Subspecialty Day

2013
New Orleans

Refractive Surgery 2013:
Perfecting Vision

American Academy® of Ophthalmology
The Eye M.D. Association

Refractive Surgery 2013
Perfecting Vision

Subspecialty Day
2013
New Orleans
November 15 – 16

Program Directors
Michael C Knorz MD and Sonia H Yoo MD

The Annual Meeting of ISRS

Sponsored by the International Society of Refractive Surgery (ISRS)

Ernest N Morial Convention Center
New Orleans, Louisiana
Friday–Saturday, Nov. 15–16, 2013

Presented by:
The American Academy of Ophthalmology

American Academy of Ophthalmology
The Eye M.D. Association

Dear Colleague:

On behalf of the International Society of Refractive Surgery (ISRS), it is our pleasure to welcome you to New Orleans and Refractive Surgery 2013: Perfecting Vision. This meeting assembles a great lineup of international leaders in refractive surgery and provides a forum for exchange of the latest information in our field.

In this year's Subspecialty Day Meeting, Friday morning will begin with corneal crosslinking and phakic IOLs. The video session that follows will focus on various lens complications and how to manage complex situations. Friday afternoon will begin with a session on femtosecond laser cataract surgery on trial. Pros and cons of the technology will be debated. In the afternoon Break With the Experts will occur, where attendees will be able to discuss clinical conundrums with colleagues specializing in various areas of interest. Friday will wrap up with interactive consultations in lens refractive surgery, followed by a session on the best procedure for the patient with refractive lens surgery presented by a panel of experts in the field. The Free Paper sessions will run concurrently throughout the refractive Subspecialty Day program on Friday, Nov. 15th.

Saturday's eye-opener will be a video session on corneal complications of refractive surgery, followed by interactive consultations in corneal refractive surgery. Treatments for presbyopia, including corneal inlays, accommodating IOLs, diffractive and refractive multifocal IOLs and laser corneal presbyopia surgery, will be tried by jury. We end Saturday with the annually anticipated "Hot, Hotter, and Hottest" topics from the *Journal of Refractive Surgery*.

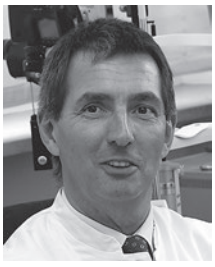
At the meeting we will also acknowledge and honor the ISRS award winners. We hope to see that at the end of the two days you will have learned enough to handle the most challenging refractive surgical cases.

Our faculty have spent innumerable hours preparing their presentations and course materials to provide the most up-to-date and comprehensive review of their topics. We thank them for all of their efforts and for sharing their expertise during the program.

It would have been impossible to develop this program without your cooperation. This is why we request that you assist us by completing the evaluation. We carefully review all comments to better understand your needs, so please indicate the strengths and shortcomings of this year's program and assist us in brainstorming about new ways to fulfill your objectives.

Again, we welcome you to Refractive Surgery 2013: Perfecting Vision; we hope you find it educational, exciting and enjoyable.

Sincerely,



Michael C Knorz MD
Program Director

Sonia H Yoo MD
Program Director

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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.

2013 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

2013 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.

2013 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. ABO does not sponsor this or any outside activity, and 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 pre-approved 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 continuing medical education (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 the Annual Meeting. 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;
- Register onsite; or
- Scan your barcode at the meeting.

CME Credit Reporting

Lobby B2 and Lobby G; Academy Resource Center, Hall G - Booth 3239

Attendees whose attendance has been verified (see above) at the 2013 Annual Meeting 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 the Annual Meeting at the CME Credit Reporting booth.

Academy Members: The CME credit reporting receipt is not a CME transcript. CME transcripts that include 2013 Annual Meeting credits entered onsite will be available to Academy members on the Academy's website beginning Dec. 10, 2013.

NOTE: CME credits must be reported by Jan. 15, 2014. After the 2013 Annual Meeting, credits can be claimed at www.aao.org/cme.

The Academy transcript cannot list individual course attendance. It will list only the overall credits spent in educational activities at Subspecialty Day and/or the Annual Meeting.

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 the Annual Meeting 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

Visit the Academy's website for detailed CME reporting information.

2013 Award Winners

2013 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.

Dimitri T Azar MD MBA

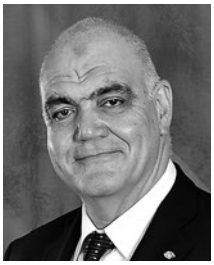
Dr. Dimitri Azar is dean of the College of Medicine at the University of Illinois at Chicago. He holds the BA Field Chair in ophthalmologic research and is distinguished professor of Ophthalmology, Bioengineering and Pharmacology. Dr. Azar joined the University of Illinois at Chicago in 2006, as head of the Department of Ophthalmology and Visual Sciences, after serving as tenured professor of Ophthalmology at Harvard Medical School, director of the Cornea Service at the Massachusetts Eye and Ear Infirmary, senior scientist at the Schepens Eye Institute, and faculty at the Johns Hopkins School of Medicine. He earned an executive MBA with high honors from the University of Chicago.

Dr. Azar is the author of over 400 scientific articles and book chapters. He is the editor of 14 books in ophthalmology, and he holds 15 patents. Every year since 1994, Dr. Azar has been named one of The Best Doctors in America® and/or one of the Castle Connolly regional Top Doctors in America. He is a leader in basic science and clinically related vision research, making significant contributions to the treatment of corneal diseases and to advances in refractive surgery through mathematical analyses and applications of advanced optics. His basic science research on matrix metalloproteinases in corneal wound healing and angiogenesis has been continually funded by the National Eye Institute R01 award since 1993. He serves as a trustee for the Chicago Ophthalmological Society and for the Association of Research and Vision in Ophthalmology.

Dr. Azar has also received multiple leadership awards, including the 2009 Lans Distinguished Award, the University of Illinois at Chicago Scholar Award, and the Distinguished Professor award in 2012.

Casebeer Award

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



Osama I Ibrahim MD PhD

Dr. Osama Ibrahim is president of Alexandria University, Egypt, and distinguished professor of ophthalmology. He is the 23rd president of Alexandria University and the first elected president (December 2011).

He completed his medical degree in the Faculty of Medicine, Alexandria University, in 1980 as the top student. He joined the Ophthalmology Department, completed his residency, and got his master's degree in 1984. His experience in cornea and refractive surgery started in 1985 with a doctoral thesis on radial and astigmatic keratotomy.

Dr. Ibrahim completed a fellowship in corneal and refractive surgery at Emory University, Atlanta, Georgia, USA, between 1988 and 1990 with Prof. George Waring. During that time he studied corneal topography and shared in the first classification of normal topography. He finished his doctorate in 1990 and joined the staff until he was promoted to full clinical professor in the Ophthalmology Department at Alexandria University in 2000.

Dr. Ibrahim was the chief of Corneal and Refractive Surgery in El-Maghraby Eye Hospital and Centers in Saudi Arabia from 1991 to 1996. He was a world leader in automated lamellar keratomileusis (ALK) in the early 1990s and innovative in excimer laser surgery with PRK and PTK. He was among the first group that developed LASIK in 1992 at El Maghraby centers.

Upon Dr. Ibrahim's return to Egypt in 1996, with the great help of his eminent professors Dr. Sheta, Dr. Hussein and Dr. El-Sahn, he established the first private subspecialty group practice, "Alex Eye Center," with great success. He also helped and promoted many ophthalmic centers, both in Alexandria and all over Egypt—the chain "Roayah," of which he is the CEO, has expanded to include six centers in Egypt and two in the Arab world.

During his 30 years of clinical practice and research development, Dr. Ibrahim has supervised and discussed more than 70 master's and doctoral theses not only in Alexandria University, but also in almost all other universities in Egypt. He is an active member of almost all prestigious ophthalmic societies in the world, including the American Academy of Ophthalmology (Academy), American Society of Cataract and Refractive Surgery, European Society of Cataract and Refractive Surgeons, International Society of Refractive Surgery, American College of Ophthalmic Surgeons, Middle East and Africa Council of Ophthalmology (MEACO), Egyptian Ophthalmic Society, and the Egyptian Society of Ocular Implants and Refractive Surgery, and he is a founding member of the African Society of Refractive Surgery. He is on the editorial board of *Journal of Cataract and Refractive Surgery* and *Middle East African Journal of Ophthalmology* and has helped to edit and publish many papers in the field of cornea, cataract and refractive surgery. Prof. Osama is the recipient of the Academy's 2012 MEACO Distinction Award and the 2012 Achievement Award.

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.

Vikentia Katsanevaki MD PhD

Dr. Vikentia Katsanevaki graduated from medical school at the University of Crete, Greece, in 1994, where she also completed her residency, a PhD and a refractive fellowship from 1995 to 2003. She served at the refractive department in the same setting from 2003 to 2006 and then completed a cornea and external disease fellowship at Moorfields Eye Hospital, London, in 2007.

Since 2007 she has been in private practice, running the refractive department at Orasis Eye Center in Athens, Greece.

Dr. Katsanevaki currently chairs the International Counsel of the International Society of Refractive Surgery and is a member of the Program Committee of the European Society of Cataract and Refractive Surgery. She is member of the editorial boards of *Eurotimes* and *Ocular Surgery News* (Europe edition). She has authored numerous peer-reviewed articles and scientific book chapters and is a reviewer for *Journal of Refractive Surgery* and *Journal of Cataract and Refractive Surgery*.

Dr. Katsanevaki was awarded with the Achievement Award by the American Academy of Ophthalmology in 2007.

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.

Renato Ambrósio Jr. MD PhD

Prof. Renato Ambrósio Jr. is a world-class cornea and refractive surgery specialist in clinical practice in Rio de Janeiro, Brazil. He is the oldest son of the late Renato Ambrósio MD, a pioneer in refractive surgery in the early 1980s, and Vera M Ambrósio MD, director of Instituto de Olhos R Ambrósio.

In November 2002, after having completed his residency at Instituto de Oftalmologia Tadeu Cvintal in 2000 and a fellowship at the University of Washington, Dr. Ambrósio joined his family practice, with his mother and younger brother, Rodrigo M Ambrósio MD, a retina and vitreous specialist. He defended his doctoral thesis on science at the University of São Paulo in 2004 and currently is associate professor of ophthalmology at the Pontific Catholic University in Rio de Janeiro and at the Federal University of São Paulo (UNIFESP). In 2004 he founded the Rio de Janeiro Corneal Tomography and Biomechanics Study Group, which includes over a dozen research associates under his mentorship.

Prof. Ambrósio has authored over 350 scientific publications and has received over 50 awards in Brazil and internationally. He is the actual and will be the last president of the Brazilian Society of Refractive Surgery (SBCR),* for which his father, Renato Ambrósio, was the second president, from 1988 to 1990.

*In 2014, SBCR will be combined with the Brazilian Society of Implants and Cataract Surgery to constitute BRASCRS, the Brazilian Society of Cataract and Refractive Surgery.

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.

Damien Gatinel MD

Damien Gatinel MD has been the head of the Anterior Segment and Refractive Surgery Department at the Rothschild Foundation, Paris, since 2007. He completed his fellowship at the Department of Ophthalmology of the University of Paris 13 and then served as assistant professor at the Department of Ophthalmology of Bichat, University of Paris 7.

His research has focused on astigmatism correction, IOL design, and laser profiles of photoablation used in refractive surgery and their consequences on the optical quality of the human eye. The challenges of the detection of early subclinical keratoconus is another field of interest.

Dr. Gatinel collaborates actively with the research and development units of companies involved in the field of ophthalmic industry and owns several patents, including the first diffractive trifocal IOL design.

Dr. Gatinel is a board member of the Research Committee of the European Society of Cataract and Refractive Surgeons and a member of the International Society of Refractive Surgery and the American Academy of Ophthalmology—from which he received an Achievement Award in 2005. He serves on the editorial board of the *Journal of Refractive Surgery* and is a reviewer for 10 different journals. He has received 12 international awards, among which he received five consecutively at the Congress of the American Society of Cataract and Refractive Surgery in 2011, 2012, and 2013. He has published more than 70 articles in peer-reviewed journals and edited three books.

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.

Joseph Colin MD

Joseph Colin received his MD in 1977 from Brest University, where he also started his ophthalmology residency and fellowship, later extended to Nantes University. He was promoted to professor of ophthalmology and chairman of the Department of Ophthalmology at Brest University Medical School. His topic was anterior segment and mainly cornea, with two main research areas of interest: infections (herpetic simplex keratitis) and keratoconus. He was the first to suggest the use of intracorneal segments in the correction of keratoconus. He was also investigator in phakic IOLs and cataract surgery. In 2000, he arrived at Bordeaux University Medical School as chairman of the Department of Ophthalmology, where one of his major accomplishments was the establishment of the Keratoconus Research Center and the basic science laboratory research and femtosecond laser technology, headed by Dr. David Touboul.

Dr. Colin participated in most of the European and international organizations of cornea and anterior segment, particularly at the European Society of Cataract and Refractive Surgeons and at the International Society of Refractive Surgery. He was also president of the French National University Council for Ophthalmology (1995-2003), president of the French Society of Cataract and Refractive Surgery (SAFIR) (2009-2011) and the French Ophthalmological Society (SFO) (2005-2008). He also served on the editorial boards of *Journal of Refractive Surgery*, *Journal of Cataract and Refractive Surgery*, *European Journal of Ophthalmology* and *Journal Français d'Ophtalmologie*.

Among his international recognitions, Dr. Colin received the 1998 Honor Award of the American Academy of Ophthalmology, the Binkhorst medal in 1990 and the Chevalier de la Légion d'Honneur in December 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.

George H H Beiko BM BCh FRCS(C)

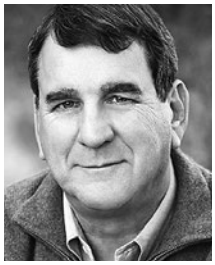
George H H Beiko is a medical graduate of Oxford University and completed his ophthalmology specialty training at Queens University in Canada. After completing his residency, he worked for one year at the St. John Ophthalmic Hospital in Jerusalem. He is a founding member of the International Society for Intraocular Lens Safety (ISIS).

Dr. Beiko has published numerous peer-reviewed articles and also authored 12 book chapters. He has given over 500 scientific presentations at meetings throughout the world. He has been awarded three best papers of session awards at the American Society of Cataract and Refractive Surgery annual meeting, one best poster award at the American Academy of Ophthalmology (AAO) Annual Meeting, one Best Paper of Session (Cataract) award at the Asia-Pacific Academy of Ophthalmology-AAO Joint Meeting and the Best Original Paper in Cataract Surgery award at the AAO Joint Meeting in 2010. Dr. Beiko has been named to 40 visiting professor/guest lectureships. He is on the review panel or editorial board of 20 ophthalmology journals. His honors include being elected to membership in the International Intraocular Implant Club, being named one of the "Premier Surgeons" of North America (which numbers 250 surgeons) and being made an officer of the Most Venerable Order of the Hospital of St. John of Jerusalem by Her Majesty the Queen of England. He is the past Canadian Hospitaller for the St. John's Ophthalmic Hospital in Jerusalem. Recently, Dr. Beiko was honored with the Gold Medal by the Indian Society of Cataract and Refractive Surgery and an Achievement award by the American Academy of Ophthalmology.

Dr. Beiko is an assistant clinical professor at McMaster University and a lecturer at the University of Toronto.

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.



William J Fishkind MD FACS

William J Fishkind MD FACS is a clinical professor at the University of Utah and the University of Arizona. He is the director of the Fishkind, Bakewell and Maltzman Eye Care and Surgery Center in Tucson, Arizona. He attained his medical degree from Tufts University School of Medicine. He is board certified in internal medicine and ophthalmology. He completed an ophthalmology residency at a combined program of the United States Public Health Service (USPHS) Hospital and Louisiana State University in New Orleans, Louisiana.

Dr. Fishkind is a fellow of the American Board of Ophthalmology and the American College of Surgeons. He is a member of the program committee of the American Society of Cataract and Refractive Surgery (ASCRS) and has served as chairman of the ASCRS Film Festival. He is chairman of the cataract section of the Annual Meeting Program Committee of the American Academy of Ophthalmology. He is past president, and president emeritus, of the Outpatient Ophthalmology Surgery Society.

Presently, Dr. Fishkind practices in Tucson, Arizona, but travels extensively, teaching both nationally and internationally. He has been a visiting professor at many universities and given many scientific presentations. He has edited a textbook, *Complications in Phacoemulsification: Avoidance, Recognition, and Management*, published by Thieme Publications in New York City. Additionally, he has authored many articles as well as book chapters on phacoemulsification and IOL implantation.

22nd 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).

David Smadja MD

Dr. David Smadja graduated from medical school in Paris, France. After completion of his residency at Bordeaux Hospital University, his interests were brought to the cornea and to refractive surgery, and he completed a clinical fellowship in anterior segment and refractive surgery under the supervision of Professor Joseph Colin at Bordeaux Hospital University.

Subsequently, he completed a postdoctoral research fellowship in cornea and refractive surgery at the Cole Eye Institute of the Cleveland Clinic under the supervision of Dr. Ronald R Krueger from 2010 to 2011. After completion of his research fellowship, he returned to France and graduated from the European Board of Ophthalmology.

Some of his awards include the Best Paper award and the Poster of Interest in refractive surgery at the 2013 meeting of the American Society of Cataract and Refractive Surgery.

Dr. Smadja is a reviewer for several international ophthalmology journals, and his research interests are focused on corneal imaging and keratoconus detection, new developments in excimer and femtosecond technologies and wavefront and IOLs.

He currently holds a faculty position in the refractive surgery department at the Bordeaux Hospital University and is also working for the French National Reference Center for Keratoconus, where he is involved in several research projects.

Faculty

No photo available

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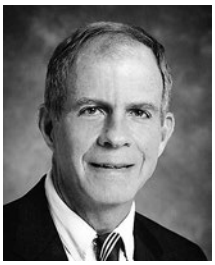

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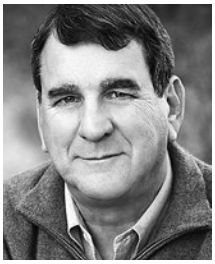

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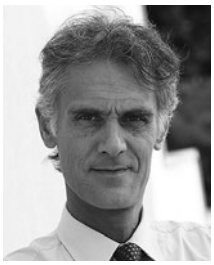

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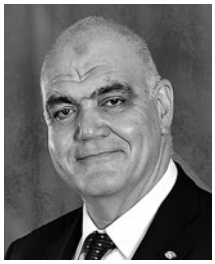

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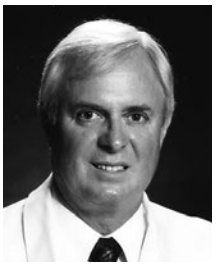

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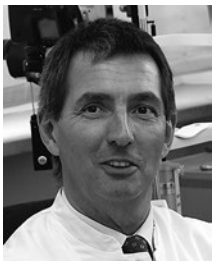

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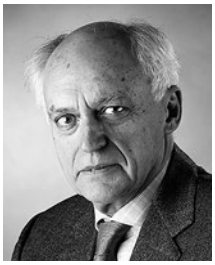

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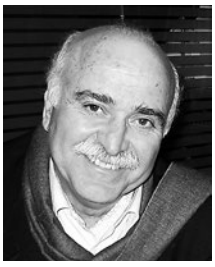

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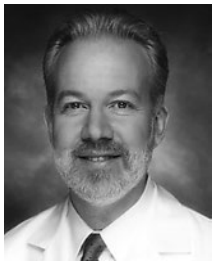

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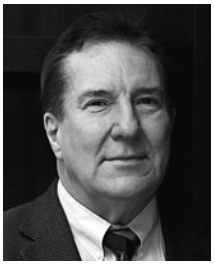

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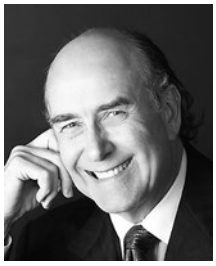

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Audience Interaction

How To Text In Your Questions to the Panel

- From your smart phone, computer or tablet, go to **http://PollEv.com.** In the message field type **963723** insert a space then type your question and hit submit.
- From your mobile device, compose a text to **22333.** In the message field type **963723** insert a space then type your question and hit send.

Refractive Surgery 2013: Perfecting Vision

FRIDAY, NOV. 15

7:00 AM	CONTINENTAL BREAKFAST		
8:00 AM	Welcome and Opening Remarks	Michael C Knorz MD* Sonia H Yoo MD*	
8:03 AM	Pre-test	Michael C Knorz MD*	

Keynote Lecture

8:05 AM	Crosslinking: Inception to Multiple Clinical Applications	Theo Seiler MD PhD*	1

Section I: Corneal Crosslinking

Moderators: Theo Seiler MD PhD*, Leopoldo Spadea MD
Panelists: Peter S Hersh MD*, William B Trattler MD*

8:15 AM	Long-term Results and Complications	Theo Seiler MD PhD*	2
8:22 AM	How to Get Riboflavin Into the Cornea	Paolo Vinciguerra MD*	3
8:29 AM	Combined Crosslinking and Laser Application	A John Kanellopoulos MD*	6
8:36 AM	Why We Should Not Use Primary Crosslinking in LASIK	Perry S Binder MD*	11
8:43 AM	Rationale and Results of Accelerated Corneal Crosslinking	John Marshall PhD*	14
8:50 AM	Discussion		

Section II: Phakic IOLs

Moderators: Jose L Guell MD PhD*, Roberto Zaldivar MD*
Panelists: Walter J Stark MD*, John Allan Vukich MD*

9:05 AM	Anterior Chamber Phakic IOLs	Georges D Baikoff MD*	15
9:12 AM	Iris-Fixated Phakic IOLs	Camille J R Budo MD*	16
9:19 AM	Posterior Chamber Phakic IOLs	Alaa M Eldanasoury MD*	17
9:26 AM	How Safe Are Phakic IOLs? A Literature Review	Thomas Kohnen MD PhD FEBO*	19
9:33 AM	Discussion		

Keynote Lecture

9:45 AM	Phakic IOLs: Where Are We Heading?	Antonio A P Marinho MD PhD*	25
9:55 AM	REFRESHMENT BREAK		

Free Paper Session I—La Nouvelle Orleans C

Moderators: Robert Bellucci MD*, George O Waring III MD*
Panelists: Perry S Binder MD*, Damien Gatinel MD*

9:10 AM	U.S. Trends in Refractive Surgery: 2013 ISRS Survey	Richard J Duffey MD	27

* Indicates that the presenter has financial interest.
No asterisk indicates that the presenter has no financial interest.

9:15 AM	Profocal Cornea: Extended Range of Vision Shaped with a Hydrogel Corneal Inlay	Roger F Steinert MD*	27
9:20 AM	Corneal Topographic Astigmatism (CorT) a Better Measure of Corneal Astigmatism That Corresponds to Manifest Refractive Cylinder	Noel A Alpins MD FACS*	27
9:25 AM	Discussion		
9:33 AM	Topographically Guided Photorefractive Keratectomy for Irregular Astigmatism Following Penetrating Keratoplasty	Simon P Holland MD*	27
9:38 AM	Refractive Outcomes of Topography-Guided Photorefractive Keratectomy With Simultaneous Crosslinking for Keratoconus	David T Lin MD	27
9:43 AM	Topography-Guided Photorefractive Keratectomy and Crosslinking for Ectasia After LASIK	Simon P Holland MD*	28
9:48 AM	Discussion		
9:56 AM	REFRESHMENT BREAK		

ISRS President's Update and Awards

10:35 AM	President's Update	Amar Agarwal MD*	
10:37 AM	ISRS Awards	Amar Agarwal MD*	

Keynote Lecture

10:50 AM	The IOL of the Future: What Is in the Pipeline?	Jack T Holladay MD MSEE FACS*	29

Section III: Video Lens Complications

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

11:00 AM	Managing the Nucleus After a Posterior Capsule Rupture	Iqbal K Ahmed MD*	30
11:07 AM	Mastering Glued IOL	Roger F Steinert MD*	31
11:14 AM	Managing Drop IOL	Amar Agarwal MD*	32
11:21 AM	Posterior Capsule Rupture in a Premium IOL Patient	David F Chang MD*	34
11:28 AM	Bag Lens Glued Exchange	Lisa B Arbisser MD*	35
11:35 AM	The Dropped Nucleus	Robert H Osher MD*	36
11:42 AM	Discussion		
11:52 AM	Advocating for Patients	Stephanie Jones Marioneaux MD	37
11:57 AM	LUNCH		

Free Paper Session II—La Nouvelle Orleans C

Moderators: Kendall E Donaldson MD, Kazuo Tsubota MD

Panelists: William W Culbertson MD*, Oliver Findl MD*

11:05 AM	Five-Year Results of Femtosecond Lenticule Extraction to Treat Myopia	Rupal S Shah MD*	39
11:10 AM	Correction of Low to Moderate Hyperopia by Noninvasive Keratoplasty: U.S. Clinical Trial	James J Salz MD*	39
11:15 AM	Use of a Small-Aperture Inlay in Emmetropic Presbyopes: Three-Year Results	John Allan Vukich MD*	39
11:20 AM	Discussion		

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11:28 AM	Photopic and Mesopic Functional Vision After Small-Aperture Corneal Inlay Implantation	Jay Stuart Pepose MD PhD*	39
11:33 AM	Selecting the Most Accurate Toric IOL and Correcting for Refractive Surprises	Noel A Alpins MD FACS*	40
11:38 AM	Removability of a Small-Aperture Intracorneal Inlay for Presbyopia Correction	Pilar Casas de Llera MD	40
11:43 AM	Refractive Results Following Femtosecond Laser-Assisted Capsulotomy	Louis D Skip Nichamin MD*	40
11:48 AM	Discussion		
11:57 AM	LUNCH		

Section IV: Laser Refractive Lens Surgery on Trial: Is It Really Better?

Judge: Eric D Donnenfeld MD*
Jury: Ronald R Krueger MD*, Robert H Osher MD*, Stephen G Slade MD FACS*

1:00 PM	The System I Use and Why I Choose It	Robert J Cionni MD*	41
1:05 PM	The System I Use and Why I Choose it	Burkhard Dick MD*	42
1:10 PM	The System I Use and Why I Choose it	Harvey S Uy MD*	44
1:15 PM	The System I Use and Why I Choose it	Gerd U Auffarth MD*	45
	Refractive Result		
1:20 PM	Prosecution: Refractive Results Are Not Better	George Beiko MD*	46
1:25 PM	Defense: Refractive Results Are Better	Zoltan Nagy MD*	47
1:30 PM	Discussion of Jury and Verdict		
	Safety		
1:35 PM	Prosecution: Laser Refractive Lens Surgery Is Not Safer	Robert K Maloney MD*	48
1:40 PM	Defense: Laser Refractive Lens Surgery Is Safer	Michael A Lawless MD*	49
1:45 PM	Discussion of Jury and Verdict		
	Time and Cost		
1:50 PM	Prosecution: Procedure Is Too Long and Too Expensive	Deepinder K Dhaliwal MD*	55
1:55 PM	Defense: Procedure Time and Cost Are Acceptable	John A Hovanesian MD*	56
2:00 PM	Discussion of Jury and Verdict		
	Phaco		
2:05 PM	Prosecution: Why I Still Prefer Phaco	Steve A Arshinoff MD*	57
2:10 PM	Defense: Why I Switched to Laser Refractive Lens Surgery	Barry S Seibel MD*	58
2:15 PM	Discussion of Jury and Verdict		

Keynote Lecture

2:20 PM	Restoration of Accommodation by Laser Surgery	Omid Kermani MD*	59

Break With the Experts—La Nouvelle Orleans Foyer

2:30 PM – 3:15 PM

Cataract and IOL Complications	Frank A Bucci Jr MD* Sadeer B Hannush MD	
Collagen Crosslinking	Fabrizio I Camesasca MD* R Doyle Stulting MD PhD*	

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Corneal Inlays	Minoru Tomita MD PhD* George O Waring IV MD*	
Elevation Corneal Tomography	Michael W Belin MD* Stephen D Klyce PhD*	
Laser Refractive Lens Surgery	Richard S Davidson MD* Simon P Holland MD* Zoltan Nagy MD* Stephen G Slade MD FACS*	
Intracorneal Rings	Renato Ambrosio Jr MD* Parag A Majmudar MD*	
Laser Vision Correction Enhancements	Arthur B Cummings MD* Osama I Ibrahim MD PhD*	
Phakic IOLs	Georges D Baikoff MD* Antonio A P Marinho MD PhD*	
Planning IOL Powers	Rosa Braga-Mele MD* Wallace Chamon MD*	
Presbyopic IOL Pearls	William A Maxwell MD PhD* Stephen S Lane MD*	
Toric IOL Pearls	Terry Kim MD* Marcony R Santhiago MD	

Section V: Interactive Consultations—Lens Refractive Surgery

3:15 PM – 4:15 PM

Moderator: Michael C Knorz MD* Panelists: Y Ralph Chu MD*, Samuel Masket MD*, Louis D Skip Nichamin MD*, Rudy Nuijts MD*, Roger F Steinert MD*		61

Free Paper Session III—La Nouvelle Orleans C

Moderators: Richard B Packard MD*, Dan Z Reinstein MD*
Panelists: A John Kanellopoulos MD*, Thomas F Neuhann MD

3:20 PM	Laser Cataract Surgery: Initial Experience With Novel Patient Interface	Michael A Lawless MD*	62
3:25 PM	Learning Curve and Safety of Early Experience With Femtosecond Laser-Assisted Cataract Surgery at a Large Multiuser ASC	Jonathan H Talamo MD*	62
3:30 PM	Discussion		
3:38 PM	Analysis of 215 Capsulotomies Created With Femtosecond Laser and a Novel Patient Interface in Cataract Surgery	John P Berdahl MD*	62
3:43 PM	Postoperative Year 1 Results of a Prospective, Randomized Study Comparing 1 Accommodating and 2 Multifocal IOLs	Robert Edward T Ang MD*	62
3:48 PM	Comparative Visual Outcomes After Implantation of 2 Trifocal IOLs and a Bifocal IOL	Jorge L Alio MD PhD*	63
3:53 PM	Discussion		
4:01 PM	NEI-RQL-42 and SVI Quality-of-Life Measures After Bilateral Implantation of 3 Presbyopia-Correcting IOLs at 6 Months Follow-up	Richard C Chu DO*	63
4:06 PM	A New Method for Calculating IOL Power and Improving Refractive Accuracy in Long or Short Eyes	Eric D Donnenfeld MD*	63

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4:11 PM	Nomogram for Femtosecond Nonpenetrating Intrastromal Astigmatic Keratotomy During Femtosecond Laser-Assisted Cataract Surgery	Nicola M Lau MBBS	63
4:16 PM	Discussion		

Section VI: ESCRS Symposium: Is There a Best Procedure for the Patient With Refractive Lens Surgery: Evidence and Assumptions

Moderators: Peter James Barry MD, Rudy Nuijts MD

4:15 PM	The Patient View: Measurements vs. Patient-Reported Outcomes	Mats H Lundstrom MD	64
4:22 PM	Can We Optimize Monovision Using Adaptive Optics?	Scott M MacRae MD*	66
4:29 PM	Evidence in Presbyopia Correction: Monovision or Multifocal IOL	Oliver Findl MD*	68
4:36 PM	Is There Anything Good About Astigmatism?	Julian D Stevens DO*	69
4:43 PM	Evidence in Astigmatism Correction: Monofocal or Toric IOLs or Incisions	Rudy Nuijts MD*	71
4:50 PM	What Is the Best Procedure for the Ametropic Pseudophakic Patient?	Roberto Bellucci MD*	74
4:57 PM	Discussion		
5:15 PM	Closing Remarks	Michael C Knorz MD* Sonia H Yoo MD*	
5:17 PM	ADJOURN		

Free Paper Session IV—La Nouvelle Orleans C

Moderator: W Bruce Jackson MD FRCSC*
Panelists: Vance Michael Thompson MD*, Rupal S Shah MD*

4:25 PM	Comparison of Laser-Assisted PTK Removal of Epithelium to Manual Debridement in Corneal Crosslinking for Progressive Keratoconus	Ronald N Gaster MD FACS*	76
4:30 PM	Aztec Protocol: Small-Incision Lenticule Extraction and Intrastromal Crosslinking in Forme Fruste Keratoconus	Enrique O Graue Hernandez MD*	76
4:35 PM	Bowman's Ectasia Index: A Novel Index for the Diagnosis of Keratoconus	Mohamed Abou Shousha MD*	76
4:40 PM	Discussion		
4:48 PM	Three-Year Clinical Outcome of Small-Incision Lenticule Extraction	Osama I Ibrahim MD PhD*	76
4:53 PM	Postoperative Relative Total Tensile Strength After Small-Incision Lenticule Extraction for Moderate Myopia Compared to Matched LASIK Controls	Dan Z Reinstein MD*	77
4:58 PM	Outcomes from a Prospective, Randomized, Eye-to-Eye Comparison of Small-Incision Lenticule Extraction vs. Femto-LASIK Treatments for Myopia	Arturo J Ramirez-Miranda MD*	77
5:03 PM	Discussion		
5:11 PM	Adjourn		

* Indicates that the presenter has financial interest.
No asterisk indicates that the presenter has no financial interest.

