects (n=18) when tested binocularly (UVAs) achieved 20/25 or better for near, 20/32 or better at intermediate, and 20/20 or better for distance. Conclusion: The Raindrop Inlay provided a full range of vision in my cohort of emmetropic presbyopes.

**Comparison of 2 Models of Trifocal IOls for the Correction of Pseudophakic Presbyopia**

**Abstract #: RP30040779**

**Presenting Author: Ahmed A Abdou MD PhD**

**Coauthors: Jorge L Alió MD PhD, Esperanza Sala OD, Ana Belen Plaza**

Purpose: To compare visual and optical quality outcomes obtained with 2 models of trifocal lenses. Methods: Group A, 40 eyes implanted with AT LISA tri 839MP (Zeiss) and Group B, 40 eyes implanted with Fine Vision (PhysIOL). Main outcomes measures were uncorrected distance (UDVA) and near visual acuity, defocus curve, and contrast sensitivity. Results: Postoperatively, significant improvement in UDVA and CDVA were found in both groups. Statistically significant differences were not found (P = 0.337) between groups in UNVA and contrast sensitivity (P ≥ 0.09) postoperatively. The defocus curves showed significantly better visual acuities in Group A (P < 0.05). Conclusions: Good results were obtained in both groups at all the distances but were better with AT LISA tri in distance and intermediate.

**Two-Year Outcomes of Small-Aperture Corneal Inlay Treatment for Post-LASIK Presbyopes, and Influence of Pupil Size**

**Presenting Author: Florian T A Kretz MD PhD**

Purpose: To evaluate the efficacy of and influence of pupil size in implanting a small-aperture intracorneal inlay for the treatment of presbyopia in post-LASIK presbyopes. Methods: 5369 post-LASIK patients had an inlay implanted in their nondominant eye. Two groups were classified, 1 small-pupil group and 1 large-pupil group for both mesopic and photopic pupil size parameters. Results: Uncorrected distance visual acuity had a 1-line decline to 20/20, and uncorrected near visual acuity improved 3 lines to J2; both remained stable throughout the 2-year follow-up period. There was no correlation between the pupil size and the visual acuity either pre- or postoperatively for either mesopic or photopic pupil groups. Conclusion: The 24-month results demonstrate that implantation of a small-aperture corneal inlay in post-LASIK patients can be an effective treatment option for their presbyopia.
Comparison of Clinical Outcomes of 3 Different Diffractive Multifocal IOLs

Abstract #: RP30040810

Presenting Author: Orkun Muftuoglu MD

Purpose: To evaluate results of 3 different multifocal IOLs. Methods: Visual acuities, contrast sensitivity, and defocus curve were measured, and a survey was done in 28 eyes of 14 patients with the AcrySof ReSTOR SN6AD3 IOL, 15 eyes of 30 patients with the AcrySof ReSTOR SV25 IOL, and 28 eyes of 14 patients with the Reviol MF 613 multifocal IOL. Results: Our results revealed that all IOLs provided good visual acuities. Under low lighting conditions, a reduction in contrast sensitivity for all lenses was noted. Higher add power IOLs provided better uncorrected near visual acuity, whereas lower add power IOLs provided better contrast sensitivity. Conclusion: Although all multifocal IOLs provide good distance and visual acuities, different models can be preferred according to the patient’s needs and expectations.

Evaluation of Visual and Optical Performance With a Small-Aperture IOL

Abstract #: RP30040842

Presenting Author: Robert Edward T Ang MD

Coauthor: Gunther Grabner MD

Purpose: To evaluate visual performance with a small-aperture hydrophobic IOL (HP-SA-IOL) in the nondominant eye. Methods: Prospective, nonrandomized study of 11 patients implanted monocularly with a single-piece hydrophobic acrylic IOL with a centrally located opaque annular mask measuring 3.23 mm in total diameter with a 1.36-mm central aperture. Results: At 6 months, mean uncorrected binocular visual acuities for distance (UCDVA) and intermediate (UCIVA) were 20/20. Mean uncorrected near visual acuity was 20/25. Additionally, 100%, 82%, and 91% of patients achieved 20/25 or better for UCDVA, UCIVA, and UCNVA, respectively. Conclusion: Early results demonstrate HP-SA-IOL implantation in the nondominant eye provides a continuous, broad range of vision and excellent acuity across all focal distances.

Predicted Effect of Ophthalmic Viscoelastic Device on Femtosecond-Laser Capsulotomy

Abstract #: RP30040864

Presenting Author: Florence A Cabot MD

Cooauthors: Carolina de Freitas, Fabrice Manns PhD**, William W Culbertson MD, Sonia H Yoo MD, Jean-Marie Parel PhD

FARVO**

Purpose: To assess the effect of ophthalmic viscoelastic device (OVD) anterior chamber refilling on femtosecond laser (FS) capsulotomy. Methods: The index of refraction of 6 OVDs was measured. The error in FS cut position caused by a change in refractive index due to OVD refilling was predicted using an optical model. Results: The index of refraction of the 6 OVDs was close to that of aqueous humor. The femtosecond cut depth error ranged from -5 to +13 µm, well below the tolerances of the laser systems. Conclusion: No change in FS geometrical parameters settings is required if the anterior chamber is filled out with OVD prior to the procedure. The change in refractive index due to anterior chamber refilling with OVDs is not sufficient to explain incomplete capsulotomies.