SATURDAY, NOV. 16

7:00 AM	CONTINENTAL BREAKFAST		
8:00 AM	Opening Remarks	Michael C Knorz MD* Sonia H Yoo MD*	

Section VII: Corneal Video Complications

Moderators: Donald Tan MD FRCS FRCOphth*, Sonia H Yoo MD*

8:05 AM	The Longest Refractive Day	Soosan Jacob FRCS	78
8:12 AM	The Longest Refractive Day	Natalie A Afshari MD	79
8:19 AM	The Longest Refractive Day	John So-Min Chang MD*	80
8:26 AM	The Longest Refractive Day	Pravin Vaddavalli MD	82
8:33 AM	The Longest Refractive Day	Anthony J Aldave MD*	84
8:40 AM	Discussion		

Keynote Lecture

8:55 AM	Epithelial Measurement and Healing	Dan Z Reinstein MD*	85

Section VIII: Interactive Consultations—Corneal Refractive Surgery

9:05 AM – 10:00 AM

Moderators: Daniel S Durrie MD*, Helen K Wu MD*
Panelists: William W Culbertson MD*, Elizabeth A Davis MD*,
Steven C Schallhorn MD*, Julian D Stevens DO* 89

Keynote Lecture

10:00 AM	The Ideal Surface Ablation: Laser, Scraping, Alcohol?	Marguerite B McDonald MD*	90
10:10 AM	REFRESHMENT BREAK and ANNUAL MEETING EXHIBITS		

Section IX: Presbyopia Surgery on Trial—Which Is the Best Procedure?

Judge: George O Waring III MD FACS*
Jury: Daniel S Durrie MD*, Jack T Holladay MD MSEE FACS*, Richard L Lindstrom MD*

	Accused: Corneal Inlays		
10:50 AM	Pinhole Corneal Inlays	Minoru Tomita MD PhD*	91
10:55 AM	Refractive Corneal Inlays	Ioannis G Pallikaris MD*	94
11:00 AM	Nonrefractive Corneal Inlays	Mark Timothy Wevill MD*	95
11:05 AM	Prosecution: Inlays Are Not the Ideal Solution	Michael A Lawless MD*	96
11:10 AM	Defense: Corneal Inlays Are Excellent	Gunther Grabner MD*	100
11:15 AM	Discussion of Jury and Verdict		
	Accused: Accommodating IOLs		
11:20 AM	Single-Optic Accommodating IOLs	Lisa B Arbisser MD*	104
11:25 AM	Dual-Optic Accommodating IOLs	Mark Packer MD*	105
11:30 AM	New Designs	Jorge L Alio MD PhD*	109
11:35 AM	Prosecution: Accommodating IOLs Are Not the Ideal Solution	Oliver Findl MD*	110

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11:40 AM	Defense: Accommodating IOLs Are Excellent	Steven J Dell MD*	111
11:45 AM	Discussion of Jury and Verdict		
	Accused: Multifocal IOLs		
11:50 AM	Diffractive Multifocal IOLs	Bonnie A Henderson MD*	112
11:55 AM	Refractive or Zonal Multifocal IOLs	Jan A Venter MD	113
12:00 PM	Trifocal IOLs	Damien Gatinel MD*	115
12:05 PM	Prosecution: Multifocal IOLs Are Not the Ideal Solution	Thomas F Neuhann MD	117
12:10 PM	Defense: Multifocal IOLs Are Excellent	Beatrice Cochener MD*	118
12:15 PM	Discussion of Jury and Verdict		

Keynote Lecture

12:20 PM	Advantages and Limitations of Corneal Laser Surgery in Presbyopia	Robert Edward T Ang MD*	119
12:30 PM	LUNCH and ANNUAL MEETING EXHIBITS		

Section X: Free Paper Session

Moderators: David R Hardten MD*, Steven E Wilson MD*
Panelists: Stephen C Coleman MD,

1:45 PM	A Comparison of Corneal Sensation and Self-reported Dry Eye Symptoms in Eyes Undergoing Femtosecond LASIK Flap Creation With an Inverted vs. a Conventional Side C	Edward E Manche MD*	120
1:50 PM	Evolution of Corneal Epithelium With High-Resolution OCT Following Myopic LASIK Surgery	Georges D Baikoff MD*	120
1:55 PM	Comparison of Corneal Epithelial Mapping With Anterior Segment OCT in Normal vs. Dry Eyes	George Asimellis PhD*	120
2:00 PM	Discussion		
2:08 PM	Three-Dimensional OCT Epithelial Thickness Mapping in Keratoconus	Georgios Chatzilaou MD	120
2:13 PM	Asymmetric Centration for Excimer Custom Treatment: Integration of Pupil and Corneal Vertex Information	Paolo Vinciguerra MD*	120
2:18 PM	Lamellar Perforating Keratoplasty: New Surgical Technique	Cesar C Carriazo E MD*	120
2:23 PM	Discussion		
2:31 PM	Pocket Corneal Collagen Crosslinking Using Corneal Pocket Formation With Intrastromal Delivery of Riboflavin	D James Schumer MD	121
2:36 PM	Evaluation of Combined Intracorneal Rings Implantation by Femtosecond Laser and Crosslinking in Keratoconus Management	Osama I Ibrahim MD PhD*	121
2:41 PM	One-Year Follow-up of Implantable Collamer Lens in Anisometropic Amblyopia of Children	Ahmed A K El-Massry MD	121
2:46 PM	Implantable Collamer Lens Complications	Alejandro Navas MD*	121
2:51 PM	Discussion		
3:01 PM	Post-test	Michael C Knorz MD*	

Keynote Lecture

3:05 PM	Quality of Vision With Presbyopia-Correcting IOLs	James T Schwiegerling PhD*	122
3:15 PM	REFRESHMENT BREAK and ANNUAL MEETING EXHIBITS		

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

Moderators: Bonnie A Henderson MD*, J Bradley Randleman MD

4:00 PM	Introduction of the Troutman Prize	J Bradley Randleman MD	
4:05 PM	Troutman Prize: Influence of the Reference Surface Shape for Discriminating Between Normal Corneas, Subclinical Keratoconus, and Keratoconus	David Smadja MD	124
4:20 PM	Spectral-Domain OCT Analysis of Regional Epithelial Thickness Profiles in Keratoconus, Postoperative Corneal Ectasia, and Normal Eyes	Karolinne M Rocha MD	125
4:27 PM	Effect of Femtosecond Laser Fragmentation on Effective Phacoemulsification Time in Cataract Surgery	Burkhard Dick MD*	126
4:34 PM	Progression of Keratoconus and Efficacy of Pediatric Corneal Collagen Crosslinking in Children and Adolescents	Farhad Hafezi MD PhD*	127
4:41 PM	Corneal Confocal Microscopy Following Conventional, Transepithelial, and Accelerated Corneal Collagen Crosslinking Procedures for Keratoconus	David Touboul MD	130
4:48 PM	Predictors for the Outcome of Small-Incision Lenticule Extraction for Myopia	Jesper Hjortdal MD*	131
4:55 PM	One-Year Safety and Efficacy Results of a Hydrogel Inlay to Improve Near Vision in Emmetropic Presbyopes	Enrique Barragan MD*	132
5:02 PM	Nonpenetrating Femtosecond Laser Intrastromal Astigmatic Keratotomy in Patients With Mixed Astigmatism After Previous Refractive Surgery	Jan A Venter MD	133
5:09 PM	Mathematical Model to Compare the Relative Tensile Strength of the Cornea after PRK, LASIK and Small-Incision Lenticule Extraction	Dan Z Reinstein MD*	135
5:16 PM	JRS QwikFacts	J Bradley Randleman MD	
5:21 PM	Discussion		
5:30 PM	Closing Remarks	Michael C Knorz MD* Sonia H Yoo MD*	
5:30 PM	ADJOURN		

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Crosslinking: Inception to Multiple Clinical Applications

Theo Seiler MD PhD

Crosslinking of the cornea has 3 main effects: (1) biomechanical stabilization, (2) biochemical stabilization, and (3) cytotoxic effect.

By far the widest application in the cornea is the biomechanical stabilization in primary and secondary keratectasia. An up to 4-fold increase of stiffness of the anterior cornea leads, in the majority of cases, to a halt of the progression of the keratoconus and, with new irradiation devices, in up to 60% of cases, to a reversal of the progression and a flattening of the cornea.

It is usually forgotten that crosslinked collagen is more resistant against digesting enzymes. Actually this was the first clinical application of crosslinking the cornea, published in 2000 (Schnitzler et al, 2000). Obviously the crosslinks are produced in the outer surface of the collagen molecule, blocking the docking stations for enzymes, and therefore the enzymatic activity is blocked for days. This biochemical effect has clinical application in melting processes of the cornea. A melting process indicates that the equilibrium between synthesis and catalysis of collagen inside the cornea is distorted, and the catalysis obviously is stronger than the synthesis. Now making the collagen more resistant against enzymes may bring this equilibrium into the opposite direction, and therefore melting can be stopped. We will present a case of morbus Terrien, where even an augmentation of the thinned cornea occurred.

The last effect of crosslinking is the cytotoxic effect. During standard crosslinking we are killing keratocytes up to 350 µm deep in the cornea, which, it is believed, happens due to the cytotoxic activity of the radicals. Now this cytotoxic activity could be also used to kill germs (fungus as well as bacteria; viruses unclear). In a prospective study in Sweden, Mortensen showed that crosslinking was very effective used even as a primary intervention in corneal infection, and only in less than 10% of the cases were antibiotics necessary at all. The first publication on this subject was in 2007, where Iseli and co-workers presented 6 cases of corneal infections that were crosslinked in order to avoid an emergency keratoplasty.

Long-term Results and Complications

Theo Seiler MD PhD

NOTES

How to Get Riboflavin Into the Cornea

Paolo Vinciguerra MD

I. Riboflavin
   A. Micronutrient with a key role in humans and animals
   B. Central component of FAD and FMN.
   C. pK_a =9.888
   D. Molecular weight (376,36 Da+Ph-)
   E. Negative charge in physiological pH
   F. High solubility in water
   G. Fluorescent

II. Corneal Collagen Crosslinking (CXL)
   A. Standard solution
      1. 0.1% riboflavin-5-phosphate + 20% Dextran
      2. But does one fit all???
   B. So, what should we evaluate when we choose our solution?
      1. Administration method
      2. Viscosity
      3. Concentration
      4. Formulation
      5. Osmolarity
   C. Administration method
      1. Drops
      2. Ring
      3. Femtosecond laser pocket
      4. Iontophoresis

III. Drops
   A. Standard → are we sure it is the best??
   B. 1 drop every 3-5 minutes
   C. Consider viscosity!
   D. Viscosity
      1. Riboflavin solution viscosity is really important because it influences breakup time (BUT) and riboflavin's layer…
      2. Riboflavin BUT
         a. 22 minutes with dextran
         b. 90 seconds if hypo-osmolar without dextran
         c. Be careful with hypo-osmolar riboflavin!
   E. Riboflavin's layer and viscosity
      1. 70 µm for the dextran–riboflavin film
      2. 300 µm for the methylcellulose-riboflavin
      3. 40 µm for the hypo-osmolar riboflavin
      4. The absorption coefficient of the hypo-osmolar film is lower than that of the other riboflavin solutions due to the thinner riboflavin film.
      5. Increased irradiance levels in the stroma, with risk of endothelial damage if not accurately swelled
      6. Another solution is to increase riboflavin concentration.

IV. Ring
   A. Concentration of riboflavin inside the stroma after 30 minutes with standard protocol is 0.067% (67% of initial concentration) and at 300 µm of depth is 0.036%.
   B. Theorizing a layer of > 400 µm (normally 70 µm with dextran), the stromal concentration will become 0.091% and 0.043%.
   C. How do we obtain this layer?

Figure 1.

   D. Changes to the protocol
      1. Apply a suction-ring/silicon ring
      2. Replace riboflavin every 5 minutes
      3. Wait 3 minutes before irradiation
      4. Impregnation time 20 min!!

V. Femtosecond pocket
   A. Not many reports
   B. Low *n*
   C. Preliminary rabbit and human studies report good results with no side effects.

D. Remember that it is transepithelial!!

E. → Epithelium in-situ blocks 30% UV-A

VI. Riboflavin and Iontophoresis

A. Low molecular weight (376,36 Da+Ph-)

B. Negative charge in physiological pH

C. High solubility in water

D. → Good candidate for iontophoresis

1. In-vivo riboflavin penetration with iontophoresis with HD-OCT. *J Refract Surg*. 2013.

CORRESPONDENCE

High Fluence Iontophoretic Corneal Collagen Cross-linking: In Vivo OCT Imaging of Riboflavin Penetration

To the Editor:

We read with interest the excellent article by Malhotra et al.[1] regarding in vivo estimation of riboflavin penetration using anterior segment optical coherence tomography (OCT). The article evaluates the effect of complete versus grid-like epithelial removal on riboflavin penetration during collagen cross-linking (CXL) in vivo using hand-held OCT. Twenty eyes of 20 patients were imaged intraoperatively at 30 and 60 minutes after starting the procedure. Results showed a homogeneous hyperreflective band extending to a mean depth of 54.2 μm after 30 minutes. In the grid-like removal group, the band was reported uneven in the epi-on areas.

We agree with the authors on the use of OCT for in vivo evaluation of riboflavin's penetration inside the stroma. Moreover, we agree that grid removal of the epithelium is not able to soak the corneal stroma evenly like the epi-off procedure.[2] In our study, we report the in vivo riboflavin penetration during CXL performed with iontophoresis versus conventional epithelium-off protocol using high-resolution OCT.

Six eyes (6 patients) undergoing CXL were measured preoperatively, intraoperatively, and postoperatively using high-resolution OCT. The epithelium was removed completely in the central 9-mm zone in 3 eyes (epi-off group), whereas riboflavin penetration through intact epithelium was promoted by an iontophoresis device in the remaining 3 eyes (iontophoresis group). The iontophoresis device for corneal application (8 mm in diameter) is placed on the cornea using an annular suction ring (low suction created by a syringe connected on the suction annulus). The device is filled with approximately 0.5 mL solution from the open proximal side, until the electrode (stainless steel mesh) is covered (**Figure 1A**). The device is connected to a constant current generator (I-ON XL, Sooft, Italy) set at 1 mA (the total dose of 5 mA × min is monitored by the generator).

The depth of the hyperreflective band (representing penetration of riboflavin) in the anterior corneal stroma was measured. In the conventional epi-off group, after 30 minutes of passive impregnation, a homogeneous hyperreflective band without fading effect was measured at mean depth of 80 μm (**Figure 1C**). In the iontophoresis group, we observed a less homogeneous hyperreflective band with a fading effect extending through the anterior 200 μm of the cornea (**Figure 1D**). This band was not visible until the end of irradiation time.

Intraoperative OCT imaging could be a useful technique to evaluate in vivo penetration of riboflavin inside the cornea. Although we still cannot demon-

Figure 2.

E. Type of riboflavin

1. With enhancer → epi-on
2. Without enhancer → epi-off
   a. With dextran
   b. Without dextran
   c. Hypo-osmolar

F. Epi-on and riboflavin: Riboflavin is a hydrophilic compound and cannot easily cross the intact epithelial barrier. So an enhancer is needed:

1. Trometamol (Tris-[hydroxymethyl]aminometane)
2. Sodium ethylenediaminetetraacetic acid (EDTA)
3. Benzalkonium chloride

G. Results
   1. Controversial
   2. Not homogeneous DL at a depth of 80-100 µm
   3. Still progressing
   4. Not suitable for pediatric patients!
   5. New Hope Iontophoresis …

H. Riboflavin without enhancer
   1. With dextran
      a. Many reports published
      b. Good results
      c. Side effects with thin cornea
   2. No dextran
      a. Our gold standard
      b. Hypo-osmolar
      c. Thin corneas
      d. CXL in infectious keratitis
   3. Osmolarity and pachymetry
      a. Stromal osmolarity is between 380-400 mOsm.
      b. Riboflavin solution with dextran is 400 mOsm.
      c. This solution was designed to avoid to increase or decrease thickness.
      d. However ... osmolarity and pachymetry
      e. Pachymetry of 400 µm is very important to prevent endothelial damage.
      f. What happens if the cornea gets too thin???
      g. So????
   4. Two options
      a. Use a solution that does not swell the cornea.
      b. Use the solution with dextran and check central corneal thickness (CCT) every 10 min.
      c. If the pachymetry gets lower than 400 µm use hypotonic solution or solution with low dextran.

         Be careful! Hypotonic solution does not mean distilled water!! That decreases riboflavin concentration.
   5. Results
      a. Less deep opacities
      b. Demarcation line more constant
      c. Possible to treat thin corneas
      d. Published protocol (Vinciguerra R, et al. *Ophthalmology* 2013.)
   6. Dextran and CCT.
      a. Vetter et al (*J Cataract Refract Surg*. 2012) did not find a correlation between osmolality and corneal thickness after eyedrop application.
      b. Inverted correlation between dextran concentration and corneal thickness exists.
      c. Dextran possesses a high affinity for water because of its abundant hydrophilic hydroxyl groups.
      d. Hypertonicity and hypotonicity of solutions (using the semipermeable cell membrane as a barrier) do not have a significant effect on stromal thickness because only 2% to 3% of the corneal stroma volume consists of cells.

VII. Riboflavin's Concentration
   A. Difference between
      1. Surface CXL
      2. Volume CXL
   B. Recently many models of CXL are trying to use different riboflavin concentration to optimize CXL or reduce time…
   C. What should we know??
      1. Concentration
      2. If we increase [C]:
         a. We get an higher stiffness.
         b. CXL more superficial (surface CXL)
      3. If the riboflavin concentration is increased > 0.15%, the stiffness increase is reduced because the riboflavin blocks the irradiation light, which then cannot reach the deeper layers of the cornea. Good for thin corneas
         a. Standard riboflavin [C] → 0.1%
         b. Volume CXL
         c. Useful in keratoconus

VIII. Conclusion
   A. One size definitely does not fit all!
   B. We need to choose the solution basing on the purpose of CXL.
   C. Optimization models are in progress.

Combined Crosslinking and Laser Application

A John Kanellopoulos MD

Selected Readings

1. Ledoux DM, Kanellopoulos AJ. Topography-guided LASIK: early experience in 7 irregular eyes. Poster Presentation. ARVO Meeting; April 27, 2004; 17:15-19:15; USA.
2. Kanellopoulos AJ, Perry HD, Donnenfeld ED, Pamel GJ, Pe L. Modified INTACS in keratoconus: the mediocre experience. Free paper presentation. Annual Meeting of the American Academy of Ophthalmology; Nov. 15-18, 2003; Anaheim, Calif., USA.
3. Lustig MJ, Kanellopoulos AJ. Topography-guided retreatment in 11 symptomatic eyes following LASIK. Poster Presentation. ARVO Meeting; April 27, 2004; 17:15-19:15; USA.
4. Kanellopoulos AJ. Topography-guided LASIK enhancements, early experience in 17 symptomatic eyes. Free paper presentation. XXII Congress of the ESCRS; Sept. 22, 2004; 8:00-10:30; Paris, France.
5. Kanellopoulos AJ. Topography guided-Lasik enhancements: early experience in 17 symptomatic eyes. Free paper presentation. Annual meeting of the American Academy of Ophthalmology; Oct. 26, 2004; New Orleans, La., USA.
6. Kanellopoulos AJ. Wavefront guided-Lasik retreatments in 26 symptomatic eyes. Free paper presentation. Annual meeting of the American Academy of Ophthalmology; Oct. 26, 2004; New Orleans, La., USA.
7. Kanellopoulos AJ. Collagen cross linking ultraviolet A radiation and riboflavin for the stabilization and possible treatment of cornea ectasia and keratoconus. Invited speaker. Videofrattiva Meeting; March 19, 2005, 10:15-10:25; Milan, Italy.
8. Krishnamurthy R, Kanellopoulos AJ, Pe L, Jankov M. Topography-guided LASIK enhancements, early experience in 17 symptomatic eyes. Poster presentation. ARVO Meeting; May 4, 2005, 8:30-10:15; Fort Lauderdale, Flor., USA.
9. Braun E, Kanellopoulos AJ, Pe L, Jankov M. Riboflavin/ultraviolet a-induced collagen cross-linking in the management of keratoconus. Poster presentation. ARVO Meeting; May 5, 2005, 10:45-12:30; Fort Lauderdale, Flor., USA.
10. Kanellopoulos AJ. Riboflavin/UVA-induced collagen cross-linking and the excimer surface ablation in keratoconus. Free paper presentation. Annual Meeting of the American Academy of Ophthalmology, Refractive Surgery Subspecialty Day; Oct. 15, 2005, 5.25-5.28 pm; Chicago, Ill., USA (nominated as one of the most innovative reports of the meeting).
11. Kanellopoulos AJ. UVA collagen cross-linking as a pretreatment for surface excimer ablation in the management of keratoconus. Free paper presentation. Course session at the Annual Meeting of the American Academy of Ophthalmology; Oct. 16, 2005, 3.55-4.02 pm; Chicago, Ill, USA.
12. Kanellopoulos AJ. The Greek results: early clinical results with collagen cross-linking. Invited speaker. First International Congress on Cross Linking; Dec. 9-10, 2005; Zurich, Switzerland.
13. Barbarino SC, Papakostas AD, Sperber L, Jue AT, Park L, Kanellopoulos AJ: Post-LASIK ectasia: stabilization and effective management with riboflavin/ultraviolet A-induced collagen cross-linking. Poster presentation at ARVO meeting; April 30 – May 4, 2006; Ft. Lauderdale, Flor., USA.
14. Kanellopoulos AJ. Post-LASIK ectasia: stabilization and effective management with riboflavin/ultraviolet A-induced collagen cross-linking. Paper presentation. 39th Panhellenic Ophthalmological Congress; June 10, 2006, 9.00-10.30; Thessaloniki, Greece.
15. Kanellopoulos AJ. Keratoconus (KCN) management: UVA induced collagen cross-linking (UVA CCL) followed by surface excimer ablation (SEA). Free paper presentation. ESCRS Congress; Sept. 10, 2006, 15:00-17:00 hrs; London, England.
16. Hafezi F, Mrochen M, Kanellopoulos AJ, Hoppeler T, Wiltfang R. Corneal collagen crosslinking with riboflavin / UVA for the treatment of induced keratectasia after laser in situ keratomileusis. Free paper presentation. ESCRS Congress; Sept. 12, 2006, 14.00-16.00; London, England.
17. Kanellopoulos AJ. Keratoconus management: UVA-induced collagen crosslinking followed by surface excimer ablation. Paper presentation PA010. American Academy of Ophthalmology Joint Meeting with the Asia Pacific Academy of Ophthalmology (APAO); Nov. 12, 2006, 12.03-12.11; Las Vegas, Nevada, USA.
18. Kanellopoulos AJ. Topography-guided hyperopic LASIK in 180 consecutive eyes. Paper presentation PA035. American Academy of Ophthalmology Joint Meeting with the Asia Pacific Academy of Ophthalmology (APAO); Nov. 13, 2006, 09.06-09.14; Las Vegas, Nevada, USA.
19. Lai EC, Kanellopoulos AJ. Keratoconus management: riboflavin/ultraviolet A-induced collagen cross-linking followed by surface excimer ablation. Poster presentation. ARVO Meeting; May 6-10, 2007; Fort Lauderdale, Flor., USA.
20. Kanellopoulos AJ. Managing highly distorted corneas. Invited speaker lecture. Annual Meeting of the American Academy of Ophthalmology, Refractive Surgery Subspecialty Day; Nov. 9, 2007, 9.23-9.28 am; New Orleans, La., USA.
21. Kanellopoulos AJ. Limited topography-guided surface ablation followed by stabilization with collagen cross-linking with UV irradiation and riboflavin for keratoconus. Paper presentation. Annual Meeting of the American Academy of Ophthalmology; Nov. 12, 2007, 9.18-9.26 am; New Orleans, La., USA.
22. Kanellopoulos AJ. Topography-guided PRK combined with cross-linking for keratoconus and post-LASIK ectasia. Invited speaker. International Refractive Surgery Symposia, Co-organized by ISRS; Nov. 24, 2007, 15.15-15.30 pm; Istanbul, Turkey.
23. Kanellopoulos AJ. Limited topography-guided surface ablation (TGSA) followed by stabilization with collagen cross-linking with UV irradiation and riboflavin (UVACCL) for keratoconus (KC). Free paper. 12th ESCRS Winter Refractive Surgery; Feb. 9, 2008, 14.12-14.18 pm; Barcelona, Spain.
24. Kanellopoulos AJ. Treatment of ectasia: update on riboflavin UV crosslinking. Invited speaker. ASCRS "Cornea Day" Meeting; April 4, 2008, 11.00-11.07 am, Chicago, Ill., USA.
25. Kanellopoulos AJ. Laboratory comparison of ultraviolet-A irradiation corneal crosslinking with topically instilled versus intracorneal riboflavin in corneal edema and bullous keratopathy. Paper presentation PA 415204. ASCRS Meeting; April 6, 2008, 3.32-3.37 pm; Chicago, Ill., USA.
26. Dupps WJ, Mamalis N, Tervo T, Donnenfeld ED, Artal P, Fine I, Roberts CJ, Kanellopoulos AJ, et al. Can we rehabilitate visual

function with customized surface ablation combined with collagen cross-linking? Invited speaker. ASCRS Meeting; Symposium S-12, 2.13-2.24 pm; Chicago, Ill., USA.

27. Ewald M, Kanellopoulos AJ. Limited topography-guided surface ablation (TGSA) followed by stabilization with collagen-crosslinking with UV irradiation & riboflavin (UVACCL) for keratoconus (KC). Poster presentation. ARVO Meeting; April 27-May 1, 2008; Fort Lauderdale, Flor., USA.
28. Kanellopoulos AJ. Long term comparison of sequential to combined CCL and limited topography-guided PRK for KCN. Free paper. XXVI ESCRS Congress; Sept 14, 2008, 8.00-10.00 am; Berlin, Germany.
29. Kanellopoulos AJ. Prophylactic, ultraviolet a cross linking combined at the completion of high risk myopic LASIK cases. Subspecialty Day Paper presentation. Annual Meeting of the American Academy of Ophthalmology; Nov. 8, 2008, 4.30-5.30 pm; Atlanta, Ga., USA.
30. Kanellopoulos AJ. Riboflavin UV cross linking and topographic guided ablations for the treatment of ectasia. Invited speaker. WOC; July 2, 2008, 9.00-9.08 am; Hong Kong.
31. Kanellopoulos AJ. Comparison of topography-guided (TGL) to standard LASIK (SL) for hyperopia: how important is adjustment for angle kappa? Free paper. WOC; July 1, 2008; 14.42-14.49 pm; Hong Kong.
32. Kanellopoulos AJ. Surface laser ablation after collagen cross linking. Invited speaker. WOC; June 30, 2008, 11.16-11.24 am; Hong Kong.
33. Kanellopoulos AJ. Limited topography-guided surface ablation (TGSA) followed by stabilization with collagen cross-linking with UV irradiation & riboflavin (UVACCL) for keratoconus (KC). Free paper. WOC; June 29, 2008, 16.35-16.42 pm; Hong Kong.
34. Nam JN, Pamel G, Kanellopoulos AJ, Perry HD. Comparison of topography-guided LASIK (TGL) to standard LASIK (SL) for hyperopia: is it important to adjust for angle kappa? Poster presentation. ARVO Meeting; April 27-May 1, 2008; Fort Lauderdale, Flor., USA.
35. Kanellopoulos AJ. Long-term comparison of sequential to combined CCL and limited topography-guided PRK for KCN. Free paper. XXVI ESCRS Congress, Sept. 14 2008, 8.00-10.00 am; Berlin, Germany.
36. Kanellopoulos AJ. Shorter duration, higher ultraviolet A irradiation UVA fluence collagen cross linking for KCN. Free paper. XXVI ESCRS Congress; Sept. 14 2008, 8.00-10.00 am; Berlin, Germany.
37. Kanellopoulos AJ. Prophylactic, ultraviolet a cross linking combined at the completion of high risk myopic LASIK cases. Subspecialty Day paper presentation. Annual meeting of the American Academy of Ophthalmology; Nov. 8, 2008, 4.30-5.30 pm; Atlanta, Ga., USA.
38. Kanellopoulos AJ. Safety and efficacy of prophylactic, ultraviolet A irradiation UVA cross linking combined at the completion for high risk myopic LASIK cases. Paper presentation. International Congress of Corneal Cross Linking; Dec. 6 2008, Session 3, 11.45 am-12.45 pm; Dresden, Germany.
39. Perry H, Kanellopoulos AJ. Long term comparison of sequential to combined collagen cross linking and limited topography-guided PRK for keratoconus. Paper presentation. International Congress of Corneal Cross Linking; Dec. 6, 2008, Session 3, 11.45 am-12.45 pm; Dresden, Germany
40. Pantelis S, Kanellopoulos AJ. Novel keratoconus management with combined: topography-guided PRK(tPRK), femtosecond laser-assisted lamellar graft (fLK) and collagen cross linking (CCL). Paper Presentation, International Congress of Corneal Cross Linking, Dec. 6th 2008, Session 3: 11.45 am-12.45 pm, Dresden, Germany.
41. Kanellopoulos AJ. Comparison of sequential to collagen cross linking and limited topography-guided PRK for keratoconus. Paper presentation, Session Cornea Day Reconstructions. 13th ESCRS Winter Meeting; Feb. 6 2009, 11.04 am; Rome, Italy.
42. Kanellopoulos AJ. Novel advanced keratoconus management with combined: topography-guided PRK (tPRK), femtosecond laser assisted lamellar graft (fLK) and cross-linking. Paper presentation, Session Cornea Day: Lamellar Corneal. ESCRS Winter Congress; Feb. 6 2009, 03:00-04:30 pm; Rome, Italy.
43. Kanellopoulos AJ. Shorter duration, higher ultraviolet A irradiation UVA fluence CCL for KCN. Free paper. 13th ESCRS Winter Meeting; Feb. 8, 2009, 08:00-10:30 am; Rome, Italy.
44. Kanellopoulos AJ. New advantages in cross-linking. Invited speaker P652. ISRS/AAO Symposium "Frontiers in Refractive Surgery," MEACO Congress; March 28, 02:04-02:10 pm; Bahrain, Kingdom of Bahrain.
45. Kanellopoulos AJ. Femtosecond laser application in LASIK, keratoplasty and collagen cross-linking. Keynote speaker. MEACO Congress; March 29, 8:30-8:40 am; Bahrain, Kingdom of Bahrain.
46. Kanellopoulos AJ. Collagen cross-linking: clinical experience and evolving indications. Lecture. Cornea & Refractive Surgery Service, Massachusetts Eye and Ear Infirmary, Visiting Professor Grand Rounds; Apr. 21, 04.00-05.00 pm; Boston, Mass., USA.
47. Kanellopoulos AJ. Collagen cross linking case presentation: clinical experience and growing potential applications. Grand Rounds, Mount Sinai School of Medicine; April 22, 08.30-9.30 am; New York, USA.
48. Ng D, Kanellopoulos AJ. Laboratory intra-stromally delivered collagen cross-linking (iCCL) in an advanced bullous keratopathy (BK) model. Poster 54466/A437. ARVO; May 3-7, 2009; Flor., USA.
49. Krueger RR, Kanellopoulos AJ. Simultaneous topo-guided PRK and riboflavin / UVA crosslinking for the correction of progressive keratoconus. Poster 5483/A454. ARVO; May 3-7, 2009; Flor., USA.
50. Cho M, Kanellopoulos AJ. Safety and efficacy of prophylactic ultraviolet-A-induced crosslinking after high risk myopic photorefractive keratotomy. Poster 5470/A441. ARVO; May 3-7, 2009; Flor., USA.
51. Kanellopoulos AJ. Collagen cross-linking (CXL) and laser surgery/customized laser cornea remodeling: theory and clinical practice. Invited speaker. 10th Symposium Refractive Surgery, NGRC Nederlands Society of Refractive Surgeons; May 9, 2009; Amsterdam, Holland.
52. Kanellopoulos AJ. Collagen cross linking and laser surgery. Invited speaker. Joint session with the ISRS/AAO. DOC 22nd International Congress of German Ophthalmic Surgeons; June 19, 2009, 2.45-3.00 pm; Nuernberg, Germany.
53. Kanellopoulos AJ. Collagen cross-linking and customized ablations. Invited speaker. Session on customized ablations in repair procedures. 22nd International Congress of German Ophthalmic Surgeons; June 20, 2009, 1.00-2.30 pm; Nürnberg, Germany.
54. Kanellopoulos AJ. PRK and cross linking, Invited speaker. ISRS/AAO session: Reflection on the present. XXVII ESCRS Congress; Sept. 15, 2009, 17.00-21.23 pm; Barcelona, Spain.
55. Kanellopoulos AJ. Comparison of sequential vs. same day CXL and topo-guided PRK for keratoconus. Subspecialty Day paper presentation. Joint Meeting of the American Academy of Ophthalmology/Pan-American Academy of Ophthalmology; Oct. 24, 2009, 8.58-9.03 am; San Francisco, Calif., USA.

56. Kanellopoulos AJ. New applications and approaches for collagen crosslinking. Subspecialty Day paper presentation. Joint Meeting of the American Academy of Ophthalmology/Pan-American Academy of Ophthalmology; Oct. 24, 2009, 4.00-4.05 pm; San Francisco, Calif., USA.
57. Kanellopoulos AJ. Long term comparison of sequential vs. simultaneous CXL and topography-guided PRK for keratoconus. Paper presentation 052. Joint Meeting of the American Academy of Ophthalmology/Pan-American Academy of Ophthalmology; Oct. 26, 2009, 4.15-4.22 pm; San Francisco, Calif., USA.
58. Kanellopoulos AJ. Long term follow-up of simultaneous collagen cross linking (CXL) and topography-guided PRK for post LASIK ectasia. Free paper. ASCRS Symposium; April 10, 2010, 1.42-1.47 pm; Boston, Mass., USA.
59. Kanellopoulos AJ, Donnenfeld E, Binder P, Stulting D. Collagen cross linking. Instructional course 10-403. ASCRS Symposium; April 10, 2010, 3.00-4.30 pm; Boston, Mass., USA.
60. Kanellopoulos AJ. Cornea keratoconus: rings and cross linking. Invited moderator. ASCRS Symposium; April 11, 2010, 1.00-2.30 pm; Boston, Mass., USA.
61. Kanellopoulos AJ. Long term follow-up of simultaneous collagen cross linking (CXL) and topography-guided PRK for post LASIK ectasia. 3 minute presentation at Cornea Clinical Committee Highlights. Invited speaker at Session S-14. ASCRS Symposium; April 12, 2010, 3.00-4.30 pm; Boston, Mass., USA.
62. Ng D, Kanellopoulos AJ. Evaluation of a novel technique in the management of post-LASIK ectasia: under the flap, partial, topography-guided therapeutic ablation (tLASIK) combined with simultaneous collagen cross-linking. Poster 2865/D1012. ARVO; May 2-6, 2010; Fort Lauderdale, Flor., USA.
63. Malhotra VK, Kanellopoulos AJ. Long term comparison of sequential vs. same-day simultaneous collagen cross-linking and topography-guided PRK for treatment of keratoconus. Poster 4967/D763. ARVO; May 2-6, 2010; Fort Lauderdale, Flor., USA.
64. Wang SL, Kanellopoulos AJ. Novel cornea OCT findings in early and long term follow-up of collagen crosslinking for keratoconus. Poster 4993/D789. ARVO May 2-6, 2010; Fort Lauderdale, Flor., USA.
65. Kanellopoulos AJ. Order of treatments-combination of custom surface ablation and CXL. Invited speaker. ISRS Symposium Controversies: Excimer laser refractive surgery, corneal collagen crosslinking and refractive cataract surgery. XXVIII ESCRS Congress; Sept. 7, 2010, 17.00-20.00 am; Paris, France.
66. Kanellopoulos AJ, Seiler T. Moderator for special CXL course, hosted by ISRS. Annual Meeting of the American Academy of Ophthalmology; Oct. 15, 2010, 6.30-8.00 am; Chicago, Ill., USA.
67. Kanellopoulos AJ. Combined use of surface ablation and crosslinking for ectasia. Invited speaker at Refractive Surgery Subspecialty Day, Annual Meeting of the American Academy of Ophthalmology; Oct. 15, 2010, 4.59-5.06 pm; Chicago, Ill., USA.
68. Kanellopoulos AJ. Laboratory evaluation of a novel technique for myopia correction: continuous wave laser cornea shrinkage coupled with corneal crosslinking. Paper presentation. Refractive Surgery Subspecialty Day, Annual Meeting of the American Academy of Ophthalmology; Oct. 16, 2010, 3.45-5.20 pm; Chicago, Ill., USA.
69. Kanellopoulos AJ. Around the world in 80 min: innovations in refractive surgery. Invited speaker, Symposium 28. Annual Meeting of the American Academy of Ophthalmology; Oct. 18, 2010, 4.15-5.35 pm; Chicago, Ill., USA.
70. Kanellopoulos AJ. Phakic IOLs after CXL. Invited speaker. 6th International Congress of Corneal Cross-Linking; Jan. 21, 2011, 11:45 am-12:00 pm; Milan, Italy.
71. Kanellopoulos AJ. Complications of combined topography-guided PRK and CXL (the Athens Protocol) in 412 keratoconus eyes. Paper presentation. January 22, 2011, 15:50-16:00 pm; Milan, Italy.
72. Kanellopoulos AJ. Laboratory evaluation of a novel technique for myopia correction continuous-wave laser cornea shrinkage coupled with CXL. Paper. 15th ESCRS Winter Meeting; Feb. 18, 2011, 10.30-11.30; Istanbul, Turkey.
73. Kanellopoulos AJ. Epithelial healing complication following CXL for keratoconus. Invited Speaker at 15th ESCRS Winter Meeting, Feb. 18th, 2011,11.20-11.30, Istanbul, Turkey.
74. Kanellopoulos AJ. Current surgical options in the management of keratoconus. Invited speaker. Expert meeting during ESCRS at the World's Eye Hospital; Feb. 18th, 2011, 17.00-20.00 pm; Istanbul, Turkey.
75. Kanellopoulos AJ. Update on ectasia management. Invited speaker. Cornea Day: Corneal Issues in Cataract and Refractive Surgery. ASCRS Symposium; March 25, 2011, 8.00-9.40 am; San Diego, Calif., USA.
76. Chatzilaou G, Kanellopoulos AJ. Customised bioptics with topography-guided laser refractive enhancements. Paper presentation. ASCRS Symposium; March 27, 2011, 3.37-3.42 pm, San Diego, Calif., USA.
77. Chatzilaou G, Kanellopoulos AJ. Laboratory evaluation of technique for myopia correction: continuous wave laser cornea shrinkage coupled with CXL. Paper presentation. ASCRS Symposium; March 28, 2011, 9.02-9.07 am; San Diego, Calif., USA.
78. Kim T, Donnenfeld E, Guell J, Kanellopoulos AJ, Mah F, Randleman J, Scoper S. S-15 ASCRS Cornea clinical committee highlights session. Invited speaker on combined topo-guided PRK and CXL. ASCRS Symposium; March 28, 2011, 3.00-4.30 pm; San Diego, Calif., USA.
79. Wang SL, Kanellopoulos AJ. Safety and efficacy of crosslinking following Intacs implantation for the stabilization of keratoconus. Poster presentation. ARVO; May 4, 2011, 3.45-5.30 pm; Fort Lauderdale, Flor., USA.
80. Cho MY, Kanellopoulos AJ. Short and long term complications of combined topography-guided photorefractive keratectomy and riboflavin/ultraviolet A corneal collagen cross-linking (The Athens Protocol) in 412 keratoconus eyes. Poster presentation. ARVO; May 4, 2011, 3.45-5.30 pm; Fort Lauderdale, Flor., USA.
81. Kanellopoulos AJ, Hafezi F, Seiler T, Mrochen M, Colin J. Collagen cross-linking: current applications, adjunct procedures and future directions. Invited moderator and speaker. ISRS CXL session. SOE/AAO; June 7, 2011, 8.15-9.45 am; Geneva, Switzerland.
82. Kanellopoulos AJ. Laboratory evaluation of a novel technique for myopia correction: continuous wave laser cornea shrinkage coupled with CXL. Paper. ISRS Symposium, 1st International Congress; July 9, 2011, 9.41-9.47 am; Grosseto, Italy.
83. Kanellopoulos AJ. Topo-guided. Invited speaker. ISRS Symposium, 1st International Congress; July 9, 2011, 11.00-13.40 pm; Grosseto, Italy.
84. Kanellopoulos AJ. Cross linking for keratoconus: different approaches. Invited speaker. Clinical Research Symposium, New Corneal Surgical Treatments. XXIX ESCRS Congress; Sept. 17, 2011, 13.30-15.30; Vienna, Austria.
85. Kanellopoulos AJ. Pearls for combining cross-linking and excimer laser reshaping of the cornea. Invited speaker. ISRS Symposium, XXIX ESCRS Congress; Sept. 20, 2011, 19.11-19.17; Vienna, Austria.

86. Kanellopoulos AJ. Refractive surgery: now and the future. Invited speaker. PanCyprian Ophthalmological meeting; Oct. 2, 2011, 9.00-9.30; Limassol, Cyprus.
87. Kanellopoulos AJ. The Athens Protocol: topography-guided partial PRK and CXL in the management of keratoconus and corneal ectasia. Invited speaker. Videocatarattarefrattiva; Oct. 15, 2011; Milan, Italy.
88. Kanellopoulos AJ. Evolution of crosslinking and customized laser cornea treatment. Invited lecturer. Johns Hopkins University School of Medicine; Oct. 17, 2011, 5.00-6.00 pm; Baltimore, Md., USA.
89. Kanellopoulos AJ. Advances in lasers and CXL (collagen cross linking) in cornea surgery. Invited lecturer as visiting professor; Wilmer Eye Institute, Johns Hopkins University School of Medicine; Oct. 18, 2011, 7.45-8.45 am; Baltimore, Md., USA.
90. Kanellopoulos AJ. Evolution of crosslinking and customized laser cornea treatment. Invited lecturer. NYU Medical School, Grand Rounds; Oct. 18, 2011, 5.00-6.00 pm; New York, USA.
99. Kanellopoulos AJ. Simultaneous surface ablation and crosslinking for correction of refractive error in eyes with early keratoconus. Invited speaker. Refractive Surgery Subspecialty Day, Annual Meeting of the American Academy of Ophthalmology; Oct. 21, 2011, 8.55-9.00 am; Orlando, Flor., USA.
100. Kanellopoulos AJ. Corneal crosslinking discussion. Where we are and what's next? Chairman at the 2nd Annual ISRS Special Crosslinking Session. Annual Meeting of the American Academy of Ophthalmology; Oct. 22, 2011, 6.30-7.45 am; Orlando, Flor., USA.
101. Kanellopoulos AJ. Corneal collagen crosslinking: does it have a role in managing infectious keratitis? Invited speaker. Cornea Subspecialty Day, Annual Meeting of the American Academy of Ophthalmology; Oct. 22, 2011, 9.40-9.50 am; Orlando, Flor., USA.
102. Vaddavali P, Belin M, Kanellopoulos AJ, et al. Keratoconus 360. Instructional course 382. Annual Meeting of the American Academy of Ophthalmology. Oct. 24, 2011, 2.00-3.00 pm; Orlando, Flor., USA.
103. Cho M, Kanellopoulos AJ. Complications of combined topography-guided photorefractive keratectomy and corneal collagen cross linking in keratoconus. Paper 054. Annual Meeting of the American Academy of Ophthalmology; Oct. 24, 2011, 3.36-3.43 pm; Orlando, Flor., USA.
104. Kanellopoulos AJ. LASIK Xtra-personal clinical experience. Invited speaker. Avedro Congress for Advancing Corneal Cross-Linking Science; Dec. 3, 2011; Milan, Italy.
105. Kanellopoulos AJ. Antimicrobial applications LASIK Xtra. Invited speaker. Avedro Congress for Advancing Corneal Cross-Linking Science. Dec. 3, 2011; Milan, Italy.
106. Kanellopoulos AJ. Efficacy, safety and new clinical findings with higher fluence (5 mW, 6 mW, 9 mW, 12 mW) UV-CCXL. Invited speaker. 7th International Congress of Corneal Cross-Linking; Dec. 10, 2011, 10:56-11:06 am; Zurich, Switzerland.
107. Kanellopoulos AJ. Pearls for combining crosslinking and excimer laser reshaping of the cornea. Paper presentation. Laservision hosts the ISRS meeting (International Society of Refractive Surgery) in conjunction with the Annual OMMA meeting; Dec. 17, 2011, 18:34-18:42 pm; Athens, Greece.
108. Kanellopoulos AJ. High refractive errors: what is working best? Topography guided laser vision correction for irregular astigmatism. Invited speaker. World Ophthalmology Congress (WOC 2012); Feb. 16, 2012, 15.30-15.40; Abu Dhabi, United Arab Emirates.
109. Kanellopoulos AJ. Topography and clinical applications (highlighting WaveLight Topolyzer and Oculyzer). Invited lecturer. NYU Medical School, Resident Grand Rounds; April 18, 2012; New York City, USA.
110. Kahn J, Kanellopoulos AJ, Song C, Cho M. Crosslinking and long term hyperopic LASIK stability: initial clinical findings in contralateral eye study. Paper. ASCRS meeting; April 22, 2012, 4.12-4.17 pm; Chicago, Ill., USA.
111. Tran K, Wang S, Kanellopoulos AJ. Contralateral eye long term follow-up of prophylactic high fluence collagen cross linking combined with LASIK for high myopia. Poster presentation. ARVO; May 10, 2012, 11.15 am-1.00 pm; Fort Lauderdale, Flor., USA.
112. Kanellopoulos AJ, Binder P, Pamel G, Stulting D, Vryghem J. Collagen cross linking: indications, applications, results, complications and evolving technology. Instructional course 42. XXX ESCRS Congress; Sept. 9, 2012, 2.30-4.30 pm; Milan, Italy.
113. Kanellopoulos AJ. Advanced corneal application with LenSx. Alcon Eurotimes symposium, XXX ESCRS; Sept. 9, 12.15-14.00; Milan, Italy.
114. Kanellopoulos AJ. CXL and long term hyperopic LASIK stability: initial clinical findings in a contralateral eye study. Paper presentation 3152. XXX ESCRS Congress; Sept. 10, 2012, 5.54-6.00 pm; Milan, Italy.
115. Pamel G, Kanellopoulos AJ. 4 year retrospective Athens Protocol (AP): combined topography-guided partial PRK and CXL in 212 keratoconus eyes. Paper presentation 3234. XXX ESCRS Congress; Sept. 10, 2012, 6.12-6.18 pm; Milan, Italy.
116. Kanellopoulos AJ, Asimellis G, Aslanides I. Correlation between overall epithelial thickness in normal corneas ectatic and ectatic previously treated with CXL corneas: can overall epithelial thickness become a very early ectasia prognostic factor? Paper presentation 3162. XXX ESCRS Congress; Sept. 11, 2012, 9.36-9.42 am; Milan, Italy.
117. Pamel G, Kanellopoulos AJ. Topography-guided LASIK for hyperopia and hyperopic astigmatism. Paper presentation 3211. XXX ESCRS Congress; Sept. 11, 2012, 4.36-4.42 pm; Milan, Italy.
118. Kanellopoulos AJ. Diagnosis of keratoconus and ectasia: a review of diagnostics and assessment. Invited speaker. ESC meeting; Oct. 18-19, 2012; Cairo, Egypt.
119. Kanellopoulos AJ. Athens protocol for KC (topoPRK+higher fluence CXL). Invited speaker. ESC meeting; Oct. 18-19, 2012; Cairo, Egypt.
120. Kanellopoulos AJ. Evolving applications of collagen cross linking. Invited speaker. NYU Grand Rounds; Nov. 6, 2012; New York, USA.
121. Kanellopoulos AJ. Pearls for combining crosslinking and excimer laser reshaping of the cornea. Invited speaker. ISRS symposium. Annual Meeting of the American Academy of Ophthalmology; Nov. 8, 2012, 5.30-8.00 pm; Chicago, Ill., USA.
122. Kanellopoulos AJ. The era of lasers and lenses. Invited speaker. Subspecialty Day, Annual Meeting of the American Academy of Ophthalmology; Nov. 9, 2012, 8.05-9.29 am; Chicago, Ill., USA.
123. Kanellopoulos AJ. Combined CXL and laser ablation. Invited speaker. Subspecialty Day meeting. Annual Meeting of the American Academy of Ophthalmology; Nov. 9, 2012, 11.50-11.58 am; Chicago, Ill., USA.
124. Kanellopoulos AJ. Ophthalmic thought leaders session. Invited panelist. Annual Meeting of the American Academy of Ophthalmology; Nov. 10, 2012, 7.00-8.30; Chicago, Ill., USA.
125. Kanellopoulos AJ. LASIK Xtra hyperopia. Invited speaker. Ophthalmic thought leaders session. Annual Meeting of the American Academy of Ophthalmology; Nov. 10, 2012, 7.00-8.30; Chicago, Ill., USA.

126. Kanellopoulos AJ. AAO spotlight session, introduction on corneal crosslinking. Invited chairman. Annual Meeting of the American Academy of Ophthalmology; Nov. 11, 2012, 2.00-3.30 pm; Chicago, Ill., USA.

127. Kanellopoulos AJ. Combined CXL and other techniques: topography-guided PRK, intracorneal ring segments and phakic IOLs. Invited speaker. AAO spotlight session. Annual Meeting of the American Academy of Ophthalmology; Nov. 11, 2012, 2.42-2.52 pm; Chicago, Ill., USA.

128. Kanellopoulos AJ. Corneal cross-linking and long term hyperopic femto LASIK stability: initial clinical findings in a contralateral eye study. Learning Lounge LL08 Meet the Producers. Invited moderator. Annual Meeting of the American Academy of Ophthalmology; Nov. 12, 2012, 9.00-10.30 am; Chicago, Ill., USA.

129. Kanellopoulos AJ. Long term follow-up of the Athens Protocol: combined topography-guided partial PRK and corneal crosslinking in 212 keratoconus eyes. Paper presentation. Annual Meeting of the American Academy of Ophthalmology; Nov. 12, 2012, 10.12-10.19 am; Chicago, Ill., USA.

130. Kanellopoulos AJ. Collagen cross linking. Meet the Experts. Invited moderator. Annual Meeting of the American Academy of Ophthalmology; Nov. 13, 2012, 7.30-8.30 am; Chicago, Ill., USA.

131. Kanellopoulos AJ. LASIK Xtra and AK Xtra. Invited speaker. Avedro: New Science, New Applications. 8th International Congress of Corneal Cross-linking (CXL); Dec. 7, 2012, 15.00-15.45; Geneva, Switzerland.

132. Kanellopoulos AJ. Reduction of femtosecond astigmatic keratotomy (fsAK) regression with combined simultaneous high fluence CXL (hfCXL): a novel refractive procedure. Invited speaker. 8th International Congress of Corneal Cross-linking (CXL); Dec. 8, 2012, 13.52-13.59; Geneva, Switzerland.

133. Chan JE, Kanellopoulos AJ. Correlation of keratoconus progression and 2 cornea topometric parameters: regularity of pachymetric map and index of height decentration. Paper presentation. American Society of Cataract and Refractive Surgery (ASCRS) meeting; April 21, 2013, 3.27-3.32 pm; San Francisco, Calif., USA.

134. Kanellopoulos AJ. Reduction of femtosecond astigmatic keratotomy regression with combined simultaneous high fluence CXL: a novel refractive procedure. Paper presentation. American Society of Cataract and Refractive Surgery (ASCRS) meeting; April 22, 2013, 9.07-9.12 pm; San Francisco, Calif., USA.

135. Pamel G, Kanellopoulos AJ. Management of corneal blindness from severe corneal scarring with Athens protocol: transepithelial topography-guided PRK therapeutic remodeling, combined with same day CXL. Paper presentation. American Society of Cataract and Refractive Surgery (ASCRS) meeting; April 22, 2013, 4.17-4.22 pm; San Francisco, Calif., USA.

136. Edell R, Kanellopoulos AJ. Evaluation of corneal topometric parameters and visual rehabilitation in clear corneal cataract surgery. Paper presentation. American Society of Cataract and Refractive Surgery (ASCRS) meeting; April 22, 2013, 4.07-4.12 pm; San Francisco, Calif., USA.

137. Taneri S, Kanellopoulos AJ. Absence of induced dry eye after corneal crosslinking. Paper presentation. American Society of Cataract and Refractive Surgery (ASCRS) meeting; April 23, 2013, 8.57-9.02 pm; San Francisco, Calif., USA.

138. Zhu F, Kanellopoulos AJ, Asimellis G. Anterior-segment OCT epithelial mapping in early and advanced keratoconic eyes. Poster presentation. ARVO; May 8, 2013, 2.45-4.30 pm; Seattle, Wa., USA.

139. Asimellis G, Kontari I, Kanellopoulos AJ. Correlation between keratoconus progression and two cornea topometric parameters: the regularity of the pachymetric map (RPM) and the index of height decentration (IHD). Poster presentation. ARVO; May 8, 2013, 2.45-4.30 pm; Seattle, Wa., USA.

Why We Should Not Use Primary Crosslinking in LASIK

Perry S Binder MD

I. Why would we use collagen crosslinking (CXL) on *every* LASIK case?
   A. Fear of post-LASIK ectasia
   B. Fear of inability to detect cases at risk
   C. Hope that CXL will be a panacea for ectatic corneal conditions
   D. Known adverse effects of epithelial removal with standard Dresden protocol CXL
   E. Theory that CXL increases flap adherence

II. What are the known morphologic and clinical effects of CXL on the cornea?
   A. Morphologic
      1. Long-term keratocyte/stromal cell loss
      2. Increase in collagen diameter; most crosslinking between α and β collagen chains and proteoglycan to proteoglycan
      3. Increased glycation; increased corneal stiffness and interlamellar adhesive strength[1]
      4. Slight crosslinking collagen to proteoglycans
      5. Cytotoxic keratocyte threshold levels 3-5 mW/cm^2
      6. Potential for endothelial cell damage due to reactive oxygen free radicals caused by riboflavin + UVA
      7. Intact tight epithelial tight junctions retard riboflavin absorption.
      8. Variation in demarcation line depth[2]
      9. Collagen lamellae become "wavy" using second harmonic stimulation.[3]
      10. Reduces stromal swelling pressure[4]
      11. Reduced pilocarpine permeability after CXL (ARVO 2013)
      12. Reverses stress distribution: flat becomes steep; steep becomes flat (ARVO 2013).
      13. Epi-on has about one-third stiffening effect of epi-off (ARVO 2013).
   B. Clinical
      1. Reduction in K-max
      2. Minimal reduction in MRSE
      3. Corneal thinning by OCT and ultrasound
      4. Slitlamp demarcation line
      5. Improved contrast sensitivity, BSCVA[5]
      6. Temporary reduction in corneal sensitivity[6]
      7. Reported complications[7]
         a. No effect
         b. Under-/no response[7]
         c. Corneal scarring[8]
         d. Corneal infiltrates
         e. Delayed epithelial healing
         f. Endothelial cell damage/loss
         g. Severe postoperative pain[9]
         h. Corneal melting after CXL for herpes simplex keratitis[10]
   C. Treatment regimens
      1. Multiple variations in riboflavin doses / concentrations / constituents / exposure time
      2. Multiple variations in UVA delivery instrumentation and irradiation; central vs. paracentral ablation[11]
      3. 3 mW/cm^2 is the current established irradiation.
      4. 7, 10, 18, or up to 45 mW/cm^2 have been suggested (recent studies, Marshall, et al, AAO 2012). Some claim increased stiffness up to 45 mW/cm^2 followed by drop-off in effect with increasing energy[12] (ARVO 2013), whereas others consider 9 and 18 mW/cm^2 to be less effective than 3 mW/cm^2 (ARVO 2013).
      5. Multiple variations in UVA exposure time
         a. 30 minutes is the established epithelial removal exposure time (Dresden protocol).
         b. 1 to 30 minutes reported
      6. Variations in epithelial removal[13,14]
         a. Epi-on
         b. Epi-off[15]
         c. Mechanical/chemical epithelial trauma
      7. Variation in treatment of corneas thinner than 400 μm[16]
      8. Multiple indications for multiple diagnoses, non-stratified cases
         a. Keratoconus[17,18]
         b. Forme fruste keratoconus
         c. Corneal edema

d. Corneal infections: bacterial (failed for mycobacteria and herpes simplex), fungus, *Acanthamoeba*

e. Post-radial keratotomy

f. Pellucid marginal degeneration (PMD)

g. Corneal melting[19]

h. Post-LASIK ectasia[17,20]

9. Alternative techniques for CXL

a. Aldehydes

b. Rose bengal/green 528-nm light[21]

c. Others[22]

III. What is the current incidence of post-LASIK ectasia? (What is the risk we are concerned about?)

New cases are decreasing.

A. Better awareness of risk(s)

B. More predictable flap thickness (femtosecond lasers), leading to more predictable residual stromal bed thickness (RSBT)

C. More ways to measure postoperative flap and RSBT thickness (OCT, high-frequency ultrasound)

IV. What are the ways to detect and eliminate eyes at risk of developing post-LASIK ectasia?

A. Improved topography algorithms / recognition

B. Improved metrics (eg, Optical Response Analyzer)

C. Newer biomechanical corneal research to detect abnormal responses

D. Measurement of epithelial thickness to detect abnormal eyes early

V. What is/are the current ways CXL is performed under a LASIK flap?

A. Most published research supports significantly more riboflavin absorption if the epithelium is removed.

B. If one does not believe in epithelium-on riboflavin delivery, what is the impact of healthy LASIK epithelium-on UVA penetration to riboflavin in the LASIK interface?

C. What is the evidence of riboflavin diffusion from the LASIK interface in either direction from the interface?

D. After LASIK, one is closer to the endothelium by 110-160 µm (possibly more with mechanical microkeratomes). If less riboflavin reaches the deeper cornea and/or less UVA penetrates the stroma due to epithelial blockage, what are the implications?

VI. What are the known risks of CXL in a case that has had post-LASIK ectasia?

A. Limited reports with few cases and short follow-up periods

B. What results exist show differences in outcomes after CXL for keratoconus vs. ectasia.

VII. What are the unknown/suspected risks of performing routine CXL at the time of a primary LASIK case?

A. Exposure to infection increased due to increased surgery and bed exposure time.

B. Long-term risk of deep loss of stromal cells vs. current more superficial cell loss[23]

C. Unknown variation(s) in UVA and riboflavin diffusion and exposure in the middle of the stroma vs. topical application

D. Unknown effects of CXL on primary and enhancement excimer laser ablation rates

E. Unknown effect of routine LASIK CXL on stability of refraction. How would one determine what portions(s) of postop acuity and refractions arise from CXL vs. routine wound healing?

F. Unknown risks to endothelium now that one would be 100-160 µm closer to the endothelium

G. Risks of routine UVA exposure to the conjunctiva and corneal stem cells

H. Long-term risk to crystalline lens

I. Will routine CXL affect calculations for a subsequent IOL implantation?

J. Lack of a comparison to established CXL treatment on the ocular surface with and without epithelial removal

K. Effect on flap adhesion and consequential risk of superficial trauma and enhancement implications such as epithelial ingrowth

L. Documented stromal "lines" suggestive of level of crosslinking effect

VIII. Conclusions

A. The risk-benefit ratio for routine CXL for primary LASIK cases does not justify routine application because PRK can be used for high-risk cases.

B. It would take a 300-patient study to detect a 1% incidence of an adverse event. How many cases of primary CXL on a primary LASIK case would it take to detect an improvement in the risk of ectasia considering the required stratification of clinical data (total corneal thickness, flap thickness, RSBT, patient age, UVA dose/exposure time, riboflavin dose, application, exposure time, etc.)?

C. Can we justify its cost to a patient in lieu of what is known about the current risk/incidence of ectasia?

D. Currently there are very limited peer-reviewed studies of CXL for a primary LASIK case.

E. If a surgeon is concerned about risk and cannot justify PRK, one can consider a phakic IOL and subsequent PRK.

IX. Recommendations

A. Do not perform CXL on a LASIK case until we can determine the risk and benefits.

B. If in doubt about a possible high-risk case, consider PRK or a phakic IOL.

C. Achieve new goals for CXL

1. Ability to irradiate focal areas of the affected cornea
2. Determine depth and/or effectiveness (stiffness index, elasticity) of treatment accurately using confocal microscopy, OCT, Brillouin microscopy combinations
3. Laboratory studies to support shorter exposure times at greater irradiation
4. Confirm best delivery: epithelium-on or -off with or without accelerators. Microneedles, pockets, iontophoresis, other methods.
5. Evaluate other, more efficient photosensitizers: eg, verteporfin (Visudyne; Novartis AG)

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Rationale and Results of Accelerated Corneal Crosslinking

John Marshall PhD

NOTES

Anterior Chamber Phakic IOLs

Georges D Baikoff MD

NOTES

Iris-Fixated Phakic IOLs

Camille JR Budo MD

In 1978 in Pakistan Worst developed the iris claw lens to be implanted after intracapsular cataract extraction. This anterior chamber lens is fixated on the iris, leaving the chamber angle free. The diametrically opposed haptics can be "pinched" on the midstromal iris tissue as "claws." In this way the lens stays fixated on the immobile part of the iris.

In 1987 Worst and Fechner developed a phakic anterior chamber lens for the treatment of high myopia based on the original iris claw lens. This new lens had a biconcave optic and the same fixation mechanism as the original iris claw lens. Several hundred of these lenses were implanted with good refractive results. However, some reports described corneal endothelial damage. In 1991, the design of the optic was changed into a convex-concave shape. The main advantage of the new iris-fixation (myopia) phakic IOL (P-IOL) is the reduction of the height of the optical rim to lower the chance of intermittent endothelial touch. In 1997, a plus-powered convex-concave lens was introduced to correct phakic hyperopia, and a P-IOL for the correction of astigmatism was added in 1999. Finally, at the beginning of 2002, the first flexible iris-fixation lens was implanted to correct myopia and in 2006 for astigmatism.

Crucial to success with any phakic IOL is careful patient selection. The surgeon should adhere strictly to the following inclusion criteria when selecting patients for iris-fixation P-IOL: flat iris, endothelial cell count (ECC) of at least 2100 cell/mm², pupil diameter smaller than 6.0 mm, anterior chamber depths (ACDs) of minimum 2.8 mm, peripheral distance from endothelium to IOL greater than 1.37 mm, internal diameter (the distance between the 2 iridocorneal angles along the horizontal corneal diameter—3 to 9 o'clock) greater than 11.5 mm, and crystalline lens rise less than 0.6 mm.

We use the Visante OCT (Carl Zeiss Meditec; Jena, Germany) to ensure that these criteria are respected. It is important to use an instrument such as the Visante OCT rather than conventional ultrasound biometry because ultrasound can overestimate ACD in patients with thick corneas. Additionally, the Visante OCT can also be used to assess the movement and position of the iris, which is also important in patient selection.

The power of the P-IOL is calculated using the Van der Heijde formula, which uses the mean corneal curvature (K), adjusted anterior chamber depth (ACD, 0.8 mm), and spherical equivalent (SE) of the patient's spectacle correction at a 12.0-mm vertex.

The surgical procedure starts with a 2-plane 6.3-mm corneoscleral incision that is centered at 12 o'clock. Two paracenteses are placed at 2 and 10 o'clock and directed toward the enclavation sites. Miosis is achieved through preoperative instillation of pilocarpine and a perioperative intracameral injection of acetylcholine 1.0% to prepare the iris for P-IOL fixation, to reduce the risk of lens-touch during implantation and to facilitate centration of the P-IOL. A cohesive viscoelastic substance is inserted through the paracenteses and primary incision to maintain sufficient anterior chamber depth, to protect the endothelium, and to facilitate adjusting the P-IOL within the eye during fixation. The P-IOL is introduced into the anterior chamber with a Budo forceps. After subtle rotation of the P-IOL, it is fixated in the horizontal axis to the midperipheral iris stroma with the use of a disposable enclavation needle, creating a bridge over the optical axis. A slit iridotomy is performed at 12 o'clock to avoid pupillary block glaucoma. The viscoelastic substance is exchanged for balanced salt solution, and cefuroxime is injected into the anterior chamber at the end of the procedure. The wound is sutured with 3 to 5 interrupted or 1 uninterrupted 10-0 nylon sutures.

The short-term results of Artisan P-IOL implantation have been demonstrated in several clinical reports with a follow-up time of up to 4 years. These reports demonstrate that stabilization of the postoperative refraction occurs within the first few years after surgery, with more than 90% of eyes achieving a refraction within 1 D of the intended correction and a high safety index. The long-term data demonstrated in our study show comparable results. Ten years after Artisan P-IOL implantation for the correction of moderate to high myopia, the mean SE (±SD) was –0.70 ± 1.00 D (range: -4.00 to 2.00 D) and remained stable over time. This finding is in accordance with the short-term literature, which demonstrated stabilization of the postoperative refraction within the first few years after surgery.

As a consequent and logical evolutionary step forward in iris-fixated P-IOL technology, the Artiflex, with a foldable lens body, permitting a small incision, and PMMA haptics, was developed and first implanted to correct myopia in 2002 and for astigmatism in 2006. The lens power calculation is identical and the surgical procedure is similar to the implantation of the rigid iris-fixation IOL, with most important differences being the size of the main incision and the subconjunctival injection of methylprednisolone (acetate) to avoid any reaction to the silicone material.

The Artiflex study shows long-term results that are generally comparable with those of previous Artisan studies. Although nonpigment and pigment precipitates have been found on Artisan P-IOLs in some cases, it seems that the occurrence of pigment precipitates is higher with the Artiflex lens. The incidence of pigment precipitates was highest at the 3-month postoperative examination. In most cases, the precipitates were transient. Several investigators treated the pigment precipitates with mydriatic eye drops or corticosteroids, after which the precipitates disappeared or stabilized without clinically significant consequences. In cases where the investigator chose not to give medication, the precipitates disappeared after 1 year. At 2 years after surgery, the incidence of pigment precipitates was 4.8% and none of the eyes had a loss of visual acuity. The multicenter study has been set up to see if the Artiflex lens can live up to the clinical standards set by the well-established Artisan lenses. The study results show that the Artiflex P-IOL is a very useful extension of the Artisan product family. Excellent results with predictability and efficacy can be obtained when good patient selection, correct surgical technique, and sufficient postoperative care according to the specifications of the manufacturer are taken into account.

Posterior Chamber Phakic IOLs

Alaa Eldanasoury MD

Introduction

Phakic IOLs (PIOLs) have passed through many stages of innovation and development over the last three decades. Today they have a central place in refractive surgical practice and are considered a valuable option for patients seeking freedom from spectacles.

PIOLs vs. LASIK

PIOLs have many advantages over LASIK especially in moderate and high myopia, including higher predictability, better stability, preserving the prolate shape of the cornea leading to better quality of vision, and maintaining corneal integrity and biomechanics, hence eliminating the risk of ectasia. Also, after PIOL implantation the tear film is not affected, abolishing the risk of dryness, a major concern after LASIK surgery.[1,2]

Available Designs

Three PIOL designs are available: angle-supported lens (AcrySof Cachet, Alcon; Texas, USA), iris-fixated lens (Artisan, Ophtec; Groningen, Netherlands), and posterior chamber phakic IOLs (ICL, Staar Surgical; Nidau, Switzerland). Each design has its advantages and potential disadvantages.

Criteria of an Ideal PIOL

1. Predictability

Predictability for a wide range of correction, including astigmatism.