Ciliary Muscle OCT Imaging of Phakic and Pseudophakic Patients During Accommodation

Abstract #: RP30040866

Presenting Author: Florence A Cabot MD

Cooauthors: Marco Ruggeri**, Fabrice Manns PhD**, Sonia H Yoo MD, Carolina de Freitas, Victor Hernandez, Jean-Marie Parel PhD

FARVO**

Purpose: To assess the ciliary muscle biometry and IOL axial shift during accommodation and pseudoaccommodation with OCT. Methods: Trans-scleral OCT was performed during naturally induced accommodation of 2, 4, and 6 D. Ciliary muscle biometry, axial shift of the lens, and movements of anterior segment structures were assessed. Patients were divided into 5 groups: accommodative IOL, monofocal IOL, phakic IOL, presbyopic patients, and control subjects. Results: Mean axial shift of accommodative IOL was 42 µm for 4 D of accommodation. No ciliary muscle movements were recorded in the accommodative and monofocal IOL groups. Conclusion: Mild IOL shift and absence of ciliary muscle movements prevent accommodation in pseudophakic patients.
Five-Year Follow-up of Patients Implanted With an Intracorneal Inlay for the Correction of Presbyopia

Abstract #: RP30040886

Presenting Author: Wolfgang Riha MD
Coauthor: Alain Saad MD

Purpose: To assess the long-term stability and biocompatibility of a small-aperture inlay. Methods: The ACI7000 corneal inlay was inserted monocularly into the nondominant eye of 32 emmetropic presbyopic patients. Monocular acuity results at 5 years are presented. Results: Mean uncorrected near visual acuity (VA) improved from J7/J8 (preop) to J2, mean uncorrected intermediate VA improved from 20/40 to 20/25, and mean uncorrected distance VA decreased from 20/16 to 20/25. Both implanted and fellow eyes showed minor age-related hyperopic refractive changes over the 5-year follow-up. No irritation or inflammatory reactions were observed. Two inlays were recentered. One inlay was removed at 4 years. Conclusion: The results demonstrate both long-term stability and biocompatibility of a small-aperture inlay.

Functional Results After Implantation of an Aberration Neutral, Aspheric IOL

Abstract #: RP30040897

Presenting Author: Ramin Khoramnia MD
Coauthors: Anna Fitting, Bettina Thomas MD, Gerd U Auffarth MD, Mike P Holzer MD

Purpose: To evaluate an aspheric, aberration-neutral, FDA-approved monofocal IOL. Methods: The C-flex / Superflex IOL (Rayner; UK) was implanted in 47 eyes of 34 patients. Results: Mean uncorrected reading acuity at intermediate distance was −0.05 logMAR (0.08 to −0.22). Median uncorrected distance VA was 0.52 logMAR (0.68 to 0.16), and median corrected distance VA was −0.05 logMAR (0.08 to −0.22). Median acuity (VA) was 0.02 logMAR (0.16 to −0.10), and median corrected acuity was 0.02 logMAR (0.10 to −0.06). Conclusion: The new IOL provides good functional results and a high percentage of patient satisfaction.

Intrastromal Astigmatic Keratotomy During Femtosecond Cataract Laser Surgery in Patients With Multifocal IOL

Abstract #: RP30040900

Presenting Author: Dilraj Singh Grewal MD
Coauthors: Sartaj Singh Grewal MD, Satinder Pal Singh Grewal MD MBBS

Purpose: To evaluate intrastromal astigmatic keratotomy (IAK) using the femtosecond cataract laser (FSL; Catalys, AMO; Calif.) during cataract surgery with multifocal IOL (ZMB00, Abbott Labs) implantation. Methods: Single or symmetric IAKs (5-μJ energy, 90° side cut angle, 8.5-mm optical zone) were created during cataract surgery at 80% of corneal depth in eyes with > 0.50 D naturally occurring regular corneal astigmatism (CA), assessed using Pentacam topography. Results: In 20 eyes CA was reduced (P < .0001) from 0.92 ± 0.38 D (range: 0.5 to 2.9 D) to 0.32 ± 0.21 D (range: 0.0 to 0.75 D) at 3 months (average reduction: 0.65 ± 0.52 D), with no posterior perforations. Uncorrected near vision improved from 0.5 to 0.15 logMAR (P < .001). Conclusion: OCT-guided FSL IAK is an effective way to reduce CA and improve performance of multifocal IOLs.

The Journal of Refractive Surgery's Hot, Hotter, and Hottest: Late Breaking News

Meta-analysis of 6 Excimer Laser Platforms: Safety and Efficacy in Myopic LASIK

Abstract #: RP30040715

Presenting Author: Christopher L Blanton MD

Purpose: To compare 6 excimer laser platforms regarding outcomes for myopic LASIK. Methods: A peer-reviewed literature search was conducted using the terms “myopia,” “LASIK,” and “outcomes.” Articles were selected based on inclusion / exclusion criteria. Data regarding visual acuity, refractive error ± 0.5 and 1.0 D and loss of BCVA were extracted. FDA approval studies were used to fill in any data gaps. Statistical analysis was performed. Results: One laser outperformed the others in acuity results at 1, 3, and 12 months. Another laser outperformed the others at 6 months regarding refractive outcome ± 0.5 D. All lasers fell within the FDA guidelines for safety regarding loss of BCVA. Conclusion: Some lasers are superior with regard to efficacy in myopic LASIK surgery.

**The co-author has not submitted financial interest disclosure information as of press date.
Optimizing Spherical Aberration and Tensile Strength Using Small-Incision Lenticule Extraction Compared to Wavefront Optimized LASIK

Abstract #: RP30040726

Presenting Author: Dan Z Reinstein MD
Coauthors: Timothy J Archer MS, Marine Gobbe PhD

Purpose: To compare the combination of postop tensile strength (PTS) and spherical aberration (SA) induction in small-incision lenticule extraction (SMILE) and LASIK. Methods: SMILE eyes using a spherical profile (6-7 mm optical zone) were matched for sphere, cylinder, and pachymetry to LASIK eyes using an aspheric profile (6-mm optical zone). Corneal SA change and PTS were plotted against SEQ. Results: Larger optical zones (6.7 and 6.1 mm) in SMILE meant 32% more tissue removal (107 and 81 μm), but achieved 64% lower SA induction (0.11 vs. 0.31 μm) and 28% greater PTS (73 vs. 57%). Conclusion: SMILE optical zones can be increased to improve SA control while still leaving higher PTS due to preservation of the stronger anterior stroma.

Comparison of the Visual and Refractive Outcomes of 1- vs. 2-Segment Femtolas er-Assisted Intrastromal Corneal Ring Implantation in Keratoconic Subjects

Abstract #: RP30040728

Presenting Author: Seyed Javad Hashemian MD

Purpose: To compare the visual and refractive outcomes of 1-segment with those of 2-segment femtolaser-assisted intrastromal corneal ring segment (ICRS) Intacs SK implantation in the treatment of keratoconus (KCN). Methods: In this prospective study 1 or 2 segments of Intacs SK ICRS were implanted using femtolas er in eyes with KCN. Visual, refractive, and corneal tomography changes and complications were analyzed over a 6-month period. Results: Thirty-six eyes received 1 segment, and 35 eyes had 2 segments. At 6 months the defocus, spherical equivalent, mean sphere, and cylinder decreased significantly. The preop logMAR uncorrected visual acuity and corrected distance visual acuity (CDVA) increased by 0.4 and 2.8. K-flat and K-steep decreased by a mean of 1.08 and 2.1 and 2.15 and 3.0 D, respectively. Ninety-four percent and 91% of eyes gained 1-6 lines of CDVA. Conclusion: Femtolaser-assisted implantation of 1- or 2-segment Intacs SK ICRS was safe and effective, leading to significant improvement in UDVA and CDVA.

Comparison of Objective and Subjective Refractive Surgery Screening Parameters Between Regular and High-Resolution Scheimpflug Imaging Devices

Abstract #: RP30040733

Presenting Author: Jihan Akhtar MD
Coauthors: J Bradley Randleman MD, Michael J Lynn MS, Renato Ambrósio Jr MD, William J Dupps MD PhD, Ronald R Krueger MD, Stephen D Klyce PhD

Purpose: To compare objective and subjective screening metrics from regular and high-resolution (HR) Scheimpflug imaging devices. Methods: Retrospective analysis of 100 eyes from 50 consecutively screened patients evaluated with HR and regular devices (REG). Objective parameters included keratometry, central corneal thickness (CCT), and keratoconus screening indices. Subjective evaluations were done in a blinded fashion. Results: Keratometric astigmatism values were not significantly different. CCT was significantly thinner in the HR group. All keratoconus indices were more suspicious for HR except index of height asymmetry and deviation. Subjectively, HR was more suspicious in 30%, and REG was more suspicious in 12% of cases. Conclusions: Regular and HR Scheimpflug imaging devices generated different objective and subjective values.

Visual and Refractive Outcomes of Small-Incision Lenticule Extraction Performed by Ophthalmology Residents and Cornea Fellows

Abstract #: RP30040735

Presenting Author: Erick Hernandez-Bogantes MD
Coauthors: Arturo J Ramirez-Miranda MD, Alejandro Navas MD, Enrique O Graue Hernandez MD

Purpose: To describe the efficacy and safety outcomes of small-incision lenticule extraction (SMILE) performed by surgeons in training. Methods: Retrospective review of consecutive surgical cases series. Results: 150 eyes with mean follow-up of 6 months. Mean preop spherical equivalent (SE) was −6.1 D. At the final visit mean SE was −0.02 D. Corrected distance visual acuity was 20/25 or better in 81.8%. Thirty-two eyes (21.3%) presented surgery-related complications, including epithelial defect, suction, and haze. Conclusion: When performed by residents, SMILE is a safe, effective, and predictable procedure. Further analysis will show stability.

**The co-author has not submitted financial interest disclosure information as of press date.
Angle and Vault Analysis After Implantable Collamer Lens (V4c Version) Implantation in Patients With High Myopia
Abstract #: RP30040746

Presenting Author: Guillermo Garcia De La Rosa MD
Coauthors: Arturo J Ramirez-Miranda MD, Arturo Gomez Bastar MD, Sandra Salazar MD, Alejandro Navas MD, Enrique O Graue Hernandez MD

Purpose: To compare angle and vault measurements before and after ICL V4c implantation in patients with high myopia. Methods: Prospective, longitudinal case series. Results: Fifty-two eyes with mean follow-up around 10 months (Day 1, Week 1, and Months 1, 3, 6, 9, and 12). Angle and vault were evaluated using an OCT Visante (Carl Zeiss, Meditec; Germany) under different conditions of light. At Day 1 angle measurement decreased around 14.27 degrees in all patients (P < .05); over time this change did not regress significantly. Mean vault value was 590 and did not change over time. Conclusion: The present study demonstrates that with implantation of the ICL V4c in patients with high myopia, angle measurements decrease to a statistically significant degree. The greater the angle measurement, the lesser the vault was reported in the majority of patients.

A New Computerized, Image-Based System for Intraoperative Toric IOL Alignment and Centration
Abstract #: RP30040749

Presenting Author: Fabrizio I Camesasca MD
Coauthors: Paolo Vinciguerra MD, Riccardo Vinciguerra MD, Silvia Trazza

Purpose: To evaluate results of cataract surgery in astigmatic eyes receiving a toric IOL aligned and centered intraoperatively with a computerized, ocular image-based system. Methods: Verion ocular image-guided system automatically accounts for cyclorotation and auto-detects scleral vessels and limbal, pupil, and iris features. We evaluated 1-month results in eyes receiving toric IOL aligned and centered intraoperatively with Verion (Group 1, 47 eyes) vs. a traditional scleral marking system (Group 2, 13 eyes). Results: After toric IOL implantation, subjective astigmatism changed from 1.77 D to 0.36 D in Group 1, and from 1.15 D to 0.68 D in Group 2 (P < .05), while topographic astigmatism remained unchanged. Conclusion: This ocular image-based system provided accurate toric IOL alignment with better reduction of subjective astigmatism.