Although all types of PIOLs have excellent efficacy and predictability in correcting spherical errors, only those PIOLs that have a toric option can correct eyes with astigmatic error.

2. Large functional optic zone

This is important for providing a good quality of vision.

3. Stability

Stability of the PIOL inside the eye is essential for long-term safety; a PIOL that rotates or sags down carries the risk damaging intraocular structures, especially the corneal endothelium and the anterior chamber angle, and can also have a negative impact on the refractive correction, especially if the lens is toric.

4. Biocompatibility

Biocompatibility is a major criterion for the long-term safety of any PIOL. PIOLs that have less than optimal biocompatibility may induce chronic inflammation and may be detrimental in the long term.

5. The ease of removal and/or exchange

The ease of removal and exchange of a PIOL is another key factor for an ideal PIOL. Many patients who receive PIOLs to correct their high myopia in their twenties or thirties will need to have these lenses removed if they develop cataract later in their lives, and a lens that cannot be safely removed through a small incision is obsolete in the era of small-incision and femtosecond cataract surgery.

6. Accurate size calculation

Accurate size calculation is mandatory in PIOL surgery. An over- or undersized PIOL carries the risk of rotation, inflammation, and intraocular tissue damage.

Posterior Chamber PIOL

The implantable collamer lens (ICL) is the most commonly used posterior chamber PIOL. With a power range between -18 and +16, it has a toric design that corrects astigmatism up to 6.0 D.

The newly introduced design Visian ICL V4c has a central hole (CentraFlow) that eliminated the need for both laser iridectomies and surgical iridectomy. The central hole improves the aqueous circulation between the crystalline lens and the implant and also from the posterior to the anterior chamber through the pupil. This new design carries the promise of a better efficacy and a higher safety profile.[3,4]

Advantages of Posterior Chamber PIOLs

The ICL has passed the test of time and fulfills most of the abovementioned criteria.

1. Predictability

The ICL and toric ICL proved to be highly predictable in the range between -18 and +12 D and also for correction of astigmatism up to 6.0 D.[5,6]

2. Quality of vision

Posterior chamber lenses, being closer to the nodal point of the eye optical system, provide a large functional optical zone and a magnification of the retinal image without significant effect on the quality of vision.[7]

3. Stability

A properly sized ICL does not rotate inside the eye, as shown by internal optical path difference measurement using the OPD-Scan III (Nidek; Gamagori, Japan) at different postoperative intervals (see Figure 1). An undersized ICL can rotate inside the eye, and in this case the lens must be exchanged for a larger better fitting lens.

4. Biocompatibility

Long-term studies showed that the ICL collamer material is highly biocompatible and safe to the corneal endothelium and other intraocular structures.

5. Removal and exchange

The ICL can be removed and replaced through a small incision if needed

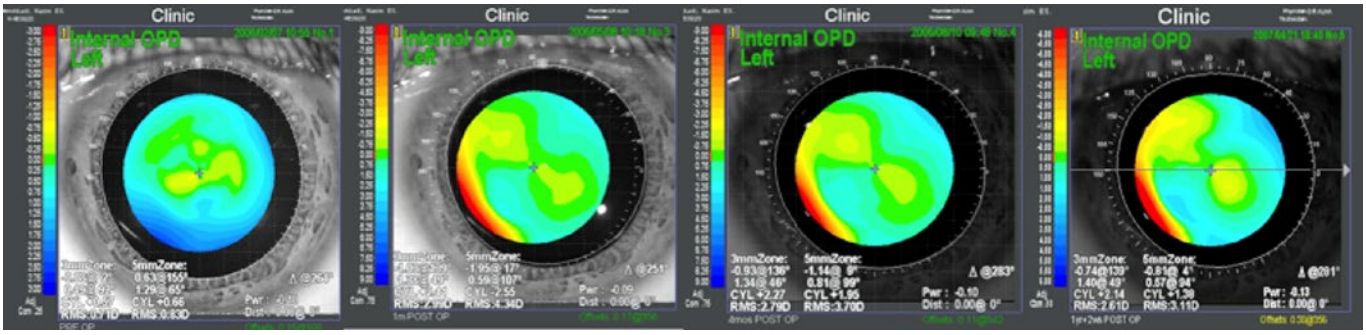

Figure 1. Evaluation of rotational stability of toric ICL over time using the OPD-Scan III. Measuring the internal optical path difference preoperatively (A), at 1 month (B), 4 months (C), and 1 year (D) shows the stability of the toric ICL inside the eye.

Disadvantages

Sizing remains the main unsolved issue in ICL surgery. White to white is the most commonly used method for sizing; it can be measured with calipers or with imaging devices including Orbscan (Bausch + Lomb; Rochester, New York, USA), Pentacam (Oculus; Wetzlar, Germany), and IOLMaster (Carl Zeiss; Oberkochen, Germany). Many studies showed no correlation between white-to-white measurements and sulcus diameter; however, clinical outcomes showed that the rate of over- or undersizing using the white-to-white measurement is less than 5%.

More recent studies evaluated the use of high-frequency ultrasound and reported more reliable results compared to white-to-white measurement.[8-10]

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How Safe Are Phakic IOLs? A Literature Review

Meta-analysis of Endothelial Cell Loss and Cataract Formation After Phakic IOL Implantation to Treat Moderate and High Ametropia

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Introduction

Phakic IOLs (P-IOLs) are implanted additionally to the natural lens to correct medium to high ametropia. There are 3 kinds of P-IOL: Anterior chamber iris-fixated, anterior chamber angle supported, and posterior chamber sulcus-fixated P-IOL.[1]

For implantation of P-IOL generally, certain selection criteria for patients are recommended, including stable refraction at least 1 year, unsatisfactory vision, no anomaly of pupil function, age-dependent minimum endothelial cell density (ECD) values, no systematic diseases, no anterior chamber anomaly or significant cataract, no increased IOP and retinal pathology.[2]

The postoperative visual outcomes are stable, predictable, effective, and safe, but there are specific complications. Among others, implantation of P-IOLs can provoke ECD loss and cataract. The reasons for postoperative ECD loss are not entirely clear, and the results of the present studies are to some extent confusing. Prospective, randomized controlled trials, evidence-based medicine level 2, are limited.

The aim of our meta-analysis was to review the results of reports on corneal ECD loss after P-IOL implantation and to make a qualitative assessment relating to the cataract rate in the same reports.

Methods

An analysis of literature (covering up until December 2012) was performed according to Preferred Reporting Items for Systematic Review and Meta- Analyses (PRISMA) guidelines.[3] Research of eligible studies was made using Medline (U.S. National Library of Medicine; Bethesda, Maryland, USA). Analysis was performed in 5 stages.

Stage 1: Identification

Defined terms linked with "or"/"and" were used in PubMed for research.

Stage 2: Titles

Two individuals separately identified eligible titles of articles through a database search. Articles that were not suitable were avoided in the following procedures.

Stage 3: Abstracts

Abstracts of articles that were included in stage 2 were screened by 2 individuals separately again. Inclusion criteria and exclusion criteria were applied. Articles that were not eligible were excluded.

Stage 4: Papers

Appropriate full-text articles were considered for eligibility. Congruent articles without relevant deviations to the abstract were identified for detailed analysis.

Stage 5: Analysis

Finally, a qualitative analysis and a quantitative synthesis were carried out. The evaluation of stage 4 and stage 5 was performed by 1 person.

Inclusion criteria

We assessed studies that were listed in the Medline database. We evaluated only original studies with a prospective design (minimum criteria). Only articles in English were taken into account for analysis.

Exclusion criteria

Reviews were excluded. Trials with a follow-up of less than 1 year or with fewer than 10 participants were excluded to ensure that up to the first postoperative year a group of patients was available.

Main outcome measures

Mainly we assessed the ECD (cell/mm^2) and the rate of new-onset cataract.

Statistics

The statistical analysis was performed by means of R software (www.r-project.org).

We used the inverse variance method, which is an approach in meta-analysis to combine results from more than 2 trials, and the random effects model, which is a statistical model to calculate pooled results. Heterogeneity of all data has been confirmed.

We investigated standard deviations (SD), standard errors (SE), and associated confidence intervals. To visualize estimated affects on ECD we created forest plots. We created funnel plots to assess possible publication bias.

Results

Study selection

1365 unique citations were identified in the literature search (Stage 1). After reviewing the titles, 1227 papers were excluded and 138 papers were retained (Stage 2). After reviewing the abstracts, 95 papers were excluded and 43 articles were retained (Stage 3). After reviewing full papers, 23 were filtered out and 20 were retained (Stage 4). Finally, 20 papers were included in the meta-analysis (Stage 5) (see Figure 1.)

Subgroup distribution

There were 9 studies of iris-fixated anterior chamber P-IOLs, 6 studies of angle-supported anterior chamber P-IOLs, 3 studies of posterior chamber P-IOLs, and 2 studies with 2 different types of P-IOLs; both looked at iris-fixated and angle-supported anterior chamber P-IOLs.

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

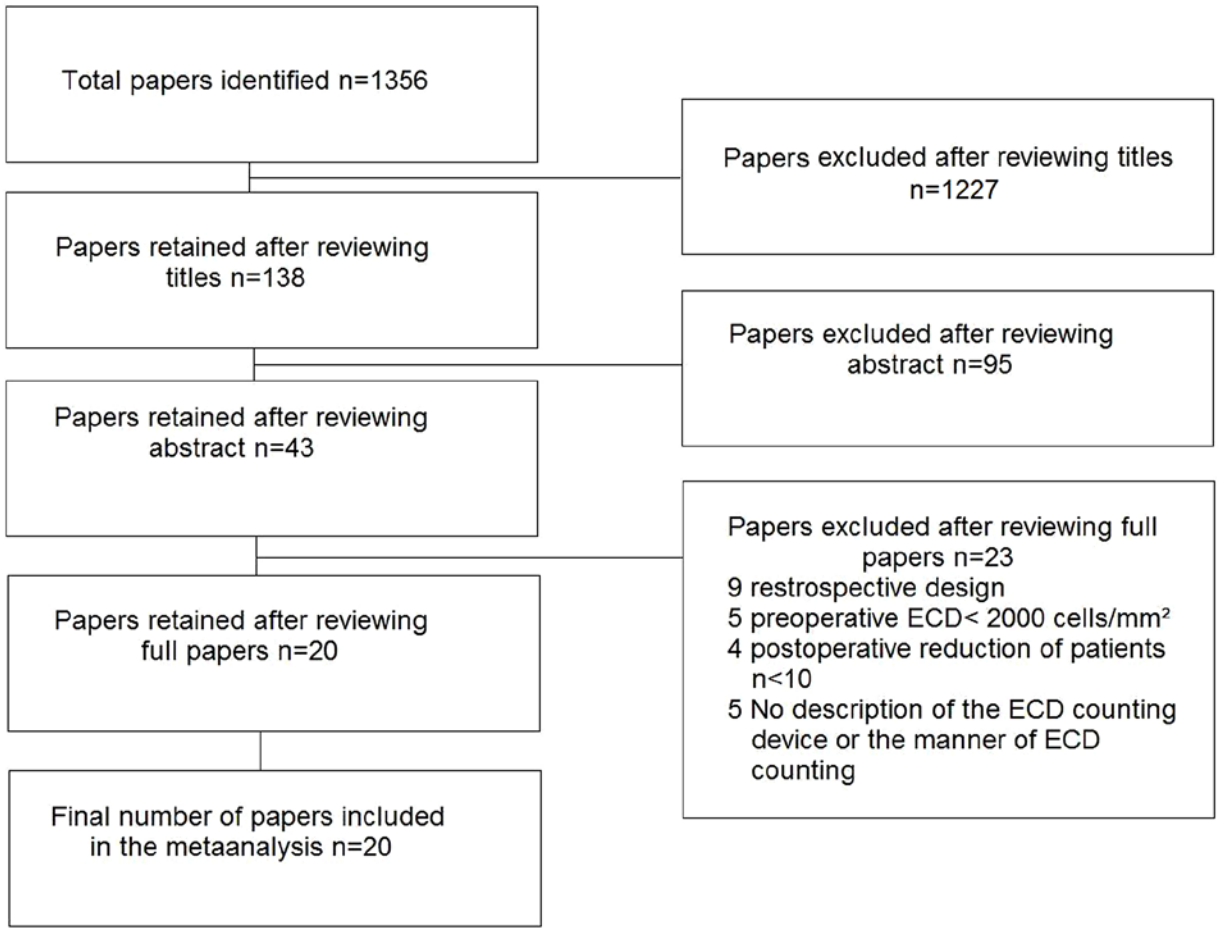

Figure 1.

Demographics and subject characteristics

We included data of 2502 eyes of 1825 examined patients; 49% female, 31% male, and 20% not specified. The mean age was 36.77 years ± SD ± 8.149 (range: 28.7-48.3 years). The mean number of examined patients was 96. The mean preoperative MRSE in the operated eye was -10.83 ± SD 3.355 D, ranging from -28 D to +11 D (see Table 1).

Table 1. Demographics and Subject Characteristics (2502 Eyes, 1825 Patients)

Age ± SD	36.77 ± 8.149 (range: 28.7-48.3)
Female	903; 49%
Male	564; 31%
Not specified	358; 20%
Patient number of each study	Mean: 95.82 (10-360)
	Median: 46.00
Preoperative MRSE ± SD	Mean: -10.83 ± 3.355 D
	Range: -28 D to +11 D

Abbreviations: SD indicates standard deviation; MRSE, manifest refractive spherical equivalent.

Confidence intervals

We investigated the ECD confidence intervals (95% true). We noted a lower and an upper value of each interval and calculated the mean value (Table 3).

Table 2. Mean Endothelial Cell Density (ECD) and Standard Deviation (SD) Over 7 Years

Period (Months)	Mean Number of Eyes	Mean ECD ± SD	Range (cells/mm^2)
0[a]	105.7	2785 ± 333.3	2432-3023
1	49.75	2806 ± 323.2	2653-2946
3	57.29	2672 ± 308.5	2258-2816
6	105.20	2678 ± 347.3	2157-2858
12	96.36	2675 ± 344.3	2102-2965
24	92.5	2609 ± 340.3	1974-2942
36	59.83	2555 ± 350.9	2441-2729
48	40.0	2523 ± 295.0	2398-2616
60	48.50	2529 ± 343.5	2379-2594
72	28	2556 ± 350.5	2552-2560
84	15.50	2473 ± 322.1	2426-2542

Abbreviations: ECD indicates endothelial cell density (cells/mm^2); SD, standard deviation.

[a] Preoperative value

Table 3. Determined ECD Confidence Intervals by Inverse Variance Method

Period (Months)	Confidence Intervals 95% Lower value; Upper value	Mean Values	*P*-Value
0[a]	(2705.763; 2857.362)	2781.563	$P < .0001$
1	(2649.052; 2950.911)	2799.982	$P < .0001$
3	(2457.390; 2888.124)	2672.757	$P < .0001$
6	(2531.259; 2829.530)	2680.394	$P < .0001$
12	(2577.240; 2801.010)	2689.126	$P < .0001$
24	(2455.432; 2787.910)	2621.671	$P < .0001$
36	(2481.995; 2683.070)	2582.532	$P < .0001$
48	(2449.713; 2674.647)	2562.180	$P < .0001$
60	(2525.416; 2647.582)	2586.499	$P < .0001$
72	(2459.992; 2660.008)	2560.000	$P < .0001$
84	(2342.035; 2533.668)	2437.852	$P < .0001$

Abbreviation: ECD indicates endothelial cell density (cells/mm^2).

P-value relating to the heterogeneity of data, $P < .0001$ confirms heterogeneous data.

[a] Preoperative value

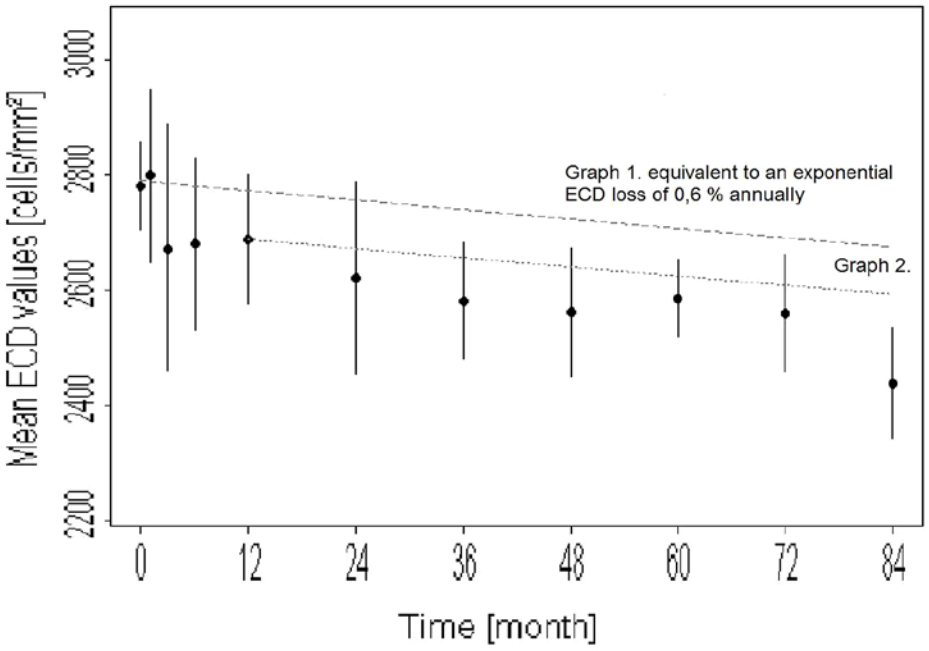

Figure 2.

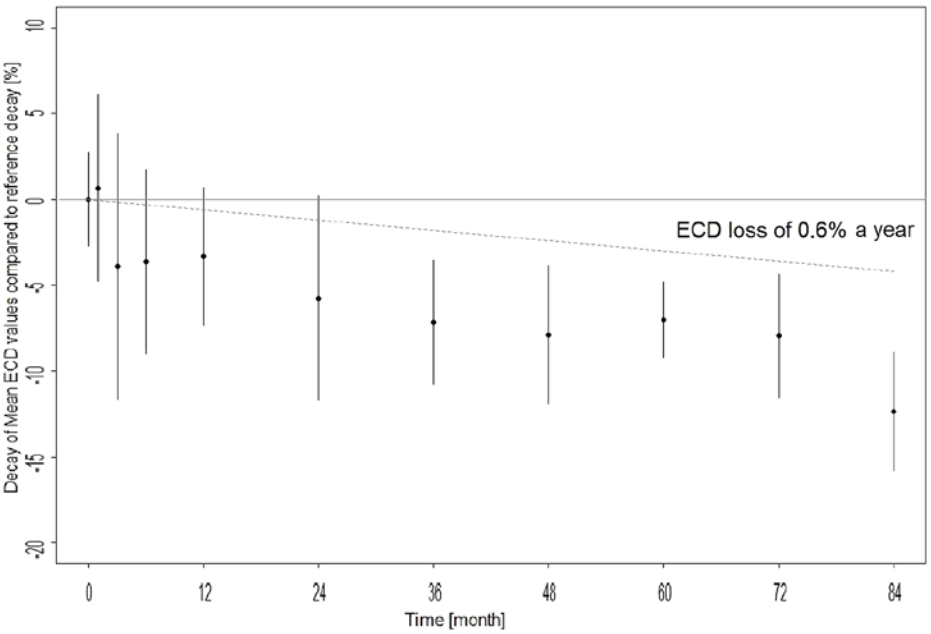

Figure 3.

Comparison to a natural exponential ECD decrease

We could not find any prospective randomized controlled trial. Thus we used the 20 eligible prospective trials (minimum criteria) for analysis. We compared the confidence intervals (CI) with a natural exponential ECD decrease of 0.6% annually in a graphic (see Figure 2, Graph 1).[4]

To exclude the influence of surgical trauma, we compared the CI to the natural exponential annual ECD loss of 0.6%, starting calculation from the 1-year postoperative value (see Figure 2, Graph 2; Figure 3).

The basic formula was: *lambda = -log (1 - 0.006); t(x) = mean ECD (time) * exp (- lambda * tx/12)*

Graph 1 was not a straight line, but a curve, which was very flat. There was not any visible deflection because the graphic had a time tracking of only 7 years.

Publication bias

Publication bias is not probable because lower and higher ECD values relating to standard errors in the funnel plots were present (in particular after 36 and 48 months).

ECD loss and cataract rate

The main ECD loss is revealed early up until the first postoperative year. Twelve eyes of 2502 eyes (0.47%) developed a cataract after P-IOL implantation (see Table 4)

Table 4. Complication Rate after P-IOL Implantation (2502 Eyes, 1825 Patients)

Complication	Eyes	(N) %
New onset cataract	12	0.47
Pupil ovalization	65	2.5
Corneal edema	2	0.07
Halos and/or glare	125	4.9
Uveitis	15	0.59
Pigment dispersion	42	1.67
IOP > 21 mmHg	43	1.71
Decentration	23	0.91
Lens rotation	0	0
Pupillary block	4	0.15
Incorrect power	0	0

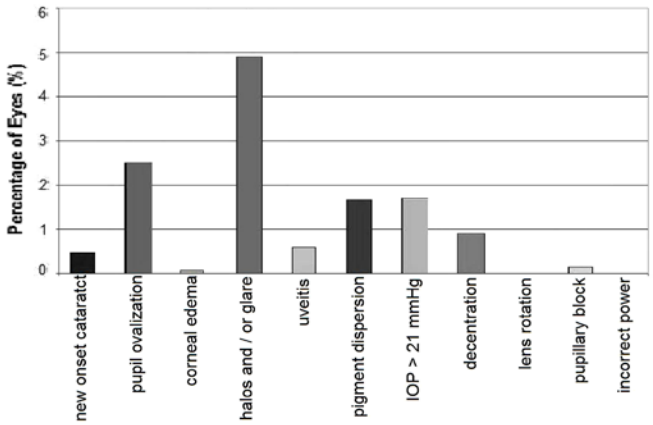

Figure 4.

Limitations

Our meta-analysis has limitations because we included only articles in English and the trials were not randomized and had no ECD values of control groups.

Because of poor data we could not review the morphometry of endothelial cells (hexagonal cells).

Conclusions

We did not find any prospective randomized control trial reports on corneal ECD loss after P-IOL implantation. Thus, a precise conclusion is not possible. Tendentious: the main ECD loss is revealed early up until the first postoperative year due to surgical trauma. After that a normalization of ECD decrease or a continuation of ECD decrease due to nontraumatic factors is possible. The absolute rate of cataract formation (0.47%) was not increased, and there is no evidence that this is due to P-IOL implantation.[5,6]

In the future, more long-term randomized controlled trials with a prospective design are needed to perform a complete evidence-based evaluation of ECD decrease and cataract formation after P-IOL.

Table 5. Estimated ECD Confidence Intervals of Iris-Fixated P-IOL Group

Time (Months)	Mean Value	Lower Value	Upper Value
0[a]	2793	2706	2880
1	2944	2866	3024
3	2804	2643	2964
6	2737	2642	2832
12	2750	2677	2824
24	2676	2604	2748
36	2610	2506	2714
48	2616	2543	2688
60	2586	2525	2647
72	2560	2460	2660

Abbreviation: ECD indicates endothelial cell density (cells/mm²).

[a] Preoperative value

Table 6. Estimated ECD Confidence Intervals of Angle-Supported P-IOL Group

Time (Months)	Mean Value	Lower Value	Upper Value
0[a]	2808	2725	2891
1	2680	2606	2754
3	2694	2644	2743
6	2767	2675	2859
12	2704	2549	2859
24	2704	2549	2859
36	2595	2031	3160
48	2595	2030	3159
60	2562	1755	3370
72	2552	1707	3397
84	2542	1710	3373

Abbreviation: ECD indicates endothelial cell density (cells/mm²).

[a] Preoperative value

Table 7. Estimated ECD Confidence Intervals of ICL Posterior Chamber P-IOL Group

Time (Months)	Mean Value	Lower Value	Upper Value
0	2828	2744	2911
1	2653	2578	2728
3	2802	2730	2873
6	2742	2666	2818
12	2712	2637	2786
24	2786	2478	3094
36	2481	2375	2587
48	2501	2409	2593

Abbreviation: ECD indicates endothelial cell density (cells/mm²)

[a] Preoperative value)

Table 8. Estimated ECD Confidence Intervals of Iris-Fixated and Angle-Supported P-IOL Group

Time (Months)	Mean Value	Lower Value	Upper Value
0[a]	2439	2393	2485
1	-	-	-
3	2258	2204	2318
6	2157	2094	2219
12	2102	2036	2168
24	1974	1898	2050

Abbreviation: ECD indicates endothelial cell density (cells/mm²).

[a] Preoperative value)

Table 9. Number of Trials in Relation to Time

Time in Months	0[a]	1	3	6	12	24	36	48	60	72	84
Number of Trials	16	4	8	10	16	12	8	4	4	2	3

[a] Preoperative

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Phakic IOLs: Where Are We Heading?

Antonio Marinho MD PhD

Introduction

The aim of refractive surgery is to modify the refractive power of the eye in a permanent and stable way. As we all know, there are two main refractive structures in the eye: the cornea and the natural lens. Changing the shape and thickness of the cornea, as in laser corneal surgery, or exchanging the natural lens by an IOL, as in refractive clear lens exchange or cataract surgery, allows us to achieve the goal of refractive surgery. However there is also another possibility: the introduction in the eye of a new refractive surface without touching the cornea or the natural lens. This is the concept of a phakic IOL.

Phakic IOLs have been part of modern ophthalmology practice since the pioneering work of Baikoff, Worst, and Fyodorov in the late eighties and early nineties of the last century. Since then, many different models have been suggested and tried, but many of them have been later discarded due to unacceptable complications. These complications occur typically as long-term complications and are due to the interference of the phakic IOL with the surrounding structures of the eye, such as the corneal endothelium, the iridocorneal angle, the iris, and the natural lens.

On the other hand, all phakic IOLs have very good accuracy of refractive correction, stability from day one, and a wide range of ametropia correction, and they provide superior quality of vision.

Looking back at 25 years of phakic IOL experience, I would like to discuss some key points, showing where we have been, where we are now, and where are we heading.

Selection of Patients

The anatomy of the eye is crucial in deciding whether or not to implant a phakic IOL. Established data show that no phakic IOL should be implanted in an anterior chamber shallower than 2.8 mm, preferably 3.0 mm (endothelium to anterior surface of the lens). Sizing of the eye (angle to angle or sulcus to sulcus) is also important, as both angle-supported phakic IOLs (eg, Cachet) and sulcus-supported phakic IOLs (eg, ICL) come in different sizes to fit perfectly in different eyes. The traditional methods of ultrasound biometry and white-to-white measurements with caliper are outdated, but even the present methods of measuring with OCT and ultrasound biomicroscopy are not perfect. If they were perfect the Cachet phakic IOL should not rotate (18%) and the vault of the ICL should be more predictable (250 to 700 micra). We certainly need more accuracy in intraocular measurements and size customization of the IOLs.

Selection of Phakic IOL

Concerning the selection of different phakic IOLs, I want to discuss four items:

1. Location
2. Material biocompatibility
3. Range of correction
4. Surgical technique

Location

Classically there are two possible locations for phakic IOLs: anterior chamber and posterior chamber. The anterior chamber is a space with easy access, making the surgery easier. Two problems have been associated with anterior chamber phakic IOLs: pupil distortion (and iris atrophy) and endothelial cell loss. The pupil distortion and iris atrophy seen in 30% of PMMA angle-supported models is not present with modern models (eg, Cachet), but endothelial cell loss is still a concern both with angle-supported (Cachet) and iris-supported (Artisan / Artiflex). Strict respect for the inclusion criteria and perfect surgery surely will reduce the risk, but there will be always a few cases of unexplained endothelial cell loss (eye rubbing, sleeping always to the same side).

It is important to realize that most cases of endothelial cell loss occur 5 to 10 years after surgery, pointing to the importance of lifetime patient follow-up. On the other hand, the posterior chamber is a tiny space (almost virtual) where the phakic IOL must be placed. Although safer for the endothelium, the intimate contact with the natural lens may cause cataract. We have come a long way from the Fyodorov (Adatomed) IOL, which showed 50% of cataracts at 5 years to the present V4c (ICL), with no more than 1%. Again, I stress the importance of the sizing of IOL. The ideal location of the IOL is still an unsolved issue.

Material Biocompatibility

Today the materials of the phakic IOLs are PMMA (Artisan), acrylic (Cachet), silicone (Artiflex), and collamer (ICL). PMMA, acrylic, and collamer are highly biocompatible, needing very few (if any) postop medication. On the other hand silicone is more proinflammatory, needing more vigorous steroid therapy. In 2014 a new Artiflex model made of acrylic will begin clinical trials in Europe.

Range of Correction

It is very important that a phakic IOL is able to correct in a wide range of situations. All phakic IOLs correct myopia, but toric models are essential. Presently Artisan and ICL have the widest range. Artiflex also has a toric model (only myopic astigmatism). Only Artisan and ICL are available for hyperopia. Table 1 summarizes the phakic IOL availability. In the future we will need more accurate IOLs and eventually a multifocal phakic IOL.

Surgical Technique

Surgical technique for phakic IOLs must be simple, atraumatic, and without complications. The incision must be small (maximum 3.2 mm). Although PMMA phakic IOLs (like the Artisan) are biocompatible, they will be slow to gain popularity worldwide due to the need of a large incision and suture (astigmatism inducement and time-consuming surgery).

In the future we will see smaller and smaller incisions. Insertion of the IOL inside the eye must be easy without the risks of damaging the IOL or implanting it upside down. This issue is very well solved with Cachet and Artiflex. The ICL insertion technique, although very elegant, is more difficult. Also here

Table 1. Availability

	AcrySof	Artisan	Artiflex	ICL
Myopia	Yes (-6.00/-16.50)	Yes (-2.00/-23.00)	Yes (-2.00/-14.5)	Yes (-0.25/-18.0)
Hyperopia	No	Yes (+2.0/+12.0)	No	Yes (+0.5/+10.0)
Astigmatism (toric)	No	Yes (+/-)	Yes (-)	Yes (+/-)

Table 2. Phakic IOLs Surgery Overview

	AcrySof	Artisan	Artiflex	ICL
Pupil	Miosis	Miosis	Miosis	Mydriasis
Side port	1 (?)	2	2	2
Incision	2.6 mm	5.2/6.2 mm	3.2 mm	3.2 mm
Visco	Cohesive	Cohesive	Cohesive	Cohesive
Iridectomy/Iridotomy	No	Yes	Yes	Yes/No
Suture	No	Yes	No	No

we will see soon an improvement with pre-charged ICL. Avoiding the need of iridectomy / iridotomy is also an advantage of Cachet and ICL (V4c model with central hole). Although easy to perform iridectomy, this changes the normal currents of aqueous humor and may be connected to early development of nuclear cataracts. Table 2 summarizes the surgical features of different phakic IOLs.

Conclusions

Phakic IOLs are an established tool in modern refractive surgery but still hold a great potential for improvement. I would like to finish with messages for the future in phakic IOLs.

- Strict inclusion criteria with precise diagnostic tools (sizing)
- Safe relations of phakic IOL with ocular environment (endothelium, angle, iris, lens)
- Biocompatible material
- Wide range of application
- Smallest incision
- No iridectomy

Are phakic IOLs the future of refractive surgery ? We do not know. Certainly the future is not in the cornea, but perhaps lens surgery will develop greatly and in the future phakic IOLs will not be needed.

Selected Readings

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Free Paper Session I

US Trends in Refractive Surgery: 2013 ISRS Survey

Presenting Author: Richard J Duffey MD

Purpose: To determine the latest trends in refractive surgery in the United States. **Methods/Results:** The U.S. membership of ISRS (approximately 1300 U.S. members) will be emailed the refractive surgery survey in August 2013. Questions regarding astigmatic keratotomy, limbal relaxing incisions, PRK, LASIK, laser-assisted subepithelial keratectomy (LASEK), epi-LASIK, intracorneal ring segments (Intacs), conductive keratoplasty (CK), phakic IOLs (P-IOL), refractive lens exchange (RLE) including accommodative and multifocal diffractive IOLs, toric IOLs, corneal inlay procedures, and the latest in femtosecond laser refractive cataract surgery will be examined in this survey. **Conclusions:** Complete results of the 1997-2012 surveys can be found at www.duffeylaser.com. The 2013 results will be presented at the Fall meeting in New Orleans and published thereafter on the same website.

Profocal Cornea: Extended Range of Vision Shaped With a Hydrogel Corneal Inlay

Presenting Author: Roger F Steinert MD
Coauthors: Arturo S Chayet MD, Enrique Barragan MD

Purpose: To establish the refractive range associated with functional visual acuity (VA) with a corneal shape-changing inlay. **Methods:** Presbyopic emmetropes and low-hyperopes (*N* = 192) were implanted in the nondominant eye with a hydrogel corneal inlay. ETDRS VAs as a function of preop manifest refractive spherical equivalent (MRSE), task performance, and patient satisfaction were assessed. **Results:** Mean uncorrected near VA of 0.1 or better was achieved by subjects with preop MRSEs between -0.5 D and +1.5 D. Mean uncorrected distance VA of 0.1 or better was attained by subjects with preop MRSEs between +0.25 D and +1.5 D. **Conclusion:** A wide range of MRSEs achieve an extended range of vision after implantation of a hydrogel corneal inlay.