Long-term Clinical Results of Transepithelial PRK
Abstract #: RP30040751

Presenting Author: Jung-Sub Kim MD

Purpose: To evaluate the effectiveness and safety of transepithelial PRK using the Amaris laser platform in myopia for 3 years. Methods: 174 eyes with myopia underwent transepithelial PRK with the Amaris laser. The postoperative state was evaluated until complete re-epithelialization. UCVA, BCVA, remaining refractive error, and corneal state were evaluated. Results: Complete epithelial healing was 100% complete at 5 days postoperatively. There was no significant difference between preoperative BCVA and postoperative UCVA throughout the postoperative 3 years. Conclusion: Long-term outcomes of this study show that transepithelial PRK for myopia using the Amaris laser was stable, safe, and effective. It seems to be another method that can be substituted for other epithelial removing methods.

Femtosecond Laser-Assisted Cataract Surgery in White Cataracts
Abstract #: RP30040753

Presenting Author: Kelvin Paul McDaniel Jr BS MS
Coauthors: Michael P Jones MD, Eric J Schmidt MD**, Parvathi Rayudu MD**

Purpose: To investigate outcomes in eyes with white cataracts undergoing laser-assisted cataract surgery (LACS) vs. standard cataract surgery (SCS). Methods: Retrospective consecutive case series. Results: Twenty eyes underwent LACS; 10 underwent SCS. Visual acuity (VA), cumulative dissipated energy (CDE), postoperative day (POD) 1 corneal edema, and capsule tears were all recorded and analyzed. Results: The LACS patients were found to have a statistical improvement in CDE (P < .0001), POD 1 VA (P < .005), and POD 1 corneal edema (P < .01). Removing patients with comorbidities led to significance in POD 30 VA (P < .05). The LACS group saw no complications, while the SCS group had 2 cases of anterior capsule tear. Conclusions: LACS is at least as safe as SCS and improves CDE, POD 1 VA, and corneal edema, and possibly POD 30 VA.

Prospective Safety Assessment of a Novel Silicone Corneal Shield for Pain Reduction in Eyes Undergoing PRK
Abstract #: RP30040761

Presenting Author: Christopher S Sales MD
Coauthor: Edward E Manche MD

Purpose: To evaluate the safety of the Nexis Vision silicone corneal shield in eyes undergoing PRK. Methods: The Nexis Vision silicone corneal shield was designed to minimize postop pain and speed visual recovery. Forty-five eyes were fitted with the device for 3 days after undergoing wavefront-guided myopic PRK. Results: Seventy-eight percent of eyes achieved uncorrected distance visual acuity (UDVA) of 20/20 or better, 13% of eyes lost 1 line of corrected distance visual acuity (CDVA), and no eye lost 2 lines of CDVA 6 months after PRK. The mean preoperative UDVA improved from 1.3 to −0.1 logMAR (P = .000). Conclusion: Preliminary 6-month results suggest that this novel corneal shield provides safe refractive outcomes.

**The co-author has not submitted financial interest disclosure information as of press date.
Surface Ablation for Enhancement of Residual Astigmatism following Phakic IOL Implantation

**Abstract #:** RP30040769  
**Presenting Author:** Irina S Barequet MD  
**Coauthors:** Eliya Levinger MD, Ami Hirsh MD**, Ori Mahler MD**, Israel Kremer MD**, Samuel Levinger MD

**Purpose:** To evaluate the safety and efficacy of surface ablation (SA) in eyes with residual astigmatism after phakic IOL (P-IOL) implantation.  
**Methods:** Eyes that required enhancement after P-IOL implantation were identified. The preoperative and postoperative data were abstracted.  
**Results:** Twenty-eight consecutive eyes (21 patients) underwent SA at least 3 months after the implantation of P-IOL for enhancement of a mean sphere of 0.62 D (±5.50 D to +2.00 D) and mean refractive astigmatism of −1.54 D (−0.5 D to −3.25 D). On last follow-up the mean spherical equivalent was +0.06 ± 0.42 D. The mean uncorrected distance visual acuity was 0.69 ± 0.16 (decimals) and best-corrected distance visual acuity was 0.75 ± 0.14; the safety index was 1, and the efficacy index was 0.93. **Conclusion:** SA is a safe and effective procedure to correct residual ametropia after P-IOL implantation.

Vector Analysis of Compound Myopic Astigmatism Comparing LASIK and PRK

**Abstract #:** RP30040772  
**Presenting Author:** Brian C Toy MD  
**Coauthor:** Edward E Manche MD

**Purpose:** To compare astigmatic outcomes in eyes undergoing LASIK and PRK.  
**Methods:** Sixty-eight eyes of 34 patients underwent wavefront-guided excimer laser refractive surgery for myopia. One eye underwent LASIK and the fellow eye underwent PRK. Eyes were stratified for subgroup analysis based on preop astigmatism: 0.25-1.0 D and 1.25-2.25 D.  
**Results:** Vector analyses for the WFG and WFO groups, respectively, were surgically induced astigmatism (0.8 ± 0.6 vs. 0.8 ± 0.6 D, P = .86), error magnitude (0.01 ± 0.2 vs. 0.03 ± 0.2 D, P = .68), correction index (1.0 ± 0.3 vs. 1.0 ± 0.2, P = .28), success index (0.5 ± 0.7 vs. 0.4 ± 0.5, P = .4), and flattening index (0.9 ± 0.3 vs. 0.9 ± 0.2, P = .5). **Conclusion:** There were no significant differences between eyes undergoing LASIK and those undergoing PRK using Alpins vector analysis of astigmatism.