Corneal Topographic Astigmatism (CorT): A Better Measure of Corneal Astigmatism That Corresponds to Manifest Refractive Cylinder

Presenting Author: Noel A Alpins MD FACS

Purpose: To determine a measure of corneal astigmatism that correlates with refractive cylinder. **Methods:** Using all axial power data from topography, an astigmatism value known as corneal topographic astigmatism, or CorT, was calculated. This was compared to the manifest refractive cylinder using the ocular residual astigmatism (ORA). The spread in ORA for the CorT was compared against other measures of corneal astigmatism: simulated keratometry (Sim K), manual keratometry (manK), corneal wavefront (CorW), and paraxial curvature matching (PCM). **Results:** CorT had a better correlation and less spread with refractive cylinder than Sim K, manK, CorW, and PCM. **Conclusion:** An alternative measure of corneal astigmatism, known as CorT, corresponds more closely to the manifest refractive cylinder than other measures of corneal astigmatism.

Topographically Guided Photorefractive Keratectomy for Irregular Astigmatism Following Penetrating Keratoplasty

Presenting Author: Simon P Holland MD
Coauthors: David T Lin MD, Choon Hwai Johnson Tan MBBS

Purpose: To evaluate efficacy and safety of topography-guided photorefractive keratectomy (TGPRK) for irregular astigmatism following penetrating keratoplasty (PK). **Methods:** Eyes with post-PK astigmatism underwent TGPRK with Allegretto Wave-Light laser and topography neutralization technique. Refractive outcomes and safety were studied. **Results:** Thirty-nine of 49 eyes completed 6 months of follow-up. Forty-six percent had uncorrected visual acuity (UCVA) ≥ 20/40, while none had preoperatively. Forty-two percent had improved BCVA, 21% gained ≥ 2 lines, and 8% lost ≥ 2 lines. Mean astigmatic reduction was 2.97 D. Mean spherical equivalent improved from -2.66 D to -0.81 D. Complications included delayed epithelialization and corneal haze. **Conclusion:** Early results of TGPRK for post-PK astigmatism are promising. Almost half achieved UCVA ≥ 20/40, and 42% had improved BCVA.

Refractive Outcomes of Topography-Guided Photorefractive Keratectomy With Simultaneous Crosslinking for Keratoconus

Presenting Author: David T Lin MD
Coauthor: Simon P Holland MD

Purpose: To evaluate 1-year result of simultaneous topography-guided photorefractive keratectomy with collagen crosslinking (S-TG PRK/CXL) for keratoconus. **Methods:** S-TG PRK/CXL performed with Allegretto WaveLight laser and topography neutralization technique. Refractive outcomes and safety were studied. **Results:** 135 of 332 eyes completed 1 year follow-up. Fifty-three percent had UCVA ≥ 20/40; 56% improved BCVA: 28% gained ≥ 2 lines, 4% lost ≥ 2 lines. Mean astigmatism dropped by 1.47 D. Mean postoperative spherical equivalent (SE) regressed from -0.89 at 3 months to -1.14 at 12 months. Ten percent had hyperopic progression, 4 had SE > 1.50 D. Complications include herpetic keratitis and delayed epithelial healing. **Conclusion:** Early satisfactory refractive outcomes with S-TG PRK/CXL. Progressive hyperopia probably related to CXL.

Topography-Guided Photorefractive Keratectomy for Irregular Astigmatism Following Penetrating Keratoplasty

Presenting Author: Simon P Holland MD
Coauthors: David T Lin MD, Choon Hwai Johnson Tan MBBS

Purpose: To evaluate efficacy and safety of topography-guided photorefractive keratectomy (TG-PRK) for irregular astigmatism following penetrating keratoplasty (PK). **Methods:** Eyes with post-PK astigmatism underwent TG-PRK with Allegretto WaveLight laser and topography neutralization technique. Refractive outcomes and safety were studied. **Results:** Thirty-nine of 49 eyes completed 6 months follow-up. Forty-six percent had UCVA ≥ 20/40 while none preoperatively. Forty-two percent had improved BCVA: 21% gained ≥ 2 lines, 8% lost ≥ 2 lines. Mean astigmatic reduction was 2.97 D. Mean spherical equivalent improved from -2.66 D to -0.81 D. Complications include delayed epithelialization and corneal haze. **Conclusion:** Early results of TG-PRK for post-PK astigmatism are promising. Almost half achieved UCVA ≥ 20/40, and 42% had improved BCVA.

The IOL of the Future: What Is in the Pipeline?

Jack T Holladay MD MSEE FACS

I. Eliminate Refractive Surprise: Adjustable
   A. Light (UV)
   B. Femtosecond laser
II. Eliminate Presbyopia Without Optical Compromise
   A. Mechanical
      1. Dual optics
      2. Microfluidics
      3. Deformable
   B. Optical: Change Index of Refraction
      1. Gravity
      2. Electrically
III. Eliminate Positive and Negative Dysphotopsias
   A. Groove on anterior optic
   B. Dual flange on edge
IV. Eliminate Dynamically Unwanted Wavelengths
   Photochromic

Managing the Nucleus After a Posterior Capsule Rupture

Iqbal K Ahmed MD

Identification of posterior capsule (PC) rupture is the first key step to managing the nucleus. The earlier one identifies a PC problem, the less likely the lens will fall posteriorly, and the less likely vitreous will prolapse forward—giving the surgeon more options in managing the remaining nucleus. The goal in these cases is to prevent posterior dislocation of the remaining nuclear fragments, prevent vitreous prolapse, manage vitreous if present, and safely extract the nuclear fragment from the eye.

The use of dispersive ophthalmic viscosurgical devices (OVDs) is critical in preventing vitreous prolapse and stabilizing the nuclear fragments by injecting around and behind lens material. Dispersives are more retentive than most cohesive OVDs and tend to sequester compartments within the eye. Furthermore, as the extraction of these nuclear fragments tends to be more anterior, dispersive OVDs are better able to coat and protect the corneal endothelium while maintaining a space clear from the anterior capsule. This can be thought of as a "lens fragment sandwich," with OVD as the "bread."

At the first sign of PC rupture, it is important to immediately pause the procedure while keeping the phaco tip in the eye, preferably on position 0. This is preferable to position 1, as irrigation may push the nuclear fragment farther posterior. The second instrument should then be removed, followed by injection of the OVD around and behind the nuclear fragment, if possible. Once the anterior chamber (AC) has stabilized, the phaco handpiece can be withdrawn. If, at the time of capsule break, it appears the nucleus is descending rapidly, it is preferred then to allow the AC to shallow (at the risk of increased vitreous prolapse) to avoid dislocation of lens fragments. Once can then inject OVD around/behind the nuclear fragments.

Once the AC has been stabilized with OVD, one should make a plan for identifying vitreous and extracting the nuclear fragments. If the lens fragments have fallen too far posteriorly, it is best to leave them for a posterior vitreoretinal approach. If the fragments are reachable, one should use a cannula or second instrument to rotate / elevate the lens material into the AC. With abundant OVD used, one should be able to do this maneuver without pulling on vitreous, which must be avoided. OVD should be injected behind the nucleus to separate the vitreous and elevate the lens. Once in the AC, a phaco glide can be used under the fragments to act as an artificial capsule. One can then perform vitrectomy if needed, either by a limbal or pars plana approach. It is important to use a bimanual vitrectomy, and avoid placing the cutter through the main incision to reduce leakage that will draw vitreous toward the wound. One should cut vitreous to draw it posteriorly away from the anterior segment. At this point, triamcinolone may be used to stain vitreous, but keep in mind that the presence of OVD can make adequate dispersion challenging. Hence, it is more helpful to use triamcinolone once the vitrectomy / irrigation has commenced.

In some instances, posterior-assisted levitation (PAL) may be considered. If the lens dislocation is not severe but difficult to levitate anteriorly and there is no vitreous prolapse in the anterior segment, a pars plana incision can be made, followed by use of an OVD cannula to levitate the lens fragments into the AC. Dispersive OVD can be injected behind the lens not only for fragment levitation but to tamponade vitreous posteriorly.

If there is no vitreous present in the AC and/or the vitreous has been cleared, assessment should be made as to whether to continue phaco or enlarge the wound and convert to extracapsular cataract extraction. This is based on the amount and density/size of lens material. If phaco is continued, it is ideal to use the phaco glide to prevent posterior luxation of fragments. One must be vigilant in identifying vitreous and to manage its presence accordingly. Furthermore, the AC shelf should be maintained to permit placement of 3-piece PC-IOL in the sulcus with possible optic capture once lens material has been removed.

Mastering Glued IOL

Roger F Steinert MD

NOTES

Managing Drop IOL

Amar Agarwal MD

Dislocation of an IOL into the vitreous can occur as an early or late complication arising from posterior capsular rupture during phacoemulsification. Management of such a situation with available instruments without compromising the visual outcome remains a challenge. Traditionally, dislocated IOLs have been managed either by repositioning the same or a different IOL with sutured scleral fixation or replacing the lens with an anterior chamber IOL. It is routinely combined with a conventional pars plana vitrectomy.

We have described a new technique of sutureless vitrectomy using 20-gauge vitrectomy instrumentation and repositioning the dislocated IOL in the posterior chamber with trans-scleral fixation of haptics, intralamellar scleral tuck, and fibrin glue-assisted flap closure. This was started by us. This is an extension of the glued IOL technique.

Chandelier Illumination

Visualization of the fundus during vitrectomy is done using a chandelier illumination in which xenon light is fixed to a trocar cannula. This gives excellent illumination, and one can perform a proper bimanual vitrectomy as it is not necessary for the surgeon to hold an endoilluminator by hand. An inverter has to be used if one is using a widefield lens. The supermacula lens helps give better stereopsis so that one will not have any difficulty in holding the IOL with a diamond-tipped forceps. One can also use a noncontact viewing system like a binocular indirect ophthalmomicroscope. When using the chandelier illumination system, one can hold the IOL with the forceps in one hand and a vitrectomy probe in the other hand to cut the adhesions of the vitreous, thus doing a bimanual vitrectomy. One can also use 2 forceps to hold the lens, thus performing a handshake technique. One can also lift the IOL from the retina using an extrusion cannula. This is easier than using a diamond-tipped forceps.

Perfluorocarbon Liquids

Stanley Chang popularized the use of perfluorocarbon liquids (PFCLs) for the surgical treatment of various vitreoretinal disorders. Due to their heavier-than-water properties and their ease of intraocular injection and removal, PFCLs are highly effective for flattening detached retina, tamponading retinal tears, and limiting intraocular hemorrhage, as well as floating dropped crystalline lens fragments and a dislocated IOL. We don't use PFCLs for dislocated IOLs generally, but they can be used. If one uses PFCL it should be removed at the end of surgery.

Subluxated 3-Piece IOL

The haptics of a subluxated 3-piece IOL are very comfortable to externalize through the sclerotomies without explanting the IOL . The reason is that the haptics are quite malleable and so can be externalized easily. The important thing is to hold the haptic with the glued IOL forceps while the vitrectomy is being done with the other hand so that there is no vitreous traction. One should also remember to grab the tip of the haptic while externalizing so that the haptic is not deformed. The handshake technique helps in achieving this.

One-Piece Nonfoldable PMMA Subluxated IOL

It is a bit tricky to reposition a single-piece nonfoldable PMMA IOL using the glued IOL technique as one can break the haptic. One should create the scleral flaps and after fixing the infusion should perform vitrectomy. Using 2 glued IOL forceps and the handshake technique, each haptic is then externalized through the sclerotomies under the scleral flaps. They are then tucked and glued in the Scharioth tunnels.

Subluxated Capsular Bag-IOL Complex

The subluxated capsular bag-IOL complex is tricky to handle. In such cases there may be thick Soemmerring rings. Vitrectomy of these can be done, but sometimes they are quite thick and can fall down into the vitreous cavity. It might be better to explant the complex through a scleral tunnel incision. Once the complex is explanted and the vitrectomy is done, a 3-piece IOL can then be glued into place.

One-Piece Foldable IOL

The IOL that cannot be fixed and glued is the single-piece foldable IOL. The reason is that for the glued IOL technique we need a firm haptic to tuck and glue into the sclera, and the haptics in a single-piece foldable IOL are too flexible to tuck and glue. In such cases, one should explant the IOL and refixate a 3-piece IOL with the glued IOL technique. We don't suture these IOLs as the results of the glued IOL are much better. So though there is a slightly larger incision for explanting the IOL we still prefer it to suturing an existing foldable single-piece IOL.

Discussion

The postoperative dislocated or luxated IOL remains an infrequent but significant complication of cataract surgery. The management options are observation, IOL exchange, or repositioning of the IOL. In all the procedures, combined pars plana vitrectomy has to be done, which requires multiple wounds of either sclerotomies or clear corneal incisions. This increases the risk of suture-induced astigmatism, postoperative inflammation, surgical time, and delayed visual rehabilitation. In this method of glued IOL repositioning, there is no IOL explantation; hence, chances of corneal wound astigmatism as seen in pars plana vitrectomy with IOL explantation and reimplantation are decreased. It can be performed with a dislocated rigid polymethylmethacrylate IOL, a 3-piece foldable posterior capsule IOL, or IOLs with modified polymethylmethacrylate haptics. Unlike other methods, in this technique, we have used the same pars plicata sclerotomy port for vitrectomy and IOL haptic externalization. If the IOL is on the retina one can lift the IOL through 23-gauge sclerotomies through the pars plana and then externalize the haptics through the pars plicata incisions. This way it is

very comfortable for the visualizing contact lens to be placed on the cornea.

Vitrectomy and IOL fixation through pars plicata have been reported in special situations. Although there is a possible risk of intraoperative hyphema because the sclerotomy is through the pars plicata, it was not observed in any of our patients. The probable reasons may be that the needle passes through the ciliary sulcus perpendicular to the sclera and continuous infusion flow is maintained to prevent decompression. Although it is known that a sclerotomy wound can cause prolapse and incarceration of uveal tissue and retinal fragments leading to vitreous traction and iatrogenic retinal breaks, the postoperative ultrasound biomicroscopy showed no vitreous traction or retinal incarceration in the pars plicata ports.

We have done an intralamellar tucking of the IOL haptic followed by fibrin glue application after externalization. We preferred this technique of glued IOL repositioning because the suture-related complications of scleral fixation IOL are reduced by this procedure. Because the IOL haptic is tucked in the scleral tunnel, it would prevent further movement of the haptic, reducing pseudophakodonesis, minimizing slippage and late re-dislocation. Although complete scleral wound healing with collagen fibrils may take up to 3 months, the IOL remains very stable from the early postoperative period because the haptic is snugly placed inside an intralamellar scleral tunnel. The risk of retinal photic injury that is known to occur in sutured scleral fixation IOLs would also be reduced in our technique because of the short surgical time.

Conclusions

This new method of glued IOL repositioning avoids additional corneal incisions or multiple sclerotomies and reduces surgical time and IOP fluctuation by maintaining a closed system.

Posterior Capsule Rupture in a Premium IOL Patient

David F Chang MD

NOTES

Bag Lens Glued Exchange

Lisa Brothers Arbisser MD

Case Presentation

- 85-year-old woman with pseudoexfoliation syndrome, pseudophakic for 10 years
- ? Minor trauma
- Bag-lens subluxation with vitreous in the anterior chamber
- No nerve fiber layer loss
- On 2 glaucoma medications
- Plan vitrectomy though sclerotomy under flaps and fixation of existing IOL with glued technique

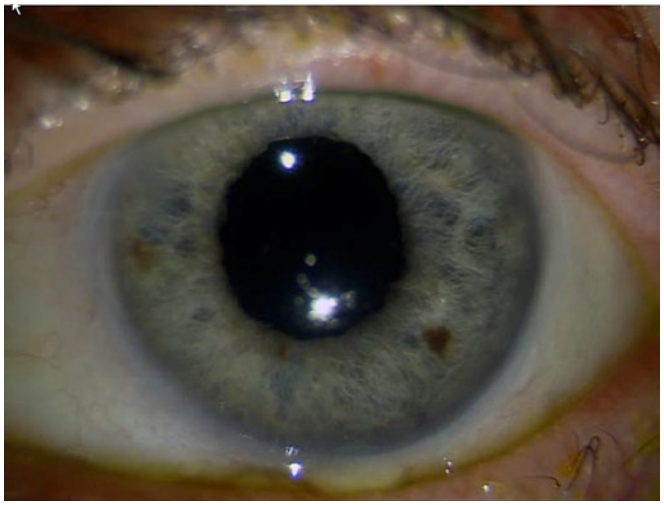

Figure 1.

Outcome

- 20/20 after 6 weeks
- Tapered off all drops over 3 months
- The most quiet eye with no pseudophakodonesis

The Dropped Nucleus

Robert H Osher MD

NOTES

2013 Advocating for Patients

Stephanie J Marioneaux MD

Ophthalmology's goal in protecting quality patient eye care remains a key priority for 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:

1. OPHTHPAC® Fund
2. Surgical Scope Fund (SSF)
3. State Eye PAC

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. At the state level, ophthalmologists serving on the Academy's Secretariat for State Affairs spend countless hours strategizing and collaborating with state ophthalmology societies to ensure Surgery by Surgeons and to protect quality patient eye care in states when dangerous scope expansion bills arise.

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 in 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 maintain 20 physicians in Congress. Among the significant impacts of OPHTHPAC:

- 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 your 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 the American Society of Cataract & Refractive Surgery (ASCRS) are part of the American Academy of Ophthalmology's Ophthalmic Advocacy Leadership Group (OALG) which has met for the past six years in January in the Washington DC area to provide critical input and to discuss and collaborate on the Academy's advocacy agenda. The 2013 OALG agenda focused on collaborative advocacy communication by the Academy and its OALG partners. As 2013 Congressional Advocacy Day (CAD) partners, 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 2013 Mid-Year Forum in Washington DC. The ASCRS remains a crucial partner to the Academy in its ongoing federal and state advocacy initiatives.

Surgical Scope Fund (SSF)

At the state level, the Academy's Surgery by Surgeons campaign has demonstrated a proven track record. The Surgical Scope Fund (SSF) provides grants to state ophthalmology societies to support their legislative, regulatory and public education efforts.

To date, the Academy's Surgical Scope Fund has helped 33 state / territorial ophthalmology societies reject optometric surgery proposals. In 2013, the Surgery by Surgeons campaign, in partnership with state ophthalmic societies and with support from the Surgical Scope Fund, helped achieve major victories for patient safety by defeating optometric surgery initiatives in: Florida, Louisiana, Nebraska, Tennessee, and West Virginia. Additionally, the advocacy preparatory work of the state society leadership, with support from the Surgical Scope Fund, caused optometry to think twice and ultimately not introduce surgery legislation to date (6/5/13) in Alabama, Idaho, Mississippi, South Carolina and Texas.

To date (6/5/13), California and Massachusetts are still faced with active OD surgery legislation, and with full support from Surgery by Surgeons, their state ophthalmic societies continue to fight these challenges head-on. Several ophthalmic subspecialty societies provided critical support to state battles when called upon.

A critical tool of the Surgery by Surgeons campaign to protect quality surgical care for our patients, the Surgical Scope Fund is our collective fund to ensure that optometry does *not* legislate the right to perform surgery. The Academy relies not only on the financial contributions to the Surgical Scope Fund by individual Eye M.D.s and practices, but also the contributions made by ophthalmic state, subspecialty and specialized interest societies. The ASCRS contributed to the Surgical Scope Fund in 2012, and the Academy counts on its contribution in 2013.

State Eye PAC

State ophthalmology societies cannot count on the Surgical Scope Fund alone—equally important is the presence of a strong state Eye PAC, which provides financial support for campaign contributions and legislative education to elect ophthalmology-friendly candidates for the state legislature. The Secretariat for State Affairs strategizes with state ophthalmology societies on target goals for state eye PAC levels.

Surgical Scope Fund	OPHTHPAC® Fund	State EyePAC
Scope of practice at the state level	Ophthalmology's interests at the federal level – Support for candidates for US Congress	Support for candidates for State House and Senate
Lobbyists, media, public education, administrative needs	Campaign contributions, legislative education	Campaign contributions, legislative education
Contributions: Unlimited	Contributions: Limited to $5,000	Contribution limits vary based on state regulations
Contributions are 100% confidential	Contributions above $200 are on the public record	Contributions are on the public record

Action Requested: ADVOCATE for YOUR PATIENTS!!

PAC contributions are necessary at the state and federal level to help elect officials who will support the interests of our patients. Academy Surgical Scope Fund contributions are used to support the infrastructure necessary in state legislative / regulatory battles and for public education. Contributions across the board are needed. 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 which 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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Free Paper Session II

Five-Year Results of Femtosecond Lenticule Extraction to Treat Myopia

Presenting Author: Rupal S Shah MD

Purpose: To investigate long-term results of femtosecond lenticule extraction to treat myopia and myopic astigmatism. **Methods:** Femtosecond lenticule extraction was used to treat myopia up to -10 D spherical equivalent (sph eq) on 120 eyes in 2008. Sixty consecutive patients were requested to come for follow-up in 2013. Outcome variables studied included refraction, uncorrected distance visual acuity (UDVA), corrected distance visual acuity (CDVA), IOP, wavefront aberrations, corneal thickness, and subjective symptoms. **Results:** Overall response rate was 67%. Mean sph eq at 5 years was -0.26 D ± 0.45 D. Eighty-nine percent of the eyes were within ± 0.5 D; 4% of the eyes lost 1 line of CDVA, while 16% gained 1 or more lines of CDVA. Ninety-two percent of eyes had an uncorrected visual acuity greater than or equal to 20/20. **Conclusion:** Long-term outcomes of femtosecond lenticule extraction for the treatment of myopia and myopic astigmatism are stable, safe, and effective.

Correction of Low to Moderate Hyperopia by Noninvasive Keratoplasty: U.S. Clinical Trial

Presenting Author: James J Salz MD
Coauthors: Harry G Glen MD, Michael Berry PhD

Purpose: To evaluate the safety and effectiveness of low to moderate hyperopia correction by noninvasive keratoplasty. **Methods:** Prospective pilot clinical study of noninvasive keratoplasty performed on 10 hyperopic patients with 24-month follow-up. **Results:** Safety: No adverse events or statistically significant (SS) changes in corrected distance visual acuity, astigmatism, IOP, corneal thickness, endothelial cell density, ocular aberrations, or corneal sensitivity occurred. Effectiveness: Post-primary treatment, mean binocular uncorrected distance visual acuity (B-UDVA) was 20/25 or better; improvements were SS (Wilcoxon $P < .05$) through 24 months. **Conclusion:** Noninvasive keratoplasty that targets stromal modifications while anti-targeting deleterious side effects is safe and effective for low to moderate hyperopia correction.

Use of a Small-Aperture Inlay in Emmetropic Presbyopes: Three-Year Results

Presenting Author: John Allan Vukich MD

Purpose: To evaluate a small-aperture corneal inlay for treating presbyopia. **Methods:** Multicenter clinical trial of 507 emmetropic presbyopes implanted with a small-aperture corneal inlay. Patients were between the ages of 45 and 60 with uncorrected near visual acuity of < 20/40 and > 20/100 and a best spectacle-corrected visual acuity of ≥ 20/20 in both eyes, with a spherical equivalent between +0.50 and -0.75 D. **Results:** Mean near acuity improved from J8 preoperatively to J2 at 3 years postop. Intermediate acuity improved from 20/32 at preop to 20/25 at 3 years postop. Monocular and binocular mean uncorrected distance visual acuities remained unchanged at 20/20 and 20/16, respectively, at 3 years. **Conclusions:** A small-aperture inlay is effective for treating emmetropic presbyopes. Three-year follow-up indicates results are maintained over time.

Photopic and Mesopic Functional Vision After Small-Aperture Corneal Inlay Implantation

Presenting Author: Jay Stuart Pepose MD PhD

Purpose: To assess patients' ability to perform daily tasks under photopic and mesopic conditions preoperatively and 12 months after implantation of a corneal inlay. **Methods:** Emmetropic presbyopes implanted monocularly with a small-aperture inlay assessed their functional ability on a scale of 1 (not easy at all) to 7 (very easy). **Results:** For distance vision tasks, scores remained constant. For near and intermediate tasks (reading newspaper, book, numbers on PDA, small print, and computer), the average preoperative and postoperative scores ranged from 1.0 to 1.5 and 2.8 to 4.0 under mesopic conditions and 1.3 to 2.6 and 4.1 to 5.6 under photopic conditions. **Conclusion:** Postoperatively, patients showed a statistically significant improvement in their ability to perform near and intermediate tasks under different lighting conditions.

Selecting the Most Accurate Toric IOL and Correcting for Refractive Surprises

Presenting Author: Noel A Alpins MD FACS

Purpose: To determine the amount of toric IOL rotation after a refractive cylinder surprise. **Methods:** Using free internet software, 2 cases of refractive surprise after toric IOL implantation were analyzed. **Results:** Case 1 preop keratometry was 41.87 / 46.00 @ 94, +10 D 5.25 D cyl was implanted with postop refraction +1.75 / -2.50 x 135. Rotation was 24 clockwise deg with refraction +0.25 / -0.25 x 90. Case 2 preop keratometry was 37.87 / 41.75 @ 13, +24 D 4 D cyl was implanted with postop refraction +0.50 / -2.00 x 75. Rotation of 11 deg clockwise with refraction +0.23 / -1.45 x 92. Hence, LASIK was the preferred option, with refraction +0.25 / -0.25 x 75. **Conclusion:** Understanding refractive surprises and how to correct for them after toric IOL implantation can determine the best secondary procedure to achieve optimal visual outcomes.

Removability of a Small-Aperture Intracorneal Inlay for Presbyopia Correction

Presenting Author: Pilar Casas de Llera MD
Coauthors: Jorge L Alio MD PhD, Daniel S Durrie MD, Alessandro Abbouda, Samira Farhad Huseynli, Michael C Knorz MD, Maria E Mulet

Purpose: To evaluate the reversibility of visual acuities (VA) and corneal topography in cases implanted with corneal inlay. **Methods:** Ten cases implanted with AcuFocus Kamra Inlay were followed for a minimum of 6 months after the removal. **Results:** The mean uncorrected distance (UDVA) and uncorrected near visual acuity (UNVA) before the implant were Snellen 20/20 and 20/40. Six months after the removal, UDVA was 20/25 and UNVA was 20/63. Weak positive correlation was found between Δt implant-removal, RMS spherical, coma, and higher-order aberrations at 6 months ($r = 0.8$; $r^2 = 0.6$, $P < .9$). **Conclusion:** In more than 60% of patients corrected near VA, corrected distance VA, UNVA, and UDVA were similar to the preoperative value.

Refractive Results Following Femtosecond Laser-Assisted Capsulotomy

Presenting Author: Louis D Skip Nichamin MD
Coauthor: Ajay Pillai MD

Purpose: To report the refractive outcomes of IOL implantation following femtosecond laser-assisted capsulotomy (FLAC). **Methods:** Patients presenting for cataract surgery were treated with Lensar capsulotomy. All capsulotomies were centered about the pupil center. Preoperative examinations and 1-month postoperative examinations were obtained. **Results:** Thirty patients were enrolled. Absolute mean (SD) refractive spherical equivalent (SE) error was 0.48 (0.35) D. Absolute achieved SE correction of 2.48 (1.96) D correlated well with absolute intended SE correction of 2.51 (1.87) D (R squared 0.90). Seventy percent of patients fell within 0.5 D of intended refractive outcome. Mean corrected distance visual acuity (SD) improved from 0.18 (0.18) to 0.02 (0.01) logMAR ($P < .5$). **Conclusion:** Precise refractive corrections are possible following FLAC.

The System and Why I Choose It

Robert J Cionni MD

I. Important Features to Be Considered in a Femtosecond Platform
   A. Ability to perform the following:
      1. Capsulotomy without tags or tears
      2. Lens fragmentation
      3. Corneal incisions (arcuate, primary, secondary)
   B. Ease of patient flow
   C. Short procedure time
   D. Safety
   E. Reliability
   F. Poised for future innovation

II. LenSx Femtosecond Refractive Cataract Laser Platform Today
   A. Most widely used platform in United States and worldwide
      1. More than 400 units installed
      2. More than 1000 surgeons using the system
      3. More than 150,000 procedures performed
   B. Capsulotomy: SoftFit interface provides nearly 100% free-floating, pristine capsulotomies
   C. Lens fragmentation
      1. Enhanced with SoftFit PI
      2. Zero phaco energy possible: Questionable benefit
      3. Numerous fragmentation patterns available
   D. Corneal incisions
      1. Precise arcuate incisions
      2. Precise primary and secondary corneal incisions including bimanual phaco/irrigation/aspiration capability
   E. Patient flow
      1. Extremely important; primary concern of most interested surgeons
      2. Surgical stretchers of choice decreases need for moving patients on and off surgical beds
      3. Docking
         a. Easy and fast; no need to mess with liquids
         b. Comfortable for patients
      4. Software: Intuitive, fast, precise
      5. Time in laser room: 3 minutes
   F. Outcomes
      1. More predictable effective lens position leads to more predictable refractive outcome[1-3]
      2. Laser-driven arcuates should lead to more predictable astigmatic correction.

III. The Future: Integration With Clinical Diagnostics
   A. Eye registration
   B. Automatic capsulotomy centration
   C. Robust arcuate / toric planning program
      1. Less time for planning
      2. No chance of transcription error
      3. Large-scale precise algorithms for spherical and astigmatic corrections

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The System I Use and Why I Use It

Choice of Laser Cataract Surgery System Dictates Clinical Outcomes and Capability to Treat All Patients

Burkhard Dick MD

I. Old patient population could create potential issues with laser cataract surgery, depending on the laser system used.

A. Patients present with comorbidities

1. Conjunctival alterations
2. Corneal opacification
3. Fuchs dystrophy
4. Intraoperative floppy iris syndrome (IFIS)
5. Optic nerve damage (ie, glaucoma)
6. Pseudoexfoliation

B. Challenging cases could complicate the laser procedure.

1. Brunescent cataracts
2. Hypermature cataracts
3. Loose zonules
4. Shallow anterior chamber
5. Small nondilating

II. Laser system features impact clinical outcomes and dictate usage in challenging cases and old patients.

A. Catalys Precision Laser System (Sunnyvale, Calif., USA)

B. Patient interface

1. Liquid Optics Interface minimizes IOP during dock over curved contact lens.[1]
2. Nonapplanating interface simplifies treatment of all patients and minimizes corneal folds.[2]
3. Gentle docking allows treatment of infants and redocking with more flexibility for procedural flow (ie, capability of entering eye first and then performing laser procedure).[3]

C. Imaging modalities

1. Full-volume 3-D OCT high-resolution images inform surgical decision making.
2. OCT capable of imaging through posterior capsule even in thick, brunescent lenses.
3. OCT capable of detecting posterior capsule with lens removed.

D. Image guidance

1. Automated image guidance minimizes time under dock.
2. Customization allows for surgeon input and creates flexibility to treat all patients.
3. Flexibility in surface fitting creates capability for new procedures, such as posterior capsulotomy with bag in the lens and posterior optic buttonhole.

E. Laser technology

Extensive grid fragmentation pattern creates capability to eliminate ultrasound energy.

III. 1900 consecutive case controlled trial

A. Capability to perform challenging cases

B. Capsulotomy, lens fragmentation, cataract and/or arcuate incisions

C. Comorbidities recorded

D. Endpoints

1. Capsulotomy precision
2. Effective phacoemulsification time during lens removal
3. Intra- and postoperative complications
4. BCVA
5. Endothelial cell loss

IV. Results

A. Successful treatment of patients with comorbidities and challenging cases

1. Glaucoma
2. Fuchs dystrophy
3. Cornea guttata
4. Post-vitrectomy
5. Pediatric cases
6. One eyed
7. Pseudoexfoliation
8. Anticoagulation
9. IFIS
10. Bag in the lens procedures
11. Corneal scars
12. Small pupils
13. Intumescent cataract case series ($N = 25$)[4]
14. Foreign body
15. Shallow anterior chamber
16. Marfan syndrome[5]

B. Limited complication rate in 1900 consecutive cases with comorbidities

C. Previously, showed 96% reduction in effective phacoemulsification time[6,7]

D. In 1900 consecutive cases, rate of complete capsulotomy: 99%

E. Analysis of 1900 case consecutive series showed > 40% requiring zero ultrasound

F. Reduced endothelial cell loss and faster visual recovery[8]

G. Improved BCVA

V. Conclusions

A. Catalys' key features enable successful laser cataract surgery in challenging cases, allowing improved clinical outcomes in all patients and revolutionary new procedures.