Incision Architecture for Minimizing Induced Higher-Order Aberrations in Femtosecond Laser Astigmatic Keratotomy: The Laser Bridge AK Evaluation Using Finite Element Patient-Specific Computational Modeling

**Abstract #:** RP30040777  
**Presenting Author:** Anita Nevyas-Wallace MD  
**Coauthors:** Cynthia Roberts PhD, Harald Patrik Studer PhD

**Purpose:** To compare, using patient-specific computational modeling, novel astigmatic keratotomy (AK) incision architectures to standard AK.  
**Methods:** Finite element modeling was used to simulate femtosecond (FS) laser AK comparing standard AK to novel “laser bridge AK” architecture (augmenting effect of incision ends by making them deeper and/or thicker than center), calculating the astigmatic effect and induced higher-order aberrations (HOA).  
**Results:** Compared with incisions of uniform depth and thickness, novel laser bridge incisions of 30° yielded an astigmatic effect 15% greater than did incisions of uniform depth and thickness, yet they diminished induced coma by 82%, trefoil by 81%, tetrafoil by 20%, and spherical aberration by 20%. **Conclusion:** Laser bridge FS laser AK yielded optimal simulation results with greater astigmatism correction, yet less induction of HOA.

Retrospective Results of Toric IOLs After Cataract Surgery

**Abstract #:** RP30040783  
**Presenting Author:** Michelle Abou-Jaoude BS  
**Coauthors:** Peter J Belin BA**, William B Trattler MD, Dayanis Adrian, Frank E Spektor MBChB**, Carlos Buznego MD, Gaston O Lacayo III MD

**Purpose:** To evaluate outcomes of toric IOL implantation after cataract surgery.  
**Methods:** The study was a retrospective analysis of 189 eyes with toric lens implantation. We analyzed the effect of preoperative K1, K2, axis, and axial length on UCVA. Patients were excluded if they had no pre- or postoperative data or if BCVA was < 20/30 at follow-up. Outcomes were compared by axial length, calculated astigmatism, and axis.  
**Results:** 168 eyes were analyzed. Postoperative UCVA was 20/31.27, with 29.17% seeing 20/40 or worse. There was no significant difference between groups of axial length or axis. Worse outcomes were found in very severe vs. severe (P = .049), moderate (P = .029), and mild (P = .015) astigmatism. **Conclusion:** Outcomes did not significantly vary with axial length or axis. Very severe astigmatism had worse postoperative UCVA.

Clinical Outcomes of Topography-Guided PRK for Irregular Astigmatism Following Penetrating Keratoplasty

**Abstract #:** RP30040785  
**Presenting Author:** Simon P Holland MD  
**Coauthors:** David T Lin MD, Choon Hwai Johnson Tan, MBBS, Christian R Diaz, MD**, Gregory Moloney, MD**

**Purpose:** To evaluate the efficacy and safety of topography-guided PRK (TG-PRK) for irregular astigmatism following penetrating keratoplasty (PK).  
**Methods:** Sixty-three eyes with post-PK astigmatism underwent TG-PRK with the Allegretto WaveLight laser.  
**Results:** Forty-five eyes completed 12 months of follow-up. Thirty-one percent had UCVA ≥ 20/40, none preoperatively. Fifty-one percent had BCVA improved; 31% or if BCVA was < 20/30 at follow-up. Outcomes were compared by axial length, calculated astigmatism, and axis.  
**Conclusion:** Early results of TG-PRK for post-PK astigmatism show satisfactory efficacy and safety, with almost one-third achieving 20/40 UCVA, but with a high retreatment rate.

**E-poster Abstracts**
Refractive Lenticule Extraction Complications

Abstract #: RP30040787

Presenting Author: Arturo J Ramirez-Miranda MD
Coauthors: Alejandro Navas MD, Enrique O Graue Hernandez MD

Purpose: To report the complications associated with refractive lenticule extraction (ReLEx) in its 2 modalities, femtosecond lenticule extraction (FLEX) and small-incision lenticule extraction (SMILE). Methods: Retrospective review of consecutive clinical case series. Results: Ninety-four eyes for the FLEX group and 160 for the SMILE group, with mean follow-up around 36 months. Fifteen FLEX eyes (18.3%) presented surgery-related complications, including suction loss, lenticule miss-dissection. Forty-three SMILE eyes (26.87%) presented surgical complications, including epithelial defect, as the most frequent, suction loss, lenticule miss-dissection, cap rupture, and lenticule rupture. Conclusion: While ReLEx complications can occur, most can be favorably resolved and are not visually significant.

Epithelial Remodeling in High Myopic LASIK With and Without Prophylactic High-Fluence Corneal Crosslinking

Abstract #: RP30040793

Presenting Author: A John Kanellopoulos MD

Purpose: To evaluate potential topographic epithelial profile thickness (EPT) changes following high myopic femtosecond-LASIK with prophylactic high-fluence corneal crosslinking (hfCXL), compared to standard LASIK. Methods: LASIK CXL: 67 eyes; Control: 72 eyes. Preoperative and 1-year postoperative EPT maps were investigated via anterior segment OCT. Central, paracentral, and overall EPT correlated to degrees corrected. Results: LASIK CXL paracentral EPT: +3.79 μm to +3.95 μm for high myopes (−7.00 D to −9.00 D) vs. +7.14 μm to +9.75 μm in controls: (P = .032) and (P = .041), respectively. Conclusion: LASIK CXL demonstrates lower EPT variation than controls, a difference correlating with lower regression rates and possible enhancement of biomechanical stability.

Customized Patterned Myopic, Astigmatic, and Hyperopic Refractive Correction With Transepithelial, Very High-Fluence Corneal Crosslinking

Abstract #: RP30040795

Presenting Author: George Asimellis PhD
Coauthor: A John Kanellopoulos MD

Purpose: To evaluate customizable application of epithelium-on high-fluence collagen crosslinking (CXL) aiming to achieve safe and predictive refractive myopic, astigmatic, and hyperopic changes. Methods: Twenty cases were treated: myopic (10), astigmatic (5), and hyperopic (5). Energy: 12 joules/cm². One-year postoperative evaluation of cornea clarity, keratometry, topography (Placido, Scheimpflug, OCT), and endothelial cell count (ECC). Results: Achieved changes: myopic, −1.3 D; astigmatic, −1.2 D; hyperopic, +0.9 D. No significant ECC change, no change in cornea clarity. Conclusion: Patterned high-fluence CXL may offer myopic, astigmatic, and hyperopic corneal refractive effect, with minimal postoperative morbidity, fast visual rehabilitation, and potential tapering possibility.