B. Limited complication rate observed in consecutive case series with high percentage of comorbidities

C. High rate of complete capsulotomy

D. Lens fragmentation results in elimination of ultrasound in large percentage of cases.

E. Reduction in endothelial cell loss and faster visual recovery with Catalys

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The System I Use and Why I Choose It
The Lensar System

Harvey S Uy MD

I. My Practice Setup
II. How the Lensar Femtosecond Laser Fits My Practice
  A. Small footprint and mobility
  B. Ergonomics
    1. Controls
    2. Adjustable screens
    3. Touch screens
    4. Staff training
III. Patient Interface Device
IV. Imaging is more than half the battle.
  A. Augmented Reality™ with intelligent imaging
  B. Image-guided cataract surgery
    1. Lens anatomy
    2. Lens grading
V. Laser Anterior Capsulotomy
  A. Tilt compensation and capsulotomy results
  B. Effective lens positioning
VI. Lens Fragmentation
  A. Range of treatable cataracts
  B. Treatment algorithms
  C. Cumulative dissipated energy reduction
VII. Corneal Incisions
  A. Triplanar clear corneal incision
  B. Arcuate incisions
VIII. Accommodation Restoration

The System I Use and Why I Choose It

Gerd U Auffarth MD

NOTES

Prosecution: Refractive Results Are Not Better

George HH Beiko MD

I. Introduction: Astigmatism Control

A. Majority of patients tolerate 0.75 D of astigmatism

B. Eyes with astigmatism greater than 2.26 D; toric IOLs outperform limbal relaxing incisions (LRI).

C. Thus, laser correction of astigmatism is possibly of value for patients with astigmatism between 0.75 to 2.00 D.

1. *34%-40% of patients*

2. Currently, LRI and toric IOLs comparable in this range (residual astigmatism was 0.42 D in toric and 0.46 D in LRI group)

II. Refractive Outcomes

A. Comparing femto to manual phaco, no difference in:

1. Mean postop sphere

2. Mean postop cylinder

3. Mean absolute refractive predictive error

4. Mean arithmetic refractive predictive error

5. Mean postop uncorrected distance visual acuity (VA)

6. Mean postop corrected distance VA

7. Mean postop uncorrected near VA

B. Comparing femto to manual phaco, femto slightly better:

1. Mean absolute error (0.38 ± 0.28 vs. 0.50 ± 0.38; $P = .04$)

2. Internal vertical tilt (0.27 ± 0.57 vs. -0.50 ± 0.36)

3. Internal coma (-0.003 ± 0.11 vs. 0.100 ± 0.15)

Selected Readings

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Defense: Refractive Results Are Better

Zoltan Nagy MD

NOTES

Prosecution: Laser Refractive Lens Surgery Is Not Safer

Robert K Maloney MD

Documented complications of femto cataract surgery:

- Malpositioned incisions
- Pupillary constriction
- Radial anterior capsule tear
- Posterior capsule tear
- Dropped nucleus

Defense: Laser Refractive Lens Surgery Is Safer

Michael Lawless MD

Femtosecond laser cataract surgery is used for a minority of lens and cataract procedures around the world. The precision and reproducibility of a femtosecond laser should provide surgeons with the ability to perform safer and more accurate surgery.

I have endeavored to provide data from the peer-reviewed literature that show improvements that can be made with laser surgery compared to manual. It has been broken down into data to support improvements in corneal incisions, less harm to the corneal endothelium as reflected in central corneal thickness, volume stress index, and endothelial cell loss, and a decrease in anterior chamber inflammation. Also improved capsulotomy strength compared to manual and more precise IOL position in terms of decentration, tilt, and higher-order aberrations. The obvious decrease in phacoemulsification time and energy and a possible improvement in macular safety are now also described in the literature.

The surgery can be performed in difficult cases such as small pupils with posterior synechiae, following trabeculectomy, following corneal transplant, floppy iris syndrome, Fuchs dystrophy, and in a variety of complex situations where the added safety may be of additional benefit to individual patients.

In particular, I also present data from a group of surgeons to show that bringing a laser to cataract surgery can allow a group ophthalmology practice to achieve complication rates that are as good, or better, than the best series from the literature—comparing, in particular, anterior and posterior capsular tears with and without vitreous loss.

The simple fact is that in 2013 laser cataract and lens surgery is supported by the peer-reviewed literature. What remains is to quantify these benefits and their value to an individual patient and surgeon.

Table 1. Corneal Incisions

First Author	Journal	Result
Masket[1]	*J Cataract Refract Surg*. 2010	LCS-made wounds may show less features of damage and faster healing.
		LCS incision may offer added stability and reproducibility in cataract wound construction.
Palanker[2]	*Sci Transl Med*.	Multiplanar incisions were self-sealing and resistant to leakage under physiological pressure.

Abbreviation: LCS, laser cataract surgery.

Table 2. Central Corneal Thickness

	Takacs, et al. *J Refract Surg*. June 2012[4]		Conrad-Hengerer, *J Cataract Refract Surg*. Epub July 2013[5]	
	Conventional Group	LenSx Group	Conventional Group	Optimedica Group
Change in CCT at Day 1 (%)	10.4	6.4*	0.9	0.0
Change in CCT at Week 1 (%)	1.6	1.6	2.4	2.8
Change in CCT at Month 1 (3)	1.3	0.0	3.2	3.3

* $P < .05$.

Abbreviation: CCT, central corneal thickness.

Table 3. Volume Stress Index

	Takacs, et al. *J Refract Surg*. June 2012[4]		Vote, et al. Presented at AUSCRS 2012[6]	
	Conventional Group	LenSx Group	Conventional Group	Optimedica Group
Volume stress index (VSI) Day 1	$5.3 \pm 6.0 \times 10^{-5}$	$3.0 \pm 2.3 \times 10^{-5}$* (43% reduction)	37.7×10^{-5}	25.4×10^{-5}* (33% reduction)

* $P < .05$.

VSI based on postoperative alteration of central corneal volume (within 3-mm diameter) and central endothelial cell density.

Table 4. Endothelial Cell Loss (Mean)

	Takacs et al. *J Refract Surg*. June 2012[4]		Abell. *Ophthalmology*. 2013[7]		Conrad-Hengerer, *J Cataract Refract Surg*. Epub July 2013[5]	
	Conventional Group	LenSx Group	Conventional Group	Optimedica Group	Conventional Group	Optimedica Group
Endothelial cell loss (1 month)	299 cells/mm^2	123 cells/mm^2 (59% reduction)	224 cells/mm^{2*}	144 cells/mm^2 (36% reduction)	297 cells/mm^2	199 cells/mm^{2**} (33% reduction)
Endothelial cell loss (3 months)	N/A	N/A	N/A	N/A	337 cells/mm^2	200 cells/mm^{2**} (41% reduction)

ECC loss positively correlated with EPT.

* $P < .05$.

** $P < .01$.

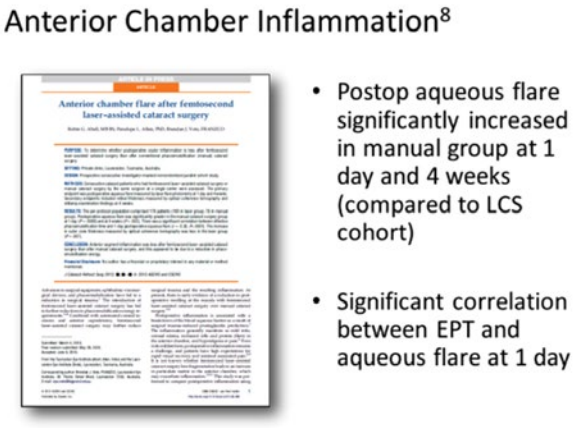

Figure 1.

Table 5.

Author	Journal	Comment
Auffarth[9]	*J Cataract Refract Surg*. 2013.	Significantly stronger anterior capsule opening.
		Mean rupture force 113 mN ± 12 in LCS 73 mN ± 22 in manual. Stretching ratios 1.60 ± 0.10 in LCS 1.35 ± 0.04 in manual.
Friedman[10]	*J Cataract Refract Surg*. 2011.	Rupture force 152 ± 21 mN for 3 mJ in LCS vs. 65 ± 21 mN in manual (porcine eyes).
Tackmann[11]	*J Cataract Refract Surg*. 2011.	Rupture force 177 mN ± 53 for LCS vs. 125 mN ± 43 for manual.
Palanker[2]	*Sci Transl Med*. 2010.	Rupture force 152 mN ± 21 for LCS vs. 66 mN ± 22 for manual.
Nagy[12]	*J Refract Surg*. 2009.	Stretching ratio 2.13 ± 0.03 for LCS vs. 1.98 ± 0.08 for manual.
Roberts, Lawless, et al.[3]	*Ophthalmology*. 2013.	0.31% (4) radial anterior capsular tears, 0.31% (4) posterior capsule tears (2 during phacoemulsification)

Abbreviation: LCS, laser cataract surgery.

Table 6. Precision of Capsulotomy

Author	Journal	Comment
Friedman[10]	*J Cataract Refract Surg*. 2011.	Deviation from intended diameter 29 mm ± 26 in LCS vs. 337 mm ± 258 in manual
Nagy[13]	*J Refract Surg*. 2011.	Circularity significantly better in LCS. Significant correlation between AL and average Ks and area of capsulotomy in manual cases but not in LCS.
Tackmann[11]	*J Cataract Refract Surg*. 2011.	Mean absolute deviation from intended diameter 0.16 mm ± 0.17 in LCS vs. 0.42 mm ± 0.54 for manual.
Palanker[2]	*Sci Transl Med*. 2010.	Deviation from intended diameter 0.03 mm ± 0.03 in LCS vs. 0.30 mm ± 0.31 for manual. Circularity 0.95 ± 0.04 in LCS vs. 0.77 ± 0.15 for manual. Precision in sizing 12x better for LCS.
Nagy[12]	*J Refract Surg*. 2009.	Reproducibility of capsulotomy significantly higher in LCS compared to manual cases.

Abbreviations: LCS, laser cataract surgery; AL, axial length.

Table 7. Capsulotomy Accuracy and Effect

Author	Journal	Comment
Szigeti[14]	*J Cataract Refract Surg*. 2012.	No significant difference between groups across decentration parameters
Nagy[13]	*J Refract Surg*. 2011.	Correlation between IOL decentration and AL in CCC but not LCS group
Nagy[12]	*J Refract Surg*. 2009.	Approximately 300 μm between x and y diameters in manual; negligible in LCS
Kranitz[15]	*J Refract Surg*. 2012.	IOLs implanted in manual showed greater horizontal and total decentration. Total decentration correlated with changes in refraction at 1 month and 12 months.
Kranitz[16]	*J Refract Surg*. 2011.	Significantly higher values of overlap and circularity in LCS. Horizontal decentration of IOL significantly higher in manual cohort.
Palanker[2]	*Sci Transl Med*. 2010.	Central position and proper sizing of capsulotomy resulted in symmetric 0.5-mm overlap of bag to edge of 6.00 IOLs.

Abbreviations: LCS, laser cataract surgery; AL, axial length; CCC, continuous curvilinear capsulorrhexis.

Table 8. IOL Tilt and Higher-Order Aberration

Author	Journal	Comment
Kranitz[15]	*J Refract Surg*. 2011.	Horizontal and vertical tilt significantly higher in manual CCC group
Szigeti[14]	*J Cataract Refract Surg*. 2012.	Vertical and horizontal tilt significantly higher in 6.0-mm than in 5.5-mm group
Mihaltz[17]	*J Refract Surg*. 2011.	Lower vertical tilt and coma, higher Strehl ratio and MTF in LCS cases than in manual cases. Capsulotomy performed with LCS induced significantly less internal aberrations.

Abbreviations: LCS, laser cataract surgery; CCC, continuous curvilinear capsulorrhexis; MTF, modulation transfer function.

Table 9. Effective Phacoemulsification Time

Author	Journal	Comments
Conrad-Hengerer[5]	*J Cataract Refract Surg*. 2013.	Mean EPT 0.0 ± 0.1 secs in LCS vs. 1.4 ± 0.1 secs in manual. Difference consistent with LOCS grades of cataract.
Abell[18]	*J Cataract Refract Surg*. Epub 2013.	Mean EPT 0.94 ± 3.47 secs in LCS vs. 6.5 ± 4.3 secs in manual.
Abell[19]	*Clin Experiment Ophthalmol*. 2013.	70% reduction in EPT
Kerr[19]	*Ophthalmology*. 2013.	Mean EPT reduced by 83.6% in LCS compared to manual. (Mean EPT reduced by 96.2% in optimized LCS compared to manual.)
Conrad-Hengerer[20]	*J Cataract Refract Surg*. 2012.	Mean absolute phaco time reduced in LCS.
Conrad-Hengerer[21]	*J Cataract Refract Surg*. 2012.	Mean EPT 0.16 ± 1.21 secs in LCS vs. 4.07 ± 3.14 secs in manual.
Palanker[2]	*Sci Transl Med*. 2010.	CDE reduced by 39% in LCS compared to manual.
Nagy[12]	*J Refract Surg*. 2009.	Reduction of 51% phaco time and U/S power by 43%.

Abbreviations: EPT, effective phacoemulsification time; LCS, laser cataract surgery; LOCS, Lens Opacities Classification System; CDE, cumulated dissipated energy; U/S, ultrasound.

Table 10. Macular Safety

First Author	Journal	Results
Abell[18]	*J Cataract Refract Surg*. Epub 2013.	OCT increase in outer zone thickness in laser group ($P = .07$)
Nagy[22]	*J Cataract Refract Surg*. 2012.	Swelling in ONL less in laser group
Ecsedy[23]	*J Refract Surg*. 2011.	Significantly lower macular thickness in IRR in laser group (adjusted for age and preop thickness). Suction excluded as cause of subclinical changes.
Palanker[2]	*Sci Transl Med*. 2010.	No retinal or ocular damage due to irradiation
Conrad-Hengerer[5]	*J Cataract Refract Surg*. Epub 2013.	Five eyes (2 LCS, 3 control) developed significant CME; 2 eyes in control group, subclinical CME.
Nagy[22]	*J Cataract Refract Surg*. 2012.	Retinal thickening in both groups at 4 and 8 weeks postop. No correlation between macular changes and U/S time.

Abbreviations: ONL, outer nuclear layer; IRR, inner retinal ring; LCS, laser cataract surgery; CME, cystoid macular edema; U/S, ultrasound.

Table 11. Safety in Difficult Cases

Author	Journal	Comment
Roberts, Lawless, et al[3]	*Ophthalmology*. 2013	Myalugin ring with stuck down, post-trabeculectomy eye
Krantiz[24]	*J Refract Surg*. Epub 2013.	LCS successfully used in phacomorphic glaucoma (± mechanical pupil dilation)
Dick[25]	*J Cataract Refract Surg*. 2013.	Great potential for anterior and posterior capsulotomies
Nagy[26]	*J Refract Surg*. 2013.	Preserving ECC in postoperative transplant corneas
Bali[27]	*Graefes Arch Clin Exp Ophthalmol*. 2012.	Phacovitrectomy appears safe and may have additional benefits.
Nagy[28]	*J Refract Surg*. 2012.	Improved outcomes in trauma cases / white cataract / AC rupture
Juhasz[29]	*Lasers Surg Med*. 1996.	Fewer collateral tissue effects with FS laser to nearby tissue (initial FS paper)
Roberts[30]	*J Refract Surg*. 2011.	Intraoperative capsular block syndrome
Palanker[2]	*Sci Transl Med*. 2010.	80% had small petechial hemorrhages and vasodilation in a ring pattern

Abbreviations: LCS, laser cataract surgery; AC, anterior capsule; FS, femtosecond.

Table 12. Published Rates of Major Complications Reported With Cataract Surgery

Authors	Study Design and Population	Surgery	AC Tear	PC Tear Without Vitreous loss	PC Tear With Vitreous loss	Posterior Lens Dislocation
Gimbel, et al (2001)	Retrospective (*n* = 18,470)	MCS	-	0.24%	0.20%	0%
				0.45%		
Tan, et al (2002)	Retrospective (*n* = 2538)	MCS	-	-	3.6%	-
Androudi, et al (2004)	Retrospective (*n* = 543)	MCS	-	3.50%	4.05%	0%
				7.55%		
Muhtaseb, et al (2004)	Prospective (*n* = 1441)	MCS	2.8%	-	1.7%	0.4%
				2.2%		
Hyams, et al (2005)	Retrospective (*n* = 1501)	MCS	-	0.99	1.93%	-
				2.9%		
Misra, et al (2005)	Prospective (*n* = 1883)	MCS	-	0.16%	0.53%	0.11%
				0.69%		
Ang, et al (2006)	Retrospective (*n* = 2727)	MCS	-	1.7%		-
Chan, et al (2006)	Retrospective (*n* = 8230)	MCS	-	1.9%		-
Marques, et al (2006)	Retrospective (*n* = 2646)	MCS	0.79%	-		-
Unal, et al (2006)	Prospective comparative (*n* = 296)	MCS	5.1%	4.05%	6.4%	2.4%
				10.4%		
Olali, et al (2007)	Interventional case series (*n* = 358)	MCS	0.56%	-	-	-
Zaidi, et al (2007)	Prospective and retrospective (*N* = 1000)	MCS	-	0.4%	1.1%	0.1%
				1.5%		
Mearza, et al (2009)	Retrospective (*n* = 1614)	MCS	-	-	2.66%	-
Agrawal, et al (2009)	Prospective (*n* = 2984)	MCS	-	1.46%		-
Narendran, et al (2009)	Retrospective (*n* = 55,567)	MCS	-	1.92%		0.18%
Greenberg, et al (2011)	Retrospective (*n* = 45,082)	MCS	-	3.5%		-
Clark, et al (2011)	Population-based study (*n* = 129,982)	MCS	-	-	-	0.12%
Lundstrom, et al (2011)	Retrospective (*n* = 602,553)	MCS	-	2.09%		-
Bali, et al (2012)[27]	Prospective (*n* = 200)	LCS	4%	0.5%	3%	2%
				3.5%		
Roberts, et al (2012, current study)	Prospective (*n* = 1300)	LCS	0.32%	0.08%	0.23%	0%
				0.31%		

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Prosecution: Procedure Is Too Long and Too Expensive

Deepinder K Dhaliwal MD

NOTES

Defense: Procedure Time and Cost Are Acceptable

John A Hovanesian MD

I. Introduction

II. Surgeons' Beliefs About Femtosecond Cataract Surgery

Results of the American Society of Cataract and Refractive Surgery member survey

A. Financial model concerns

B. Technical concerns

III. State of the Technology

IV. Henry Ford and Latent Need

V. Where Demand and Supply Are Likely to Meet

Prosecution: Why I Still Prefer Phaco

Steve A Arshinoff MD

The world tends to amalgamations in endlessly increasing complexity, as long as the sum of benefits to the amalgamating parties exceeds zero.

Previous Innovation in Cataract and Refractive Surgery

Common examples of previously successful innovations in cataract and refractive surgery:

- IOLs
- Ophthalmic viscosurgical devices
- Phaco (permitted small incisions, rrhexis, IOL adaptation)
- Limbal relaxing incisions, toric IOLs
- Monovision, multifocal IOLs

Common factors of previously successful innovations in cataract surgery:

- Previous advances in cataract and refractive surgery have always allowed us to do something we could not do before.
- Does femto have the potential to do something really new, and thereby join the above as a great innovation?

Art & Money

The period from 1970 to 2005 consisted of an endless series of innovations in cataract surgery, mostly coming from cataract surgeons, who developed an enviable "art of cataract surgery."

From 2005 to the present, we have witnessed the gradual corporatization of cataract surgery, where mechanical devices, and other professions, have gradually assumed roles that remove much of the art of cataract surgery, including astigmatism and presbyopia correction, postoperative management and refraction, and now, with femtosecond lasers, incisions, capsulorrhexis and nuclear disassembly. Some of these new approaches compensate for, rather than correct, specific problems.

Are femtos really better than an excellent surgeon, or do they simply present different complication risks? The price/performance ratio of femtos hardly seems worth the gain, and unlike phaco, may severely limit the potential market.

1. Femtos will encourage corporate cataract centers.
2. Femtos are not amenable to surgery in remote areas, socialized health care schemes, or anywhere except the most wealthy countries.

I expect that some day we will all use femtosecond lasers, but I also hope that the lasers will adapt to our surgical needs better than they have so far.

Defense: Why I Switched to Laser Refractive Lens Surgery

Barry S Seibel MD

NOTES

Restoration of Accommodation With Laser Surgery

*Omid Kermani MD, Georg Gerten MD**, Uwe Oberheide MS, Holger Lubatschowski PhD**, Rudolf F Guthoff MD*

Introduction

The focus shift from far to intermediate to near vision is a complex process that is well known and described by Helmholtz as accommodation.[1] The process of accommodation involves the convergence of both eyes, pupil and ciliary muscle constriction, with the subsequent enhancement of the crystalline lens refractive power following the steepening of its anterior and posterior curvature.

Presbyopia or age-related loss of near vision commonly has its onset around age 45.[2] Presbyopia is a dysfunction that is universal—independent of race, sex, and refractive status. Presbyopia, therefore, is the most common refractive dysfunction known.

The cause of presbyopia, very likely, is the aging of the crystalline lens.[3] The crystalline lens stays under constant mechanical stress (accommodation); it is the central UV light filter for the eye, does not have blood supply and, therefore, does not benefit from the circulation of nutrients.

The loss of elasticity is caused by the sclerosis of the lens nucleus. The ciliary muscle remains active throughout life.[4] The lens capsule, actually the driving force for the ability of the lens to deform, presumably keeps its elasticity beyond the onset of presbyopia.[5]

Over the years many different approaches for the surgical treatment of presbyopia have been evaluated. The majority of these approaches have targeted the cornea for treatment and typically have involved the use of some type of monovision. The common link with each of these methods is that they take a static approach to solve the problem, whereby presbyopia is a dynamic and progressive process.

The most commonly used approach with the crystalline lens involves removal and replacement with a multifocal IOL.

In 1998, Ray Myers and Ron Krueger proposed a novel approach to correction of presbyopia with laser modification of the lens.[6] One year later, they verified this idea using a Q-switched Nd:YAG laser to liquefy the hardened lens nucleus using a nonlinear photodisruption process, known from secondary cataract treatment. In the following years, several groups have also attempted to correct presbyopia using this approach, but up until now, no one has been successful with it.

Ten years later, femtosecond lasers became commercially available for lens surgery. However, the target was not for presbyopia reversal but cataract surgery. Opening the capsular bag (anterior capsulotomy) and cracking the hardened nucleus appeared much easier and, both medically and commercially, more promising.

In 2004, our group began to develop a femtosecond laser that is entirely designed for the purpose of presbyopia reversal.[8,9] In this presentation, an update on the milestones that have been achieved to date and an outlook on where laser presbyopia reversal (LPR) will head will be provided.

Femtosecond Laser System for LPR

The Rowiak Femtosecond Laser for Presbyopia Reversal (Rowiak GmbH; Hannover, Germany) is a low-energy (2.0 µJ to 5.0 µJ per pulse) and high-frequency (100 kHz) infrared laser (1040 nm). The width of each single laser pulse is less than 400 femtoseconds. The laser process is controlled by an integrated OCT imaging system. The laser is able to cut 3-dimensional patterns with a working field diameter of up to 9.0 mm within the crystalline lens. The presbyopia reversal cutting process is characterized by an extremely low gas bubble production due to a low energy threshold.

Milestones Achieved

Animal model

In vivo intralenticular laser surgery was performed on rabbit eyes. There was no onset of lens opacification or cataract formation over the follow-up period of up to 6 months.[10] Cuts remained visible. The width of the cuts within the crystalline lens did not exceed 50 µm.[11] Adjacent tissue was obviously not damaged.

Human donor eyes

Human crystalline lenses of varying age were investigated ex vivo.[12] Pole thickness, elasticity, and refractive changes were measured before and after laser treatment. Different treatment patterns were tried out. Experimental setups used were the Fisher spinning test and a specially designed lens stretcher combined with an optical pathway analyzer. It could be demonstrated ex vivo that the LPR treatment could theoretically lead to an increase in gain in accommodation corresponding to a refractive power of up to 4 D.

Finite element simulation

In order to optimize the treatment pattern, complex finite element simulations of the human crystalline lens and varying treatment patterns were investigated. This process led to a distinctive treatment pattern that should be applied in the first in vivo human eye studies.

Human eye study

Again it was Ron Krueger who first investigated the effect of intralenticular femtosecond laser surgery on accommodation. Kruger and Huy treated more than 80 precataractous eyes with the LensAR femtosecond laser system (LensAR Inc.; USA) in the Philippine Islands. The follow-up post-laser treatment was 1 month, after which all patients underwent cataract surgery. Kruger and Huy reported at the 2012 Academy meeting that one-third of the subjects showed an improvement in objective accommodation and over half of the subjects showed an improvement in subjective accommodation. More than 40% of the subjects showed an increase of best distance-corrected near visual acuity. No increase in cataract opacification was noted.

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

It must be taken into consideration that the LensAR system is optimized for cataract surgery and therefore the laser parameter (pulse-width, -energy, and repetition rate) applied have to be improved with respect to presbyopia treatment.

In the summer of 2013, the first human eye trial for LPR with a specifically designed femtosecond laser (Rowiak GmbH; Hannover, Germany) was performed at the Augenklinik am Neumarkt in Cologne by GG and OK. The protocol, which was approved by a federal ethical committee, allowed for the treatment of 5 precataractous, sighted eyes. Surgery was documented, and within the follow-up period, subjective accommodation, as well as objective accommodation, will be documented. In order to establish a solid proof of the treatment effect a wavefront aberrometer (iTrace, Inc.; USA) was coupled with the cornea module of an OCT device (Heidelberg Instruments; Germany).

Conclusion

Reliable and significant accommodative restoration using laser surgery is theoretically possible. Ex vivo and in vivo experiments as well as initial human eye studies confirm that there can be a significant gain in accommodation without the induction of early lens opacification or cataract enhancement. Clinical studies will be necessary with a specifically designed femtosecond laser technology and optimized treatment patterns striving for the best possible treatment option for presbyopia.

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Interactive Consultations—Lens Refractive Surgery

NOTES

Free Paper Session III

Laser Cataract Surgery: Initial Experience With Novel Patient Interface

Presenting Author: Michael A Lawless MD

Purpose: To describe the experience with the LenSx SoftFit patient interface (PI). **Methods:** The initial 300 cases undergoing surgery between February and May 2013 were included. Preoperative demographics and intraoperative complications such as number of docking attempts, suction breaks, corneal incision assistance, and anterior radial capsule tears were collected. **Results:** 96.8% of cases had free floating capsulotomies. Laser-created incisions were completed in 84.5% of eyes. There were 16 cases of redocking before the ablation. There were no suction breaks. No patient experienced significant complications due to the procedure. **Conclusion:** The new SoftFit PI appears to be more comfortable, and the rate of free capsulotomies is significant. This has contributed to a further reduction in intraoperative complications.

Learning Curve and Safety of Early Experience With Femtosecond Laser-Assisted Cataract Surgery at a Large, Multiuser ASC

Presenting Author: Jonathan H Talamo MD

Purpose: To assess early safety and complication rates with laser-assisted cataract surgery (LCS) at a large multiuser ASC. **Methods:** Initial 363 cases performed by 19 surgeons with a femtosecond laser (Catalys; Sunnyvale, CA) were analyzed for safety and complications. Capsulotomy, fragmentation, arcuate incisions, and/or cataract incisions were performed. **Results:** The procedure was safe, with a low complication rate. Two complications were observed in the first 363 cases. The liquid optics interface enabled gentle docking, with no loss of vision. The learning curve was short, with 10 cases being sufficient for certification. **Conclusion:** Laser-assisted cataract surgery with a liquid interface is a safe procedure with a short learning curve.

Analysis of 215 Capsulotomies Created With Femtosecond Laser and a Novel Patient Interface in Cataract Surgery

Presenting Author: John P Berdahl MD
Coauthors: Stephen G Slade MD FACS, Michael C Knorz MD

Purpose: To evaluate the performance of a novel patient interface (Alcon LenSx SoftFit) in laser capsulotomy procedures using Alcon LenSx Laser. **Methods:** 215 consecutive eyes underwent LenSx Laser cataract surgery using SoftFit patient interface. Usability, corneal compression / wrinkles, completeness, and edge quality of capsule were evaluated. **Results:** Ninety-eight percent of eyes showed no corneal wrinkles, and 100% had complete capsulotomy. Also observed was 66% laser energy reduction while using SoftFit. Improved spot/layer separation allowed 33% reduction of procedure time. **Conclusion:** The SoftFit improves usability and performance of the laser system. It has provided the precision of laser targeting that resulted in 100% capsulotomy success rate. There is no on-the-eye assembly or fluid required for the interface.

Postoperative Year 1 Results of a Prospective, Randomized Study Comparing 1 Accommodating and 2 Multifocal IOLs

Presenting Author: Robert Edward T Ang MD

Purpose: To compare long-term visual outcomes among patients implanted bilaterally with 1 of 3 types of presbyopia-correcting IOLs during cataract surgery. **Methods:** Prospective, randomized study in 71 patients followed for 1 year after bilateral implantation of Crystalens AO accommodative IOL, ReSTOR +3 multifocal IOL, or Tecnis Multifocal IOL during routine phacoemulsification. **Results:** At postoperative Year 1, binocular mean visual acuities (VA) in the Crystalens, ReSTOR, and Tecnis groups, respectively, were uncorrected distance VA (UDVA): 20/20, 20/20, 20/21, uncorrected intermediate VA (UIVA): 20/20, 20/24, 20/26, uncorrected near VA (UNVA): 20/25, 20/20, 20/23, distance corrected intermediate VA (DCIVA): 20/20, 20/24, 20/25, and distance corrected near VA (DCNVA): 20/26, 20/19, 20/21. **Conclusion:** UDVA was similar with each lens. UIVA and DCIVA were better with the accommodating lens. UNVA and DCNVA were better with the multifocals.

Comparative Visual Outcomes After Implantation of 2 Trifocal IOLs and a Bifocal IOL

Presenting Author: Jorge L Alio MD PhD
Coauthors: Ana Belen Plaza, Raul Montalban MSC, Peter Mojzis PhD**, Alfredo Vega-Estrada MD

Purpose: To compare the visual outcomes with 2 trifocal IOLs and a bifocal IOL. **Methods:** 133 eyes were divided in 3 groups: Group A, 35 eyes with the Lentis Mplus LS-313 IOL; Group B, 38 eyes with the FineVision; and Group C, 60 eyes with the AT LISA tri839MP IOL. **Results:** Uncorrected intermediate visual acuity was better in Group C ($P < .01$). Scotopic contrast sensitivity was higher in Group C ($P < .01$) for all spatial frequencies. In the defocus curve significantly better visual acuities were found in Group C for defocus levels of -1.5, -1,0, and 0,0 D ($P < .01$) and significantly better for Group A for defocus level of -2.5 D ($P < .01$). **Conclusions:** The AT LISA tri839MP IOL provided the most complete visual rehabilitation after cataract surgery.

NEI RQL-42 and SVI Quality-of-Life Measures After Bilateral Implantation of 3 Presbyopia-Correcting IOLs at 6 Months Follow-up

Presenting Author: Richard C Chu DO
Coauthors: Mujtaba A Qazi MD, Jay Stuart Pepose MD PhD

Purpose: To compare quality-of-life surveys following implantation of presbyopia-correcting IOLs. **Methods:** Following randomized, masked, bilateral implantation of Crystalens AO ($n = 26$), ReSTOR +3 ($n = 24$), or Tecnis Multifocal ($n = 22$), the National Eye Institute Refractive Error Quality of Life Instrument (NEI RQL-42) and the Subjective Visual Index Questionnaire (SVI) were administered at 1 and 6 months. **Results:** There were no statistically significant differences for the distance subscale ($P > .28$). Multifocal IOLs had the best spectacle independence at 1 month ($P < .01$) but showed no statistical significance by 3 months ($P > .4$). The Crystalens AO had the lowest glare responses ($P < .01$), with Tecnis MF and ReSTOR 3.0 mean scores > 2x. **Conclusions:** Subjective visual experiences corroborated visual acuity and optical scatter outcomes. Patient subjective responses to these instruments highlight each IOL's inherent strengths and weaknesses.

A New Method for Calculating IOL Power and Improving Refractive Accuracy in Long or Short Eyes

Presenting Author: Eric D Donnenfeld MD

Purpose: To determine efficacy of a new method of calculating IOL power in long and short eyes using intraoperative aberrometry. **Methods:** Mean absolute value of the prediction error (MAVPE) was calculated for 119 short and 189 long eyes implanted with the SN60WF IOL and compared to MAVPE for 33 short and 97 long eyes after optimization of the power calculation model. **Results:** Prior to the change, MAVPE was 0.47 D ± 0.36 D in short and 0.40 D ± 0.32 in long eyes, with 84% and 93%, respectively, within 0.75 D of the predicted postop refraction. With the new model, MAVPE was 0.41 D ± 0.21 D in short and 0.36 D ± 0.31 in long eyes, with 94% and 95% within 0.75 D. **Conclusion:** A refined power calculation model improves refractive outcomes in eyes with unusual axial lengths implanted with the SN60WF.

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

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

Purpose: To describe a nomogram for femtosecond laser intrastromal astigmatic keratotomy during femtosecond laser-assisted cataract surgery. **Methods:** Fifty-two eyes with corneal astigmatism had femtosecond laser cataract surgery with concurrent paired femtosecond laser intrastromal astigmatic keratotomy (FSAK), created at between 20% and 80% corneal depth and from 30% to 80% depth, at 8.0-mm optical zone. Using pre- and postoperative topography and refractive data at 1 and 6 months, a nomogram was created using regression analysis. **Results:** Mean vector magnitude using nomogram v1 was 60% of intended, increased to 82% of intended with v2, with significant change between 1 to 6 months. It takes into account cylinder magnitude, age, and angle of cylinder. **Conclusion:** A nomogram has been created to enhance accuracy of FSAK during laser cataract surgery.

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

The Patient View: Measurements vs. Patient-Reported Outcomes

Mats H Lundstrom MD

Quality outcomes of cataract and refractive surgery include both clinical outcomes and patient-reported outcomes.

Within ophthalmology we have a long tradition for measuring clinical outcomes after a surgical intervention. For refractive and cataract surgery these measures concern visual outcomes, refractive outcomes, and the occurrence of complications. The visual outcome can include glare measurements and contrast sensitivity. In clinical practice surgeons are usually satisfied with a good visual and refractive outcome and as few complications as possible.

Measuring the patient-reported outcomes in ophthalmology has a shorter history and started more broadly in the 1990s. The early patient questionnaires had a simple construction with a number of items and response options that generated ordinal data to a summary score. More recently, questionnaires have been constructed by item-response theory, especially so-called Rasch analysis.[1] These modern questionnaires give interval-scored results and as measures are as valid as clinical data. This development has opened the way for more solid patient-reported outcomes and the possibility to better compare the clinical outcomes with the patient-reported outcomes.