Interoperator Variability in Refractive Outcomes of 4 Surgeons Performing LASIK

Abstract #: RP30040799

Presenting Author: Hon Shing Ong MBBS
Coauthors: Alexander Charles Ionides MD, Vincenzo Maurino MD**, David S Gartry MD FRCS FRCOphth**, Mark R Wilkins MD MBBS

Purpose: To investigate interoperator variability in refractive outcomes when 4 refractive surgeons perform LASIK using the same excimer laser machines. Methods: Data from 400 patients (50 for each machine per surgeon) with −0.5 D to −6.5 D myopia, with LASIK performed using 2 excimer laser machines (Technolas 217 and Visx S4), were included. Results: Preoperative spherical equivalent (SE) of patients were similar among the 4 surgeons (F = 0.432, P = .73, ANOVA). At 3 months, there was no significant interoperator difference in postoperative unaided distance visual acuities (UDVA) or SE for either machine. UDVA: F = 1.294, P = .278 (Technolas), F = 1.125, P = .340 (Visx). SE: F = 2.153, P = .095 (Technolas), F = 1.438, P = .233 (Visx). Conclusion: There was no significant intersurgeon variability in outcomes when myopic patients underwent LASIK using the same machine.

Long-term Safety and Efficacy of Small-Incision Lenticule Extraction for High Myopia More than 10 D

Abstract #: RP30040800

Presenting Author: Osama I Ibrahim MD PhD
Coauthor: Moones Fathi Abdalla MD

Purpose: To evaluate the safety and efficacy of small-incision lenticule extraction (SMILE) on follow-up for high myopia more than −10 D. Methods: Prospective noncomparative case series carried out on 236 eyes of 134 myopic patients of errors more than 10 D treated with femtosecond laser SMILE. UCVA, BSCVA, manifest refraction, and contrast sensitivity were measured in all cases. Results: Mean preoperative UCVA, BSCVA, and spherical equivalent were 0.05, 0.67, and −12.93, respectively. Mean postoperative UCVA, BSCVA, and spherical equivalent were 0.78, 0.86, and −0.83, respectively. A few operative and postoperative complications were reported in our case series. Conclusion: SMILE is a safe and effective procedure with long-term refractive stability.

**The co-author has not submitted financial interest disclosure information as of press date.
Long-term Follow-up of Laser-Assisted Subepithelial Keratomeulectomy (LASEK) for Myopia in Thin Corneas

Abstract #: RP30040804

Presenting Author: Montserrat Garcia Gonzalez
Coauthors: Pilar Drake MD, Jose M Sanchez-Pina**, Javier Paz**, Miguel A Teus MD

Purpose: To evaluate the long-term outcomes of LASEK with mitomycin C (MMC) performed on thin corneas. Methods: Retrospective study of 100 eyes with a preoperative central corneal thickness < 500 μm that had LASEK + MMC. We evaluated the efficacy, safety, and predictability at 3 months and 5 years postop. Results: Both the sphere and cylinder showed a slight regression (P < .05). Five years postoperatively, 85 eyes were within 0.50 D and the safety index remained stable (0.96). Conclusions: LASEK + MMC seems to be safe and effective to correct myopia in corneas < 500 μm, with good visual and refractive outcomes in a 5-year follow-up.

Prospsective Randomized Contralateral Eye Study of Subjective Quality of Vision After Wavefront-Guided vs. Wavefront-Optimized LASIK

Abstract #: RP30040813

Presenting Author: Jennifer S Kung MD
Coauthor: Edward E Manche MD

Purpose: To prospectively compare subjective quality of vision after wavefront-guided (WFG) and wavefront-optimized (WFO) LASIK. Methods: 132 eyes of 66 patients underwent excimer LASIK: one eye with WFG (AMO Visx CustomVue S4 IR), the fellow eye with WFO (Alcon Allegretto Wave Eye-Q). Questionnaires assessed quality of vision preoperatively and at postoperative months 1, 3, 6, and 12. Results: Patients reported dry, scratchy eyes for 3 months and more night-time glare and haze for 6 months (P < .01). Worsened halos and visual fluctuation persisted for 1 year (P < .04). At 1 year, more WFG eyes had “excellent vision” than did WFO eyes (P = .04). Otherwise, visual symptoms were similar between WFO and WFG eyes at all times. Conclusions: Adverse patient symptoms did not differ in WFG vs. WFO eyes. Excellent vision was reported more in the WFG group.

Functional and Cosmetic Therapeutic Keratopigmentation: Five Years Follow-up

Abstract #: RP30040821

Presenting Author: Jorge L Alió MD PhD
Coauthors: Alejandra Rodriguez MS, Mohamed O El-Bahrawy MD**

Purpose: Analysis of the 4 years of follow-up outcomes of keratopigmentation: cosmetic, therapeutic, and functional. Methods: Study of 20 keratopigmentation patients, with an average follow-up of 7.15 years (± 1.85). Surgery was done either by manual intrastromal dissection (17) or superficial corneal pigmentation (3), using black and brown medical-grade chemical and certified pigments. Results: Eighty-five percent of patients expressed satisfaction with their results. Only 10% experienced discomfort. Complications were recorded in 3 patients. Although pigmentation pattern was excellent in 65% of the patients, repigmentation was required in 50% of cases. Conclusion: At 5 years follow-up, all patients expressed significant cosmetic satisfaction, while maintaining excellent pigmentation stability.