The medical literature has a tendency to report only positive results. There exist many reports about different surgical techniques and use of IOLs with both a good clinical and a good patient-reported result. Examples of such reports concern phakic IOLs,[2] bilateral implantation of multifocal IOLs,[3] and toric IOLs.[4] However, there is also a lack of reports for frequent procedures. A search on PubMed for "refractive lens exchange" AND "patient-reported outcomes" gives: No items found; and the same goes for searching on "clear lens extraction" AND "patient-reported outcomes."

It is well known that an uneventful phacoemulsification with implantation of an IOL may result in patient complaints even with perfect vision because of negative or positive dysphotopsia.[5] Many reports confirm and discuss this phenomenon.[6,7] It has also been stated that in a normal cohort of pseudophakic patients, dysphotopsia is the most frequent reason for patient dissatisfaction although the visual outcome is good.[8]

The correlation between clinical outcomes and patient-reported outcomes can, of course, be studied in small cohorts when a new surgical technique is tested. However, a more structured approach can be used on population studies. Examples of different approaches have recently been published.[9] Common reasons for both poor clinical and patient-reported outcomes are poor indications for surgery, ocular comorbidity, complications, and refractive surprises. The most interesting study, however, concerns when the clinical outcomes and the patient-reported outcomes disagree.

The purpose of the present study is to explore when clinical outcomes and patient-reported outcomes disagree; more specifically, when clinical outcome is good and patient-reported outcome is poor.

The study material consists of follow-up data on cataract extractions collected by the Swedish National Cataract Register in 2008-2012. Patient-reported outcome was measured using the Catquest-9SF—a Rasch analyzed questionnaire. A total of 14,928 pairs of questionnaires completed before and after a cataract extraction were analyzed together with clinical data. The number of participating clinics was 42. The analyses were performed for the total number of patients and for each clinic.

In the total material, 7341 patients achieved a best corrected distance vision of 20/20 or better after surgery. Among these patients 6854 reported improved self-assessed outcomes (= benefit), while 487 (6.6%) had more problems in performing daily life activities after surgery than they had before (= no benefit). When these 487 patients were compared with the self-assessed improved group we could see no difference in gender, surgical or postoperative complications, or ocular comorbidities. The no-benefit group was slightly older on average (73.4 years vs. 72.2). When the 9 items in the Catquest-9SF were analyzed separately one by one, the no-benefit group of patients had more problems with near vision activities after surgery than they had before surgery. Distance vision activities were almost unchanged and on a high level. For the benefit group of patients, both near and distance items improved after surgery.

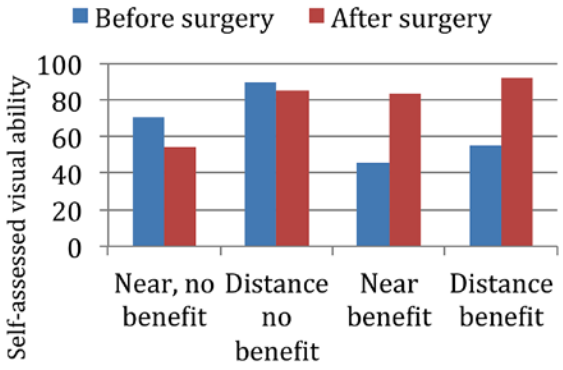

Figure 1. Patient-reported outcome for near and distance activities in daily life before (shaded) and after (unshaded) a cataract extraction. Maximum ability to perform activities = 100.

The outcomes of the 42 clinics were analyzed separately. The group of patients with visual outcome of 20/20 and no benefit varied from 0% to 15.6%. The tendency for this group was the same for all clinics: good self-assessed near vision before surgery but poor after surgery while the self-assessed distance vision was relatively good before surgery and unchanged after surgery.

Conclusion: Poor self-assessed near vision is a frequent finding when clinical and patient-reported outcomes disagree.

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Can We Optimize Monovision Using Adaptive Optics?

Binocular Summation and Adaptive Optics Modeling of Presbyopic Corrections

*Scott M MacRae MD, Len Zheleznyak MS, Geun Young Yoon PhD***

Binocular Summation: *"Two eyes are better than one."*

To understand how to optimize monovision, it's helpful to understand two simple concepts:

1. Binocular Summation
2. Binocular Inhibition

Let's review binocular summation first.

Binocular Summation

When comparing monocular with binocular visual performance, one of the most important factors to consider is binocular summation, which simply means that two eyes are better than one. The study by Campbell and Green in 1965 first demonstrated this by measuring both monocular and binocular contrast sensitivity functions. They found that binocular contrast sensitivity function (CSF) was better than monocular CSF and the ratio was about the square root of 2, or sqrt(2). In other words, binocular CSF is 40% better than monocular CSF. This is called "binocular summation." Later, the quadratic summation model was proposed to explain binocular summation. Using this model, we can easily come up with a factor of sqrt(2) improvement with two eyes if visual performance of the two eyes is similar.

What if the two eyes have significantly different optical quality, such as in monovision correction? Does this sqrt(2) remain true?

Of course, there was a vision scientist addressing this question in 1990. The answer is, it depends on the magnitude of the optical difference. What they did is they measured binocular summation factor as a function of the magnitude of anisometropia in diopters, just like monovision correction. So, the summation ratio of 1 indicates binocular suppression, where binocular performance is same as monocular performance, the ratio larger than 1 indicates binocular summation, and smaller than 1 means there was binocular inhibition, or the visual performance was less with both eyes than with one eye.

Binocular Inhibition

Vision scientists found that binocular summation decreases with an increase in the amount of anisometropia. What's more interesting is that when there is 1.5 D anisometropia, binocular visual performance becomes worse than monocular performance. This is called "binocular inhibition"—that is, "Two eyes are worse than one."

What Adaptive Optics Can Model for Us to Optimize Monovision

We developed one of two binocular adaptive optics systems in the world. The binocular adaptive optics system employs a *wavefront sensor* to detect the aberrations in each eye and then a *deformable mirror* for each eye, which can correct out each eye's aberrations and then add in whatever aberration pattern we wish to simulate. By doing this, we can then evaluate visual performance, including visual acuity and contrast sensitivity for each eye and binocularly, in addition to stereoacuity, under a variety of conditions.

We first looked at binocular summation with classic monovision and found that the tipping point where binocular summation drops off is at 1.5 D, which is consistent with the literature. We then looked at adding varying amounts of *positive and negative spherical aberration* and a variety of strategies to improve binocular visual performance for both distance and near, with patients being tested in the binocular adaptive optics system.

We found that one could add a modest amount of spherical aberration to the near eye, and this resulted in improved depth of focus for both near and distance. We call this approach "Modified Monovision." Some contrast was lost at the 1.5 D near range, where the image peaks with classic monovision. Modified Monovision is a tradeoff in that there is some minimal contrast loss at the peak of monovision focal distance (1.5 D), but there is better binocular summation and the depth of focus is better, resulting in improved intermediate vision as well as better vision at focal points nearer than the 1.5 D peak of traditional monovision.

One might think of this as like marked anisometropia, where the brain has a difficult time interpreting and fusing two different but similar images simultaneously. The brain is a remarkable organ, but it does have limitations in accurately interpreting and integrating similar but disparate images when larger amounts of monovision are present.

One can use both negative and positive spherical aberration to improve depth of focus.

How can we apply this to our clinical practices?

- One can increase spherical aberration in the near and distance eye by using a spherical rather than aspheric IOL. Because the older cornea normally has modest positive spherical aberration, it is actually better to just put in a spherical lens in the nondominant eye. This actually creates a modest amount of spherical aberration that improves depth of focus and intermediate vision in both eyes. Interestingly, our work also found that some spherical aberration in both eyes brings the two images closer together so the brain can optimize them more with binocular summation. Thus a bit of spherical aberration even in the dominant distance eye improves binocular summation more than having no spherical aberration.
  (Another approach is to use a Crystalens HD—which has a small central 1 D add—in the nondominant near eye and leave that eye 0.75 D myopic. The small central add acts like spherical aberration.)

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- Monovision targets: Target -1.25 to -1.50 D of monovision to optimize both distance and near vision without compromising distance vision. Most people have a strong preference for strong distance vision, so one can maintain distance vision by preserving binocular summation or at least not introducing binocular inhibition (distance contrast vision loss) by going beyond 1.5 D of anisometropia or "interocular difference." Interocular difference is the difference in refractive error between the two eyes.
- Optimize distance vision image quality with correction of astigmatism, coma, and nonspherical aberration higher-order aberration in both eyes. This improves image quality and optimizes binocular summation.
- Ocular Dominance
  - We also looked at the role of ocular dominance and found that high-contrast visual acuity is not affected by eye dominance but contrast sensitivity is. In other words, both eyes may be able to read the 20/20 line, but the dominant eye performs better with contrast sensitivity.
  - Preliminary studies on our adaptive optics system noted binocular contrast sensitivity was improved when the superior optical quality is in the dominant eye. In other words, the dominant eye is like the MVP of the visual system. When it has the best optics, the binocular contrast sensitivity is improved compared to when the nondominant eye has the best optics. Thus, this explains why we should use the dominant eye for distance and the nondominant eye for near if distance vision is more critical for most people.
- Stereo acuity decreases with greater interocular differences in refractive error, especially when the interocular difference is greater than 1.5 D.

We will discuss other interesting findings we've noted using these techniques.

Evidence in Presbyopia Correction: Monovision or Multifocal IOL

Oliver Findl MD

Multifocal IOLs are known to improve unaided near acuity and reduce overall spectacle dependence. Despite these benefits, multifocal IOLs are not routinely used in all patients because of their higher cost, concerns about postoperative dysphotopsia, and reduced efficacy in patients with postoperative refractive error or preoperative ocular comorbidity.

Monovision, implanting monofocal IOLs targeting emmetropia in one eye and myopia in the other, is a highly accessible alternative strategy for improving unaided near vision after cataract surgery in which there are no additional costs. Monovision is widely used for the presbyopic age group in laser refractive surgery and contact lens fitting. There remains surprisingly little evidence about the outcomes of this technique in pseudophakes. Most reports have been descriptive studies showing high acceptance rates. Very little is known about spectacle independence in pseudophakic monovision. The rate varies from 27% independence with mini-monovision of about 1.25 D monovision, up to 81% with more pronounced monovision of 2.25 D.

In a randomized clinical trial performed at Moorfields Eye Hospital in London, we compared the visual outcomes of patients randomized to receive either bilateral multifocal IOLs or monofocal IOLs targeting monovision with emmetropia in one eye and -1.25 D myopia in the other. The study was performed by the Moorfields IOL Study Group with Mark Wilkins as the principal investigator.

Altogether, 212 patients with bilateral visually significant cataract were randomized (allocation ratio 1:1) to receive either bilateral Tecnis ZM900 diffractive multifocal lenses or Akreos AO monofocal lenses with the powers adjusted to target -1.25 D monovision. Outcomes were assessed 4 months after the second eye was operated on.

The primary outcome was spectacle independence. Secondary outcomes included questionnaires (VF-11R dysphotopsia symptoms and satisfaction) and visual function measures (near, intermediate, and distance visual acuities, stereoacuity, contrast sensitivity, and forward light scatter).

Of the 212 patients recruited, 187 patients (88%) returned for assessment 4 months after surgery. Uniocular distance refractions in the monovision arm showed a mean spherical equivalent of +0.075 D in the distance eye and -0.923 in the near eye. In the multifocal arm, the mean distance spherical equivalents were -0.279 D and -0.174 D in the right and left eyes, respectively. 24/93 monovision patients (25.8%) and 67/94 multifocal patients (71.3%) reported never wearing glasses ($P < .001$; Fisher exact test). The adjusted odds ratio of being spectacle free was 7.51 (3.89, 14.47). Bilateral uncorrected acuities did not differ significantly for distance (0.058 logMAR for monovision vs. 0.76 for multifocal, $P = .3774$) but were significantly worse in the multifocal arm for intermediate (0.221 vs. 0.149, $P = .0001$) and in the monovision arm for near (0.013 vs. -0.025, $P = .037$).

We found little evidence of any differences between IOL groups in contrast sensitivity, forward light scatter, and most of the subjective responses, except for glare. Multifocal patients reported glare more frequently (82% vs. 57%, $P < .001$) and were more likely to state that it was “annoying” or “debilitating” (43% vs. 18%, $P = .0003$) than monovision patients.

Patients randomized to bilateral implantation with the diffractive multifocal IOL were much more likely to report being spectacle independent, but also to report being troubled by glare than those randomized to receive monofocal implants with the powers adjusted to give low monovision.

To our knowledge this is the only sufficiently powered trial comparing multifocal IOL to monovision.

Is There Anything Good About Astigmatism?

Julian D Stevens DO

Introduction

The term "astigmatism" is the joining of "a" and "stigmata," a term suggested by Dr. William Whewell (1794-1866), who was Master of Trinity College Cambridge. Previously Sir Isaac Newton described astigmatism in his series of *Lectiones Opticae* between 1670 and 1672. During this time he noted that oblique incident rays through a refracting surface generated 2 principal centers of radiation, or foci. He also noted there is a circle of least confusion at the midpoint between the 2 foci, so describing some of the optics of classical astigmatism.

In an astigmatic eye the circle of least confusion is in a plane midway between the foci of the 2 primary meridia. The light ray bundles form ovals or ellipses. If the circle of least confusion is in the plane of the outer limiting membrane of the retina, both principal meridia are equally defocused, which is the best acuity in the uncorrected eye.

Can any astigmatism be good?

Astigmatism and Blur

The presence of astigmatism causes some blur or an increase in the point spread function, and so degrades acuity. The greater the cylinder, the more the blur. There are neurological effects, and subjective blurring depends upon not only the magnitude of astigmatism but also the meridian.

A simple table of acuity with residual astigmatism present is presented in Table 1.

Table 1.

		Uncorrected Cylinder (Dc)
6/6	20/20	≤ 0.25
6/9	20/30	1.00
6/12	20/40	1.50
6/18	20/60	2.00
6/24	20/80	3.00
6/36	20/120	4.00
6/60	20/200	≥ 5.00

The blur of regular astigmatism is approximately half that of the equivalent sphere, so a 1 D sphere is equivalent in blur to about 2 dc astigmatism.

Manifest Refraction

It is well recognized that objective measures of astigmatism and subjective manifest cylinder correction commonly differ. Those who have with-the-rule astigmatism commonly prefer some residual cylinder by manifest refraction, whereas those who have against-the-rule astigmatism commonly prefer an overcorrection. There can be a subjective preference to retain some small astigmatism of 0.25 to 0.50 D. Some residual with-the-rule astigmatism appears to be comfortable and the preferred state for many people.

Why? What is it that people have a preference to retain some low astigmatism?

Depth of Focus

Since with astigmatism Sturm's conoid may have an elliptical cross section, some astigmatism may be helpful to increase depth of focus by reducing defocus blur for a given defocus. To assess this effect Nanavaty et al[1] analyzed eyes with good unaided distance and near acuity after monofocal IOL implantation. Specifically eyes with ≥ 6/12 (20/40) and ≥ J4 for near and found there to be a significant role of against-the-rule corneal astigmatism in good uncorrected distance and near vision after monofocal IOL implantation.

However Naeser and Hjortdal[2] also analyzed eyes with good unaided distance and near acuity after monofocal IOL implantation and found that in monofocal pseudophakia, the best possible acuity over the most extended fixation ranges is achieved with slight myopic sphere without astigmatism present.

The tolerance of astigmatic blur was assessed by adaptive optics by Atchison et al[3] where blur due to defocus, crossed-cylinder astigmatism, and trefoil became noticeable, troublesome or objectionable. Blur was induced with a deformable, adaptive-optics mirror. Crossed-cylinder astigmatic blur limits had considerable meridional influences.

Accommodation

During accommodation there is miosis of the pupil, reducing aberrations, but there is a change in shape of the crystalline lens. A change in ocular spherical aberration takes place, moving from positive to negative. Also there is a change in the astigmatism present. Astigmatism together with spherical aberration appears to be part of the accommodative optical response.

There may be "no astigmatism," where there is a relaxed distance focus, but there may be induced astigmatism when accommodating, so no eye may be truly astigmatism free.

Other Effects of Astigmatism

Astigmatism together with high-order aberrations may help with the accommodative response and also may have some role in ocular growth and regulation. Currently these effects are poorly understood.

Summary

Astigmatism is present in all eyes, even if not in the relaxed unaccommodated state. Minor amounts appear to degrade subjective optical quality very little, and some low astigmatism can be preferred by many people.

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Evidence in Astigmatism Correction: Monofocal or Toric IOLs or Incisions

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Introduction

In modern cataract surgery, spectacle freedom is becoming increasingly important. Emmetropia can be achieved for patients with myopic or hyperopic refractive errors by selecting the appropriate spherical lens power. However, approximately 20% to 30% of patients who undergo cataract surgery have corneal astigmatism of 1.25 D or more, and approximately 10% of patients have 2.00 D or more of corneal astigmatism.[1,2] Not correcting the astigmatism component at the time of cataract surgery will result in failure to achieve spectacle independency in the majority of cases.

Currently several toric IOL models are available. However, so far only one randomized clinical trial (RCT) has been performed comparing toric with monofocal IOL implantation in patients with cataract and corneal astigmatism.[3] Patients in this study underwent unilateral cataract surgery with toric or monofocal IOL implantation. Since spectacle use for distance vision depends on the refractive status of both eyes, this approach does not allow the evaluation of spectacle independence for distance vision.

In a RCT we enrolled 86 patients: 41 received bilateral toric IOLs and 45 received bilateral monofocal IOLs.

Visual Acuity, Refractive Astigmatism, and Spectacle Independence

Postoperatively, the uncorrected distance visual acuity (UDVA) was significantly better in the toric group than in the monofocal group: 0.06 ± 0.14 logMAR vs. 0.21 ± 0.16 logMAR, respectively ($P < .001$). The best corrected distance visual acuity (BDVA) was comparable in both groups: 0.00 ± 0.11 logMAR vs. -0.01 ± 0.09 logMAR, respectively ($P > .05$). As shown in Figure 1, 70% of patients in the toric group achieved UDVA of 20/25 or better, compared to 30% of patients in the monofocal group ($P < .001$). A BDVA of 20/25 or better was achieved in 89% and 91% of patients in the toric and monofocal group, respectively ($P > .05$). The postoperative uncorrected near visual acuity (UNVA) in the toric and monofocal groups was 0.47 ± 0.17 logMAR and 0.43 ± 0.18 logMAR, respectively ($P > .05$).

Figure 2 demonstrates the results of a subgroup analysis of the UDVA results in patients with a relatively low amount of corneal astigmatism. In eyes with 1.25 to 1.50 D of corneal astigmatism, UDVA of 20/20 or better was achieved in significantly more patients with toric IOLs than with monofocal IOLs. In patients with 1.50 to 2.00 D or 2.00 to 2.50 D of corneal astigmatism, UDVA of 20/25 or better was achieved in significantly more patients with toric IOLs than with monofocal IOLs.

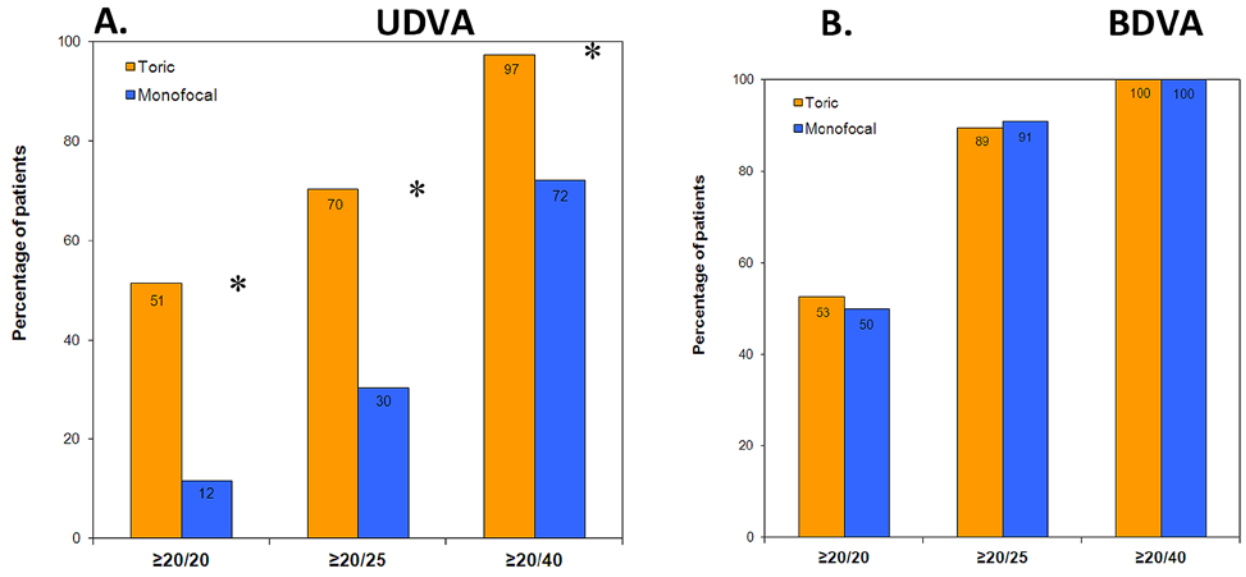

Figure 1. Cumulative binocular uncorrected (A) and best corrected (B) distance visual acuities in the toric and monofocal groups at 6 months postoperatively. Asterisk indicates $P < .05$.

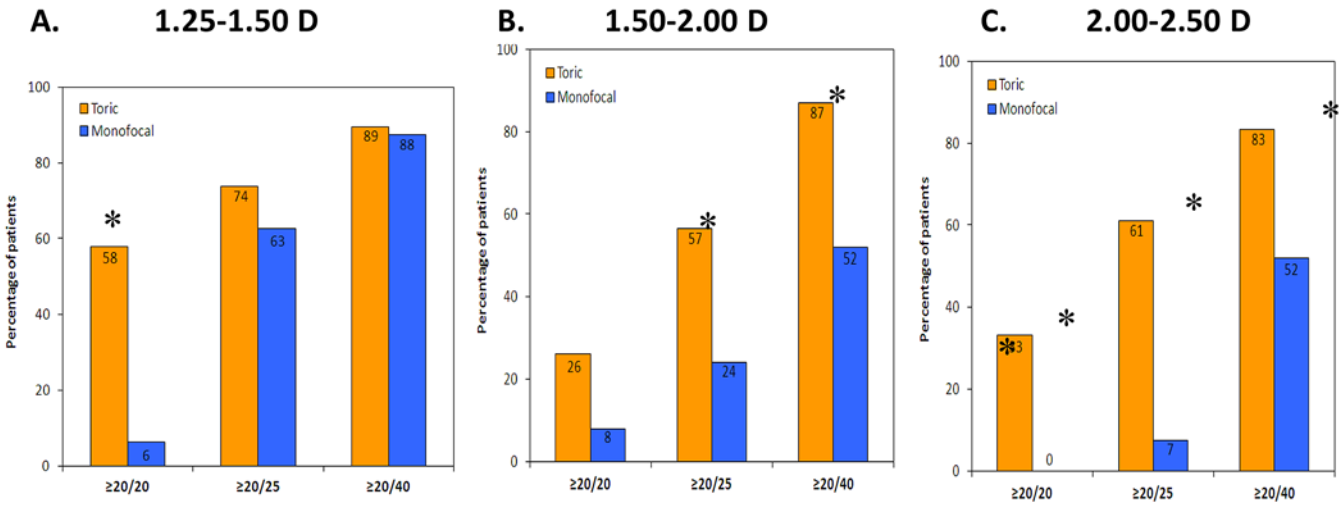

Figure 2. Subgroup analysis of the cumulative UDVA in eyes with 1.25-1.50 D (A), 1.50-2.00 D (B), or 2.00-2.50 D (C) of corneal astigmatism. Asterisk indicates $P < .05$.

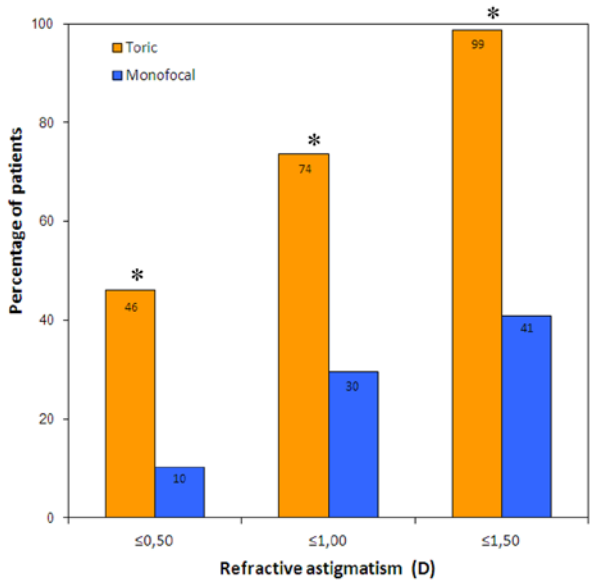

Figure 3. Cumulative residual refractive astigmatism in the toric and monofocal groups at 6 months postoperatively. Asterisk indicates $P < .05$.

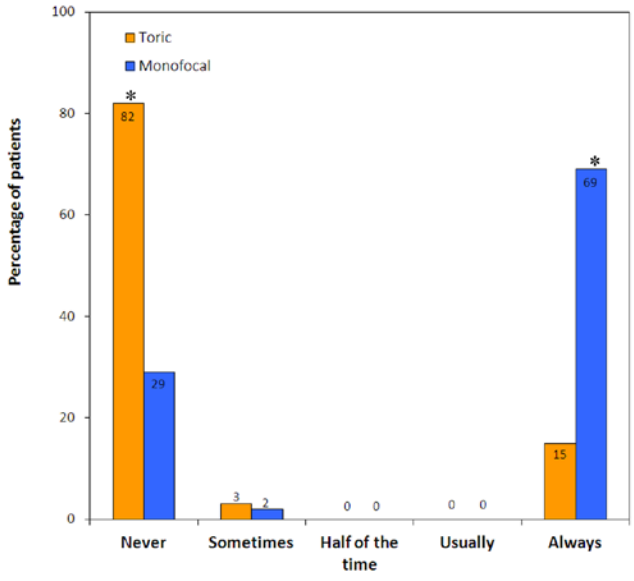

Figure 4. Spectacle use for distance vision in patients implanted with bilateral toric or bilateral monofocal IOLs. Asterisk indicates $P < .05$.

Preoperatively, the mean magnitude of refractive astigmatism was 2.02 ± 0.95 D in the toric group and 2.00 ± 0.84 D in the monofocal group ($P > .05$) and postoperatively -0.77 ± 0.52 D in the toric group and -1.89 D ± 1.00 D in the monofocal group ($P < .001$). As shown in Figure 3, 74% of patients in the toric group showed a refractive astigmatism of 1.00 D or less, compared to 30% of patients in the monofocal group ($P < .001$). A refractive astigmatism of 0.50 D or less was achieved in 46% and 10% of patients in the toric and monofocal group, respectively ($P < .001$).

Figure 4 demonstrates spectacle use for distance vision in both groups. Significantly more patients with toric IOLs reported never using spectacles for distance vision, compared to patients with monofocal IOLs: 82% vs. 29% ($P < .001$). Sixty-nine percent of patients in the monofocal group reported always using spectacles for distance vision, compared to 15% of patients in the toric group ($P < .001$).

Complications: Misalignment

Crucial to the efficacy of toric IOLs is the position of the IOL with regard to the intended alignment axis, since the amount of misalignment contributes to residual astigmatism. Misalignment may be caused by two factors: inaccurate alignment of the toric IOL during surgery or postoperative rotation following surgery. Rotational stability used to be an issue in toric IOLs made from silicone material.[4-6] However, for acrylic toric IOLs, the postoperative rotation has been shown to be less than 1 degree.[7] The accuracy of toric IOL alignment during surgery has been reported to result in a mean error of approximately 5 degrees.[8] In the current RCT, mean toric IOL misalignment at 6 months postoperatively was 3.6 ± 3.2 degrees. A misalignment of more than 10 degrees occurred in 4 eyes (11, 11, 13, and 17 degrees). In one of these eyes an IOL repositioning was performed due to a misalignment of 17 degrees. After IOL repositioning, the UDVA improved from 20/40 to 20/20 Snellen. Other patients were satisfied with their visual outcome and did not wish to undergo IOL repositioning.

Conclusions

In our study we compared the efficacy of bilateral toric IOL and bilateral monofocal IOL implantation in patients with cataract and corneal astigmatism and found a significantly better UDVA and a lower residual refractive astigmatism. As expected, intraoperative and postoperative complications were comparable in both groups. Spectacle independence for distance vision was achieved in approximately 80% of patients with toric IOLs, compared to approximately 30% of patients with monofocal IOLs. This indicates that toric IOLs are an effective treatment in patients with cataract and corneal astigmatism. Currently, no RCTs are available that compare the effect of corneal incisions vs. toric IOLs for reducing corneal astigmatism.

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What Is the Best Procedure for the Ametropic Pseudophakic Patient?

Roberto Bellucci MD

Introduction

Pseudophakic eyes may require refractive correction for a variety of reasons, the most common of which is a refractive surprise or inaccuracy that may occur after cataract surgery in normal eyes and especially in highly ametropic eyes.[1,2] Eyes already operated with refractive corneal surgery before cataract surgery are also at risk for pseudophakic ametropia, unfortunately taking place in patients who do not accept any type of spectacle correction.[3,4] Patients operated for refractive lens surgery, particularly if implanted with a multifocal or accommodative IOL, also do not accept any degree of pseudophakic ametropia limiting UCVA.[5,6] In addition, a percentage of emmetropic patients implanted with a monofocal IOL may ask for presbyopia correction after hearing about multifocal IOLs.[7] Finally, pseudophakic eyes with high corneal astigmatism may require refractive surgery, eg, after penetrating or lamellar keratoplasty.

Criteria for the Selection of the Procedure

The most common procedures available are excimer laser corneal surgery and add-on IOLs. IOL exchange should be limited to the recent implantation of wrong power IOLs, as with time the difficulties of surgery and the risk for cystoid macular edema increase significantly.[8] Limbal corneal incisions are limited to very special cases. Arcuate incisions may help especially in post-keratoplasty eyes and are frequently followed by LASIK. Corneal remodeling by conductive keratoplasty or by accelerated cross-linking has not yet proved to offer stable results.[9,10] Femtolaser modification of the IOL power is currently under investigation.

In pseudophakic eyes, the refractive procedure must be individually selected according to preoperative evaluations that consider both the conditions of the eye and the patient's needs and expectations. Before surgery we need a thorough evaluation of the case. Scheimpflug or OCT corneal analysis should be available, and an evaluation of corneal elasticity should be performed in eyes with previous corneal refractive surgery. The corneal endothelium should be evaluated as well. A very important point: the reason for the pseudophakic refractive error should be clarified, and the need for additional surgery confirmed. A secondary procedure is frequently perceived by the patient as the remedy of a failure, and the previous surgeon is considered responsible for the bad result. Therefore, the patient's expectations are fundamental in the selection of the procedure: the patient should be properly informed about all the possible options, complications, and the expected outcome. A specific consent form should be signed.

Corneal Procedures

Corneal procedures are usually safer than intraocular procedures, as the involved infection risk is lower, and there is no risk of damaging the corneal endothelium. However, they are only carried out if the corneal biomechanics are expected not to worsen with surgery. The obtained refractive precision is also better with corneal surgery; therefore, it should be preferred in highly demanding patients. However, the achieved optical quality may be lower than with add-on IOLs, and these should be suggested when retinal sensitivity is impaired as in many highly myopic eyes. Corneal surgery is favored in eyes with multifocal or accommodative IOLs because of the refractive precision that can be achieved, although patient dissatisfaction may persist after LASIK. In addition, substantial reduction in modulation transfer function has been measured after surgery.[11] Corneal surgery is not reversible and should be selected with caution, especially in young patients with a long life span.

We prefer LASIK in pseudophakic eyes because of the re-epithelialization problems that many ageing patients may develop after PRK, and because of the lower pain. In addition, thin-flap LASIK may offer monofocal pseudophakic eyes a unique opportunity to also improve near vision. Different approaches to presbyLASIK are available in Europe that may challenge multifocal IOL implantation in the near future.

Intraocular Procedures

Despite the increased infection risk as compared with corneal surgery, and despite being a more demanding surgical procedure, intraocular surgery has several advantages. It is reversible and already known to the patient, and for these reasons better accepted by dissatisfied or anxious patients. It can be applied regardless of the corneal biomechanics, although it is potentially harmful for the corneal endothelium. It does not require expensive equipment. By implanting an add-on IOL we can virtually correct for any degree of pseudophakic refractive defect, either spherical and astigmatic.[12-15] Custom-made add-on IOLs can improve the results up to those of corneal surgery, and multifocal add-on IOLs can also correct for presbyopia. A variety of IOLs have been used for sulcus implantation in pseudophakic eyes, including IOLs specifically designed as add-on, posterior chamber phakic IOLs, and IOLs designed for sulcus implantation. The main criteria for an add-on IOL to be successful are (1) sulcus implantation, so not to touch or displace posteriorly the optics of the first IOL, (2) compatible material, to avoid any opacification in case of optics touch, and (3) large optics, to reduce any risk for dysphotopsia. Published results with add-on IOLs are encouraging;[12-15] however, sulcus ovalization may limit success of toric add-on IOLs in astigmatic pseudophakic eyes because of possible rotation eventually requiring suture.[16]

A very special intraocular procedure is IOL relocation outside the original capsular bag position. If the spherical refractive error is a very low hyperopia, sometimes the IOL can be extracted from the capsular bag and relocated in the ciliary sulcus to obtain about 0.5 D of myopization,[17] a procedure that can be performed only with selected IOLs, and only up to 4-6 weeks after surgery.