Optical Zone Enlargement and Recentration After Myopic LASIK Using Topography-Guided Custom Ablation

Abstract #: RP30040825

Presenting Author: Anas A Anbari MD PhD FACS
Coauthors: Samer Hamada,** Damian Lake**

Purpose: To determine the cylindrical power change of the eye and compare it with IOL models without transitional conic surface. Methods: Prospective, nonrandomized, single center; with cataract patients with pre-existing corneal astigmatism. Fifteen subjects were enrolled. Implantation was performed in all subjects. Results: At 3 months of follow-up, there was a significant improvement compared with preoperative measurements. Uncorrected distance visual acuity (0.8 ± 0.22 vs. 0.10 ± 0.24 logMAR; P < 0.05), cylindrical refraction (−2.72 ± 1.04 vs. −1.21 ± 0.9 D; P < .01), and refractive spherical equivalent (−3.46 ± 4.58 vs. −0.34 ± 1.1 D; P < .05). Residual astigmatism on the target axis was less than 0.5 D (P < .01). Total ocular coma and trefoil were reduced, and average Strehl ratio was 0.064. Conclusions: Precizon toric IOL is safe and effective.
Preoperative Visual Indices and Surgical Parameters That Influence Achieved Visual Acuity After Trans-PRK
Abstract #: RP30040840

Presenting Author: Soheil Adib Moghaddam MD
Coauthors: Saeed Soleymanjahi, Fatemeh Adili-aghdam**

Purpose: To investigate surgical and visual parameters predicting trans-PRK treated eyes’ visual acuity. Method: 108 eyes were recruited prospectively from 2010 to 2012, Bina Eye Hospital, Tehran, Iran. All cases underwent trans-PRK. Mean follow-up time was 7 months. Patients were divided into postop uncorrected distance visual acuity (UDVA) above 20/20 and below 20/20 groups. Results: Preoperative cylindrical refraction, secondary astigmatism, trefoil, coma, treatment centration offset distance, and applied transitional zone were significantly lower in the UDVA > 20/20 group. Conclusion: Some preoperative visual parameters could be considered to estimate postop UDVA. Lower transitional zone and treatment centration offset yield better UDVA.

Microbial Sampling Evaluation of Patient, Personnel, and Operating and Accessory Rooms in an Eye Unit
Abstract #: RP30040847

Presenting Author: Georgios Chatzilaou MD
Coauthors: Costas H Karabatsas MD, A John Kanellopoulos MD

Purpose: To evaluate microbial load in patient and personnel (PandP) and ophthalmology unit operating and accessory rooms (OR). Method: PandP were sampled with swab smears (nasal and conjunctival mucosa). Swab smear samples from floors, walls, and ceilings were stained and cultured; microbial levels of large volumes of air were assessed with a specialized device. Results: Staphylococcus epidermidis lugdunensis and Streptococcus pneumoniae were identified in PandP. Three levels of sterility were defined. Microbial evaluation showed (in CFU/m³ air/swabs): Level 1: 88/3, Level 2: 120/2, Level 3: 1200/5. Conclusion: Microbial data may be helpful in designing antimicrobial prophylaxis as well as OR disinfection monitoring.

Comparison of Efficacy, Visual Functions in Wavefront-Guided vs. Standard LASIK
Abstract #: RP30040857

Presenting Author: S Bala Murugan
Coauthors: Shivananda Narayana, Swati Upadhyaya Dom MBBS**, Thiruvengada Krishnan**

Purpose: To assess the efficacy, changes in higher-order aberrations (HOA), contrast sensitivity (CS), and night vision comfort after wavefront-guided LASIK (WFG-LASIK) vs. standard LASIK (S-LASIK) correction of myopia and myopic astigmatism. Methods: Prospective, nonrandomized, controlled interventional study done on 80 consecutive eyes with myopia, myopic astigmatism. HOA, CS, and Night Vision Quality Score (NVQS) were analyzed at 1, 3, and 6 months. Results: The efficacy index was 0.99 in the S-LASIK group and 0.97 in WFG-LASIK. HOA increased in both groups, to a lesser extent in WFG-LASIK (P < .001). There was no difference in CS between the groups (P = .32). The S-LASIK group had poor NVQS compared with the WFG-LASIK group (P < .0001). Conclusion: WFG-LASIK provides superior outcomes in quality of night vision that correlated with changes in HOA.

Femtosecond Laser-Assisted Anterior Lamellar Keratoplasty: A Possible Solution to Recurrent Anterior Corneal Dystrophies
Abstract #: RP30040859

Presenting Author: Mukesh Taneja MD
Coauthors: Pravin Yaddavalli MD, Somasheela I Murthy MD, Pravin Yaddavalli MD, Bhupesh Bagga MD FRCS MBBS

Purpose: To report the outcomes of femtosecond laser-assisted anterior lamellar keratoplasty (FALK) for recurrent anterior corneal dystrophies. Methods: Sutureless FALK was performed for 7 eyes of 7 patients with recurrent anterior granular dystrophy (4) and gelatinous drop-like keratopathy (3) having undergone earlier multiple procedures like phototherapeutic keratectomy, deep anterior lamellar keratoplasty, or penetrating keratoplasty. The outcomes were recorded in terms of symptoms, visual acuity, and complications. Results: Mean duration of follow-up was 11 months. All the patients’ symptoms improved considerably, LogMAR visual acuity improved significantly following FALK, from a mean of 1.92 to 0.9. No significant complications were noted in any case. Conclusion: FALK appears to be an effective procedure for recurrent anterior corneal dystrophies, providing excellent improvement in vision and symptoms, without the need for sutures or tissue ablation.

Laser Vision Correction Outcomes With Very High Cylinder
Abstract #: RP30040867

Presenting Author: Avi Wallerstein MD
Coauthors: Xiao-Yang Liu PhD, Eser Adiguzel PhD, Mark J Cohen MD**

Purpose: To determine the outcomes of laser vision correction (LVC) for high cylinder. Methods: Retrospective chart review of eyes ≥ 5 D cylinder having aspheric PRK or LASIK targeting emmetropia. Results: 184 eyes, cyl −5.89 ± 0.77 D (−5.00 to −7.75 D). Thirty-two (17%) had retreatment. Ninety-four eyes postop ≥ 6 months, mean follow-up 16 ± 8 months. 54%, 77%, 98% were within ± 0.25, ± 0.50, and ± 1.00 D. Cumulative uncorrected distance visual acuity: 20/20, 20/30, 20/40 in 38%, 88%, and 98%; preoperative corrected distance visual acuity (CDVA): 48%, 94%, and 98%; efficacy index, 0.95. Two lines CDVA loss, 1%; 1 line, 7%; no change, 59%. No loss ≥ 2 lines; safety index, 1.08. MRSE stable. Vector analysis: correction and error ratio, 0.95 ± 0.10 and 0.11 ± 0.08. Error of magnitude and axis: 0.28 ± 0.59 D and −0.55 ± 2.55°. Conclusion: LVC for very high cylinder has excellent outcome profiles, with a high degree of precision in treating these highly astigmatic eyes.

** The co-author has not submitted financial interest disclosure information as of press date.
**Treatment of Emmetropic Presbyopes With a Small Aperture Inlay: Three-Year Results**

*Presenting Author: John Allan Vukich MD*

*Purpose:* To evaluate safety and effectiveness of a small-aperture corneal inlay for the treatment of presbyopia. *Methods:* Prospective, nonrandomized clinical trial of 154 emmetropic presbyopes (+0.50 D to −0.75 D) implanted in the nondominant eye. Visual acuity (VA), refractive stability, and satisfaction were evaluated. *Results:* Mean uncorrected near VA improved 5 lines, from J8 at preop to J2 at 3 years postop. Mean uncorrected distance VA showed minimal change, from 20/18.5 to 20/20. Ninety-two percent of patients were 20/25 or better at 3 years; 96% were within 1.00 D of intended target. No patient sustained a loss of 2 or more lines of best corrected distance VA at 3 years. *Conclusion:* Near VA improves with implantation of a small-aperture inlay, while good distance vision is retained over the long term.

**Monocular LASIK in Adult Patients With Anisometropic Amblyopia**

*Presenting Author: Alejandro Tamez MD*

*Coauthors: Julio Hernandez Camarena MD, Jesus Lozano MD, Juan F Lozano MD, Guillermo Mendoza**, Jorge E Valdez-Garcia MD**

*Purpose:* To investigate the efficacy and safety of LASIK for the correction of anisometropic amblyopia in adult patients. *Methods:* A retrospective case series. From a random sample of 1500 patients, we found 12 amblyopic adult patients who underwent monocular LASIK for anisometropia. *Results:* Five patients (42%) gained 1 line of vision, 1 patient (8%) gained 2 lines of vision, 1 patient (8%) gained 3 lines of vision, and the rest (42%) remained unchanged compared to preoperative BCVA. Statistically significant differences were observed between the preoperative UCVA and the postoperative UCVA, and between the postoperative BCVA and the preoperative BCVA. *Conclusion:* Monocular refractive surgery in adult patients with anisometropic amblyopia is a safe and effective therapeutic option.

**Anterior Chamber Depth in a Hispanic Population**

*Presenting Author: Jesus Lozano MD*

*Coauthors: Alejandro Tamez, Jorge Valdes, Guillermo Mendoza**

*Purpose:* To define anterior chamber depth (ACD) measurements in a Hispanic population. *Methods:* A retrospective study evaluating 124 Hispanic patients using Orbscan II to measure ACD and central corneal thickness. Descriptive statistics, comparative analysis, and normality test were performed. *Results:* A total of 124 patients were evaluated. The average ACD was 2.92 ± 0.44 for the general population. The mean ACD for myopics was 3.16 ± 0.30 mm, while for hyperopics it was 2.52 ± 0.34 mm, and an independent sample test was performed showing a significant difference (P < .001). *Conclusion:* The average ACD in our study population (2.92 ± 0.44 mm) is similar to the mean ACD (3.00 ± 0.35 mm) found in a previous study. There was a significant difference between myopic and hyperopic patients and between males and females.

**The co-author has not submitted financial interest disclosure information as of press date.**
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Bettina Thomas MD
Abbott Medical Optics Inc.: S
Alcon Laboratories, Inc.: S
Alimera Sciences, Inc.: S
Allergan: S
Bausch + Lomb: S
Carl Zeiss Meditec: S
Contamac: S
Dr. Schmidt Intraocularlinsen: S
Heidelberg Engineering: S
Novartis Pharmaceuticals Corporation: S
Oculentis: S
Physiol: S
Powervision: S
Rayner Intraocular Lenses Ltd: S

William B Trattler MD
Abbott Medical Optics: C,L,S
Allergan, Inc.: C,L,S
Bausch + Lomb: S
CXLO: C,O
CXLUSA: C
LensAR: C
Oculus, Inc.: L
Rapid Pathogen Screenings: S
Tear Science: C

Silvia Trazza
None

Pravin Vaddavalli MD
None

Jorge E Valdez-Garcia MD
None

Rohin Vij BS MA
None

Paolo Vinciguerra MD
Nidek, Inc.: C
Oculus, Inc.: C
SCHWIND eye-tech-solutions: C

Riccardo Vinciguerra MD
Optimeyes: C

Mark R Wilkins MD MBBS
None

Sonia H Yoo MD
Abbott Medical Optics Inc.: S
Alcon Laboratories, Inc.: C
Allergan, Inc.: S
Bausch + Lomb Surgical: C
Carl Zeiss Meditec: S
Optimedica: C
SLACK, Incorporated: L
Transcend: C

Charles Q Yu MD
None

Aasem Wagih Zahran MD
None
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