Conclusion

There is no best procedure for refractive correction of pseudophakic eyes. As a rule, excimer laser corneal surgery is preferred when precision is the main objective, while add-on IOLs are

especially useful with large errors or when complex equipment is not available. Both procedures can be used to gain multifocality; however, only add-on IOLs can offer the advantage of reversibility.

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Free Paper Session IV

Comparison of Laser-Assisted Phototherapeutic Keratectomy Removal of Epithelium to Manual Debridement in Corneal Crosslinking for Progressive Keratoconus

Presenting Author: Ronald N Gaster MD FACS
Coauthors: Ana Laura Caiado Canedo MD, Yaron S Rabinowitz MD

Purpose: To determine whether epithelial removal with phototherapeutic keratectomy (PTK) yields better outcomes than manual debridement in corneal crosslinking (CXL) of patients with progressive keratoconus (KC). **Methods:** We analyzed uncorrected visual acuity (UCVA), best spectacle-corrected visual acuity (BSCVA), and central K values at 6 months in 67 patients (77 eyes) with progressive KC who had undergone CXL. Sixteen patients (17 eyes) had epithelial removal by PTK, and 51 patients (60 eyes) underwent manual debridement. Statistical significance: $P < .05$. **Results:** The mean number of lines of improvement in the PTK and manual groups were UCVA 1.53 ± 0.49 and 1.28 ± 0.40 lines, respectively, and BSCVA 0.24 ± 0.16 and 0.57 ± 0.14 lines ($P > .05$). The central K values decreased by a mean of 1.35 ± 3.1 and 0.41 ± 3.5, respectively ($P < .05$). **Conclusion:** Laser PTK removal of epithelium appears to give better results than manual debridement in CXL for progressive KC.

Aztec Protocol: Small-Incision Lenticule Extraction and Intrastromal Crosslinking in Forme Fruste Keratoconus

Presenting Author: Enrique O Graue Hernandez MD
Coauthors: Arturo J Ramirez-Miranda MD, Gabriela Lucia Pagano MD, Karla P Lopez Dorantes MD, Julio Hernandez Camarena MD, Patricia Chirinos-Saldaña**, Alejandro Navas MD

Purpose: To report visual and refractive outcomes. **Methods:** Prospective single center study. Inclusion criteria: forme fruste keratoconus (FFKC), corrected distance visual acuity (CDVA) ≥ 20/40, age ≥ 21 years, and pachymetry > 400 mm before intrastromal crosslinking (CXL). Patients were treated with small-incision lenticule extraction (SMILE) followed by intrastromal CXL (loading 15 min., UVA 3 mW/cm^2 for 30 min.). Follow-up at 1 day, 1 week, and 1, 3, 6, 9, and 12 months. **Results:** Seven eyes, mean age 31.2 years. Mean follow-up: 11 ± 1 months. Preoperative spherical equivalent refraction (SE) was -4.50 ± 1.39 D and postoperative SE was -0.14 ± 0.5 D ($P < .001$). Mean uncorrected distance VA (logMAR) was 1.28 preoperatively and 0.11 ± 0.12 postoperatively ($P < .001$). Mean pre- and postoperative CDVA (logMAR) was 0.03 ± 0.05 and 0.04 ± 0.05, respectively ($P = .178$). One eye lost 1 line of CDVA. **Conclusion:** Combined SMILE and CXL may be an efficacious, safe, and stable treatment option in FFKC.

Bowman's Ectasia Index: A Novel Index for the Diagnosis of Keratoconus

Presenting Author: Mohamed Abou Shousha MD
Coauthors: Victor L Perez MD, Ana P Fraga Santini Canto MD, Fouad El Sayyad MD, Florence Cabot MD, Juan Carlos Murillo MD, William J Feuer MS, Jianhua Wang, Sonia H Yoo MD

Purpose: To evaluate the use of Bowman's ectasia index (BEI) in the diagnosis of keratoconus (KC). **Methods:** BEI of 20 control and 20 KC patients were computed from Bowman layer (BL) vertical topographic maps obtained using ultrahigh-resolution OCT. BEI was defined as the inferior minimum BL thickness divided by superior BL average thickness multiplied by 100. BEI predictive accuracy and correlation to keratometric astigmatism (AsgK) were calculated. **Results:** BEI showed excellent predictive accuracy in diagnosing KC (AUC 1). In our study, cutoff value of 70 yielded 100% sensitivity and specificity. BEI showed highly significant correlation to AsgK ($r = -0.75$; $P < .001$). **Conclusion:** BEI showed excellent accuracy, sensitivity, and specificity in the diagnosis of KC. BEI accurately describes KC severity.

Three-Year Clinical Outcome of Small-Incision Lenticule Extraction

Presenting Author: Osama I Ibrahim MD PhD
Coauthors: Amr Said, Ahmed A K El-Massry MD, Moones Abdalla MD

Purpose: To evaluate safety and efficacy of small-incision lenticule extraction (SMILE) over 3 years follow-up. **Methods:** Prospective noncomparative case series carried out on 85 eyes of 44 myopic patients treated with femtosecond laser SMILE. **Results:** Mean preoperative uncorrected visual acuity (UCVA) was 0 .1 (range: 0.03-0.4), mean corrected distance visual acuity (CDVA) was 0.8 (range: 0.4-1.2), and mean spherical equivalent SEQ was -5 (range: -3 to -12). All these parameters showed statistically significant change in the postoperative period ($P < .01$). Mean postoperative UCVA, BSCVA, and SEQ were 0.88 (range: 0.5-1.2), 0.98 (range: 0.5-1.2), and -0.5 (range: -1.5-0), respectively. No operative or 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.

Postoperative Relative Total Tensile Strength After Small-Incision Lenticule Extraction for Moderate Myopia Compared to Matched LASIK Controls

Presenting Author: Dan Z Reinstein MD
Coauthors: Timothy J Archer MS, J Bradley Randleman MD

Purpose: To compare postop total tensile strength (PTTS) after small-incision lenticule extraction (SMILE) with matched LASIK controls. **Methods:** Using published data of stromal tensile strength as a function of depth, PTTS was calculated as the area under the regression line for the residual uncut stroma. PTTS was calculated for 96 consecutive SMILE eyes (SEQ mean: -4.83 D, max: -8.00 D) and 96 LASIK eyes matched for sphere and cylinder. **Results:** Mean optical zone was 6.7 mm in SMILE, 6.2 mm in LASIK. Mean ablation depth was 107 µm (72-149) in SMILE, 87 µm (24-138) in LASIK. Mean SMILE cap was 130 µm (120-140). Mean LASIK flap was 92 µm (80-110). Mean PTTS was 73% (65-82) in SMILE, 61% (50-76) in LASIK. **Conclusion:** PTTS was 12% greater for SMILE than LASIK despite using a larger optical zone, higher ablation depths, and thin LASIK flaps.

Outcomes From a Prospective, Randomized, Eye-to-Eye Comparison of Small-Incision Lenticule Extraction vs. Femto-LASIK Treatments for Myopia

Presenting Author: Arturo J Ramirez-Miranda MD
Coauthors: Tito Ramirez-Luquin MD, Angie De La Mota MD, Alejandro Navas MD, Enrique O Graue Hernandez MD

Purpose: To compare small-incision lenticule extraction (SMILE) and femtosecond-assisted LASIK (F-LASIK) in myopes. **Methods:** Prospective, randomized, eye-to-eye study. Twenty-six eyes of 13 patients were randomized to receive SMILE or F-LASIK. Uncorrected distance visual acuity (UDVA), refraction, esthesiometry, and Schirmer test were assessed preoperatively and on 1 day, 1 week, and 1, 3, and 6 months postoperative. A satisfaction questionnaire was assessed at Week 1. **Results:** At 6 months, differences in UDVA and SE were statically significant ($P < .05$), mean corneal esthesiometry values were similar in both groups ($P = .65$). On the questionnaire, SMILE was superior to LASIK but no statistical differences were encountered. **Conclusion:** SMILE and F-LASIK provide similar results in myopic patients regarding visual acuity, refraction, and dry eye symptoms.

Buttonholes and Free Caps

Dr. Soosan Jacob FRCS

Every refractive surgeon should be aware regarding the management of flap-related complications, as these can sometimes occur unexpectedly. Common causes are microkeratome malfunction, corneal curvature anomalies, and inadequate suction.

Buttonholing of the flap is a dreaded complication, as it often occurs in the visual axis and heals with scarring and loss of BCVA. Poor quality blades, inadequate IOP, keratome malfunction, and steep corneas are predisposing factors. Other predisposing factors, especially with femtosecond flaps, include attempts to make flaps less than 100 microns, previous scars, old surgery, and breaks in the epithelium involving the Bowman membrane. This is recognized intraoperatively as a clear area in the advancing raster pattern or as an escaping bubble and is also called vertical gas breakthrough. With the microkeratome, corneas steeper than 48 D may buckle centrally, leading to a buttonhole. Buttonholing should be recognized immediately by the surgeon and the surgery aborted. Proceeding with ablation can cause severe irregularities and a loss of BCVA.

Though a smaller suction ring can help, femtosecond flap creation and surface ablation are better options. In case of buttonholing with a microkeratome, the procedure should be aborted and the flap realigned. The patient should be followed up for epithelial ingrowth or opacity. Fibrin glue may be used to prevent this. The patient can undergo a PRK/ PTK with application of mitomycin C at a later date or can have a deeper recut with customized ablation.

Free caps are another disastrous complication. The cap is carefully placed epithelial side down in a drop of BSS to avoid stromal hydration. Alignment marks help in identifying the side, as well as in realigning the flap in the appropriate position. Time should be allowed for the flap to adhere well. Sutures or a bandage contact lens may also be used to secure the flap. Incomplete or partial flaps may also occur. The procedure generally has to be aborted, and a new flap with a deeper cut is made 3 to 6 months later. Alternatively, a surface ablation may be performed. Manual dissection of the flap should never be attempted, as this can lead to severe topographical abnormalities and loss of BCVA.

Rarely, a buttonhole can be very large. In this case, the management strategy may vary, depending on ablation zone available, as shown in the video being presented.

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LASIK Interface Fluid Syndrome: "Open Water"

Natalie Afshari MD

Background

Although postoperative complications of LASIK are uncommon, they still occur. One of the rare noninfectious complications is LASIK interface fluid syndrome, first described by Lyle and Jin in 1999.[1] Corneal flap architecture, which is inherently weak, has been previously reported in 2007 by Dawson et al as a hypocellular primitive stromal scar.[2,3] Case reports have described the accumulation of fluid in the LASIK flap interface due to steroid-induced IOP spike, uveitis, and vitreoretinal and cataract surgery, as well as endothelial decompensation. We describe a case of LASIK interface fluid syndrome after trabeculectomy revision for hypotony maculopathy.[4-9]

Case Report

A 70-year-old woman presented to Cornea and Refractive Surgery Clinic for evaluation of central corneal edema in the right eye. Her ocular history included uneventful bilateral simultaneous myopic LASIK in 1999. The patient has a history of uncontrolled glaucoma and has had trabeculectomies in both eyes. Nine years after trabeculectomy in the right eye, the patient experienced hypotony maculopathy and underwent a successful revision of her trabeculectomy. Her postoperative Day 1 IOP was 24 mmHg, up from a preoperative pressure of 1 mmHg. On presentation to the Cornea and Refractive Surgery Clinic, the patient's visual acuity was counting fingers in the right eye and 20/25 in the left eye. IOPs were 5 mmHg and 7 mmHg, respectively. Slitlamp examination of the right eye revealed diffuse haze and extensive edema within the LASIK flap. There was also evidence of posterior stromal edema. The patient underwent successful Descemet-stripping automated endothelial keratoplasty with venting incisions to drain the LASIK interface fluid.

Discussion

In recent years, LASIK interface fluid syndrome has been classified into 2 distinct etiologies: increased IOP and endothelial cell dysfunction. Usually, the condition manifests 1-3 weeks after the LASIK procedure secondary to steroid-induced IOP rise; however, there have been several reports of interface fluid syndrome years after LASIK secondary to a rise in IOP or endothelial decompensation.[4-9] Dawson et al reported that a hypocellular primitive stromal scar after LASIK has an increase in nonfibrillar proteoglycans and may be the reason behind the preferential accumulation of fluid in the LASIK flap interface.[3] Our patient presented 15 years after her initial LASIK and had elements of relative pressure elevation and endothelial cell dysfunction to account for the development of LASIK interface fluid syndrome.

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Vertical Gas Breakthrough

John So-Min Chang MD

Part I: Vertical Gas Breakthrough

Case

- Male/53 years old
- O.D. -3.50/+2.25x105 (20/25+)
- O.S. -3.75/+2.50 x 88 (20/20-2)
- 90-µm intended flap thickness superior hinge
- O.S. uneventful
- *O.D.: vertical gas breakthrough (VGB), 1.5 mm x 1.5 mm, at 12 o'clock, 2 mm from limbus* (see Figure 1)

Figure 1.

- Superior hinge was used (the same as the other eye).
- Microkeratome recut in any direction could be done without risking flap shredding as the laser cut was only partially completed (superior third of cornea).

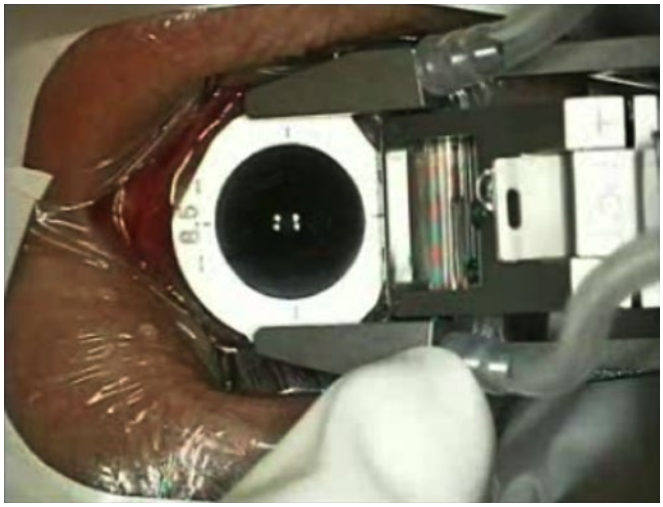

Figure 2.

- Gas escapes anteriorly to the corneal surface through epithelium.
  - VGB under epithelial surface → usually small and surgery can be continued
  - VGB through epithelium → large bubble and surgery cannot go on
- Force lifting of the flap will cause button-hole like complication.
  - At periphery and the area is small: Laser can be performed without causing any problems.
  - On or near the visual axis: Scarring and possible visual loss

Why is immediate management needed?

- Trend to have thinner flaps (eg, 90 µm or less)
- Patient inconvenience
  - Anisometropia (intolerance to spectacles if one eye was corrected)
  - Cannot wear CTL for a few days after VGB occurs
  - Off CTL for another week before repeating surgery
  - No guarantee VGB won't occur again!

Table 1.

Scenario	Direction of Microkeratome Recut	Remarks
VGB at initial stages: < 1/2 bed was dissected by IntraLase; no side cut	Any direction	Cornea is relatively intact.
Laser flap creation completed with/without side cut performed	Same as previous cut	• Do not dissect the bed. • Sweep along the flap. • Hinge acts as a stopper but it can tear.

Part II: Dropped IOL

Case

- Female/50 years old / O.D.
- Lens: 2+nuclear sclerosis; axial length: 26.65 mm; anterior chamber depth: 3.86 mm; white-to-white distance: 12 mm
- Preop: -11.25/+1.25x82 (20/30) add +2.50
- Planed IOL: Multifocal toric 9.0 D
- Tight injector → causing injection of IOL → posterior capsule tear, IOL dropped → posterior vitrectomy performed
- IOL implanted after removal of multifocal toric in vitreous: AR40e 9.5D optic captured at capsule continuous curvilinear capsulorrhexis
- Duration: 2 hours, 2 mins.
- Postop
  - 1 week: -0.75/+1.75x75 (20/30)
  - 1 month: -0.75/+1.00x75 (20/25+2)
  - 6 months: uncorrected distance visual acuity 20/20

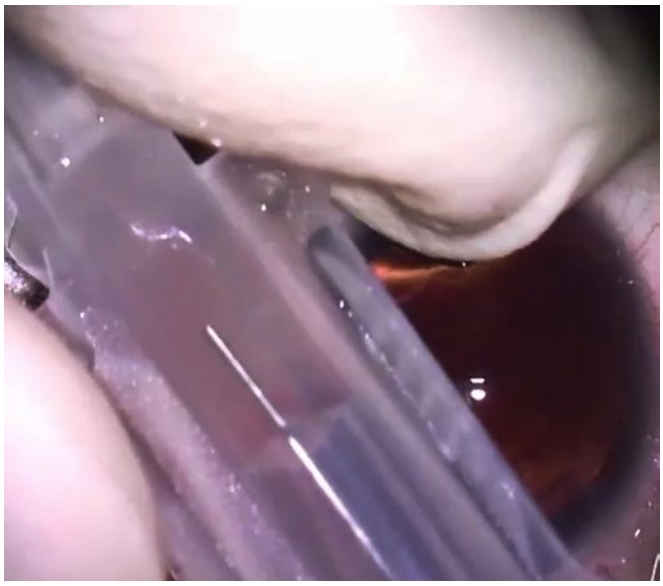

Figure 3.

. . . And Longer Nights: A Series of Unfortunate Events

Pravin Vaddavalli MD

Phakic IOL implantation has gained prominence as a refractive surgery for patients with high refractive errors and for patients unsuitable for conventional corneal ablative surgery. They have been reported to be safer than LASIK for moderate to high myopia between -6 and -20 D, and patients reported greater satisfaction with phakic IOLs compared to LASIK.[1]

Three major types of phakic IOLs have been in use around the world: angle supported, iris fixated, and posterior chamber phakic IOLs. Among these, the iris-fixated IOLs and posterior chamber lenses have been shown to be safer and have been approved for use in the United States.

Over the years, various complications have been reported, including endothelial cell loss, cataract formation, secondary glaucoma, iris atrophy, and traumatic dislocation.[2] The major complications with the Verisyse iris-fixated IOL have been spontaneous disenclavation and recurrent inflammation. Endothelial cell loss with this lens has been reported to be 9% over a period of 5 years.[3-5] Though intraocular inflammation is not as commonly reported with the posterior chamber phakic IOLs, they have a greater potential to induce cataract or significantly increase the progression of pre-existing lenticular opacities. The incidence of cataract following a posterior chamber phakic IOL implantation has been reported to be 9.6%, much higher than with iris-fixated phakic IOLs.[6]

Raised IOP following implantation of the posterior chamber phakic IOLs has been reported as a significant complication in large series, but incidence rates do not seem to be available. Reported mechanisms of glaucoma include pigment dispersion, pupillary block, angle closure, pupil ovalization and iris atrophy and malignant glaucoma.[2, 7, 8]

Case Report

A 24-year-old female student with high myopia presented to us with complaints of diminution of vision in the left eye following ICL implantation surgery done elsewhere 1 month back. There were no complaints in the right eye. The referring surgeon gave a history of a second surgery done 1 day after the ICL implantation to create a peripheral iridotomy under topical anesthesia when the patient developed a vasovagal attack, leading to the surgery being abandoned with residual viscoelastic in the anterior chamber. Apparently, 4 days following ICL implantation, she received intravitreal antibiotics and steroid injections for suspected endophthalmitis. Five days before presenting to us, she had undergone a membrane peeling surgery for an inflammatory pupillary membrane. At the time of presentation, she was on oral and topical steroids, a topical alpha-2 agonist, brimonidine, topical antibiotic, and a mydriatic-cycloplegic. From the referring ophthalmologist, we gathered that there was delay of 4 days in initiating steroids because of suspicion of endophthalmitis, and patency of iridotomies was questionable.

Her best distance visual acuity was 20/40p in right eye and 20/50p in left eye. IOP was 13 mmHg in the right eye and 14 mmHg in the left eye. Clinical examination in the right eye was within normal limits. The left eye showed signs of anterior segment inflammation with iris neovascularization and an inflammatory pupillary membrane covering the ICL. The iridotomy was probably not patent. Posterior segment examination was normal in both eyes. A diagnosis of high myopia in both eyes and secondary glaucoma with exaggerated postoperative inflammation following ICL implantation in the left eye was made. Since the IOP was under control, we decided to observe her with no active intervention planned.

She presented 7 weeks later with symptoms of pain, and lid swelling in the left eye. On examination right eye was within normal limits. Distance visual acuity in the left eye was 20/60. Anterior chamber showed signs of inflammation with cells, flare, and 360° posterior synechiae. IOP was 10 and 26 mmHg in the right and the left eye, respectively, on maximum antiglaucoma medications. Ultrasound biomicroscopy was done, which revealed normal cornea, ciliary body, deep anterior chamber, and apparently normal angle configuration in the right eye and closed angles in all quadrants in the left eye. Anterior segment OCT showed anterior vaulting of the lens.

Patient underwent an ICL explantation with membranectomy and trabeculectomy with mitomycin C under general anesthesia. Postoperatively she was treated with topical and systemic steroids, topical antibiotics for 1 week and cycloplegics for 2 weeks. Histopathology of pupillary membrane and excised tissue revealed fibrosis and neovascularization of iris and a fibrovascular pupillary membrane. At the 1-month postop follow-up, her BCVA was 20/50 in the right eye and 20/60 in the left eye. Slitlamp examination of left eye conjunctiva showed congestion with a diffuse superior bleb, corneal stromal edema with pigments on the endothelium and intact sutures. The anterior chamber was deep centrally with 1+ flare and cells, peripheral anterior synechiae in all quadrants, and an inflammatory membrane covering the anterior surface of iris; pupil was irregular. IOP was 11 mmHg in the right eye and 14 mmHg in the left eye. Fundus examination of the left eye showed 0.5 cupping with sloping of inferior rim. Meanwhile, she started to develop anterior capsular and subcapsular opacities in the crystalline lens in her left eye.

She was continued on topical antiglaucoma medications and topical and oral steroids, and her inflammation seemed to reduce with time. However, she presented 2 months later with severe pain in the left eye. At this visit, her vision had dropped to counting fingers, IOP was high, and the anterior chamber was very shallow, with the iris lens complex shifted anteriorly. Ultrasound B-scan showed fluid pockets in the vitreous, and she was scheduled for a pars plana lensectomy and vitrectomy. Following the surgery, her IOP gradually settled with a reduction in the inflammation, and she was continued on topical steroids. The retina was attached and her optic disc showed a cup-to-disc ratio of 0.5:1. Over the course of the next 6 months, though her IOP was controlled, her cornea gradually decompensated and the vision in the left eye dropped to counting fingers. Options of undergoing a Boston type 1 keratoprosthesis or a penetrating keratoplasty were discussed, as endothelial keratoplasty was not an option due to the shallow anterior chamber and the extensive peripheral anterior synechiae.

Discussion

This case demonstrates the importance of a peripheral iridotomy during implantation of a phakic IOL and the consequences of inaccurate diagnosis and management. Though the ICL has been a very successful phakic IOL, especially for high myopes, one must be mindful of the consequences that its implantation may have on the functioning of the eye.

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A Compilation of Complications in Femtosecond Laser Keratoplasty

Anthony J Aldave MD

The femtosecond laser has the potential to revolutionize incisional corneal surgery, given the precision of incision creation and the unlimited number of incision configurations. However, obtaining good outcomes and avoiding intraoperative and postoperative complications requires appropriate patient selection, careful preoperative planning, and meticulous surgical technique. To minimize the risk of complications, surgeons should follow established protocols:

Appropriate Patient Selection

- Good candidates
  - Corneal stromal opacification or ectasia in the absence of comorbid ocular pathology
- Marginal candidates
  - Moderately dense midperipheral corneal opacity
  - Previous incisional corneal surgery, such as PK, LASIK, or radial keratotomy
    - ∞ Gas breakthrough into transplant incision, lamellar plane, or radial incision possible
  - Factors that may predispose to suction loss
    - ∞ Trabeculectomy
- Poor candidates
  - Dense midperipheral corneal opacity
  - Midperipheral corneal thickness < 400 microns or > 1200 microns
  - Significant corneal stromal thinning or Descemetocele

Preoperative Evaluation

- Measurement of corneal diameter
  - Consider slightly smaller diameter for younger recipient.
- Measurement of corneal pachymetry
  - 7-9 mm diameter zone using ultrasonic pachymetry and/or corneal tomography
    - ∞ Minimum 400 microns; prefer > 500 microns (ring lamellar cut @ 250-350 microns)

Surgical Technique

- Donor cornea trephination
  - Use surgical calculator and preset donor specifications to minimize risk of donor/host mismatch.
  - Debride epithelium or request that eye bank do so to minimize poor-quality trephination in region of epitheliopathy.
    - ∞ Decrease ring lamellar cut depth by 50 microns.
  - Maximize width of radial alignment marks (50 microns) to enhance visibility.
  - Inspect donor cornea prior to trephination of recipient.
    - ∞ Do not proceed if more than 1 clock hour of poor-quality wound configuration.
- Recipient cornea trephination
  - Leave posterior stroma intact.
    - ∞ 70 microns for PK and 100 microns for DALK
  - If bubbles seen in anterior chamber, immediately stop trephination and reset depth to at least 70 microns less.
  - In the event of suction loss during trephination, abort procedure.
    - ∞ Wait 3 months prior to performing femtosecond laser-assisted or manual keratoplasty.

Epithelial Measurement and Healing

Dan Z Reinstein MD

Introduction

The corneal epithelium is a highly active, self-renewing layer; a complete turnover occurs in approximately 5 to 7 days.[1] Despite this high turnover rate, the epithelium must maintain the same thickness profile over time to maintain corneal power and, hence, ocular refraction. As described by Alfred Vogt in 1921,[2] it is known that the corneal epithelium has the ability to alter its thickness profile to compensate for changes in stromal surface curvature in order to try and re-establish a smooth, symmetrical optical surface. Understanding this epithelial compensatory mechanism is crucial to fully understanding how the cornea will respond to different conditions and surgical procedures. As the refractive index of epithelium and stroma are sufficiently different (1.401 vs. 1.377),[3] the epithelial-stromal interface constitutes an important refractive interface within the cornea, with a mean power contribution estimated at approximately -3.60 D.[4] Therefore, knowledge of the epithelial thickness profile and how it may change after corneal surgery could positively contribute to the accuracy of refractive corneal and IOL surgery.

Understanding the Predictable Behavior of the Corneal Epithelium

Before looking at more complicated situations, it is useful to consider the epithelial thickness profile in a population of normal eyes.[5] Somewhat surprisingly, we demonstrated using VHF digital ultrasound that the epithelium was not a layer of homogeneous thickness as had previously been thought, but followed a very distinct pattern; on average the epithelium was 5.7 µm thicker inferiorly than superiorly, and 1.2 µm thicker nasally than temporally, with a mean central thickness of 53.4 µm. This nonuniformity seems to provide evidence that the epithelial thickness is regulated by eyelid mechanics and blinking, as we suggested in 1994.[6] We postulated that the eyelid might effectively be chafing the surface epithelium during blinking and that the posterior surface of the semi-rigid tarsus provides a template for the outer shape of the epithelial surface. During blinking, which occurs on average between 300 to 1500 times per hour,[7] the vertical traverse of the upper lid is much greater than that of the lower lid. Doane[8] studied the dynamics of eyelid anatomy during blinking and found that during a blink the descent of the upper eyelid reaches its maximum speed at about the time it crosses the visual axis. As a consequence, it is likely that the eyelid applies more force on the superior than the inferior cornea. Similarly, the friction on the cornea during lid closure is likely to be greater temporally than nasally as the outer canthus is higher than the inner canthus (mean intercanthal angle = 3°), and the temporal portion of the lid is higher than the nasal lid (mean upper lid angle = 2.7°).[9] Therefore, it seems that the nature of the eyelid completely explains the nonuniform epithelial thickness profile of a normal eye.

Epithelial thickness changes have been described after myopic excimer laser ablation,[10-12] hyperopic excimer laser ablation,[13] radial keratotomy,[14] orthokeratology,[15] intracorneal ring segments,[16] irregularly irregular astigmatism after corneal refractive surgery,[17-20] and in keratoconus[21-23] and ectasia.[24] Figure 1 shows the epithelial thickness profile in a number of different situations.

In all of these cases, the epithelial thickness changes are clearly a compensatory response to the change to the stromal surface and can all be explained by the theory of eyelid template regulation of epithelial thickness. Compensatory epithelial thickness changes can be summarized by the following rules:

1. The epithelium thickens in areas where tissue has been removed or the curvature has been flattened (eg, central thickening after myopic ablation[10-12] or radial keratotomy[15] and peripheral thickening after hyperopia ablation[13]).
2. The epithelium thins over regions that are relatively elevated or where the curvature has been steepened (eg, central thinning in keratoconus,[21-23] ectasia[24] and after hyperopic ablation[13]).
3. The more irregular the topography, the more epithelial remodelling will have occurred.
4. The amount of epithelial remodelling is defined by the rate of change of curvature of an irregularity; there will be more epithelial remodelling for a more localized irregularity.[17,19,20] The epithelium effectively acts as a low-pass filter, smoothing small changes almost completely but only partially smoothing large changes.

The rate of change of curvature is really the key to understanding the entirely predictable epithelial response. This can be appreciated by the fact that there is almost twice as much epithelial thickening after a hyperopic ablation[13] as after a myopic ablation,[11] and by the total epithelial compensation for small, very localized stromal loss such as after a corneal ulcer.[13] Similarly, the effectiveness of a transepithelial phototherapeutic keratectomy (PTK) procedure increases as the localization of the irregularities increases (see more later).[20]

Rate of Change in Epithelial Thickness

The other aspect of the changes in the epithelial thickness profile described above is the speed at which the changes occur. This turns out to be extremely fast, with dramatic overnight changes having been demonstrated after myopic LASIK[12] and complete epithelial remodeling one day after flap rotation of a free cap.[25] Orthokeratology is another example of this, as it has been shown that the refractive changes are mainly due to epithelial thickness changes; overnight, the lenses compress the central cornea to induce central epithelial thinning and allow paracentral epithelial thickening.[15] Therefore, the temporary nature of the effect demonstrates the speed of epithelial remodeling as it returns to its natural state.

The epithelial thickness changes observed in orthokeratology add more weight to the theory that the epithelium remodels to fit the template in front of the cornea. In orthokeratology, the template normally provided by the posterior surface of the semi-rigid tarsus is replaced by a contact lens that is designed to fit tightly to the center of the cornea and loosely paracentrally.

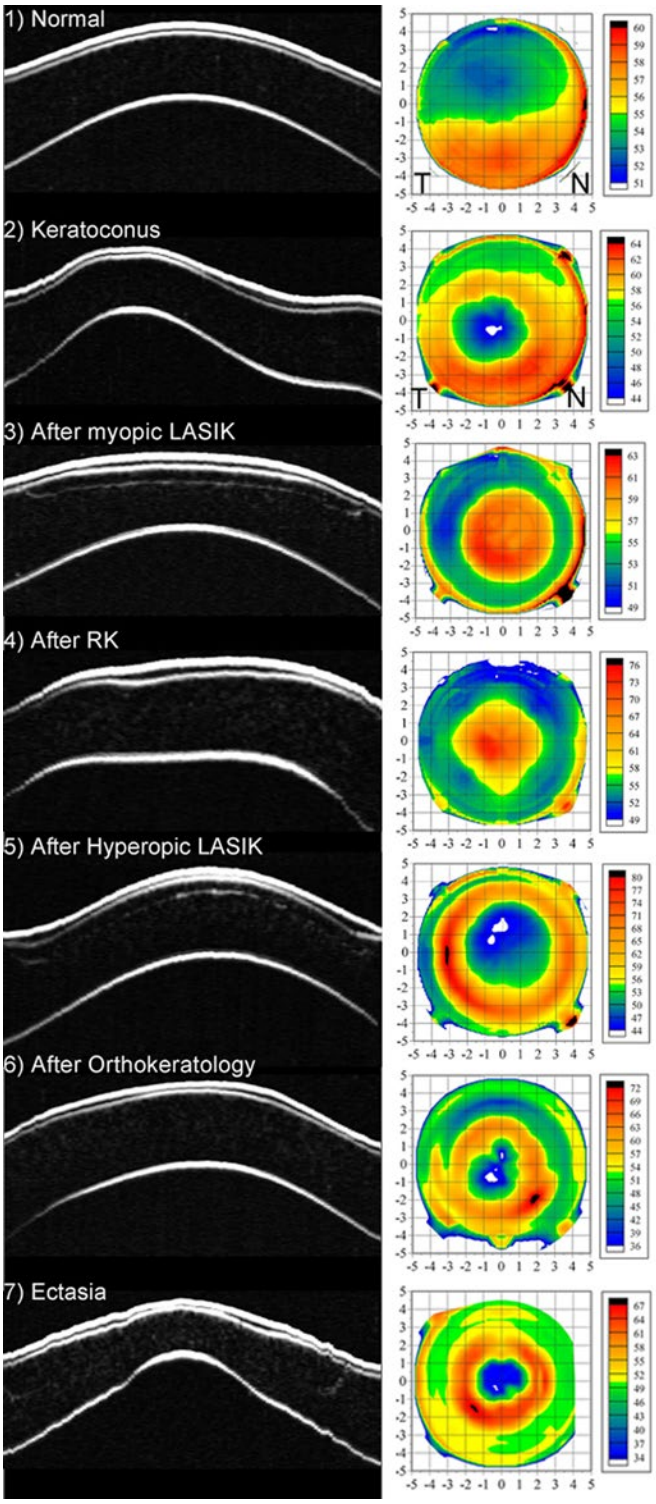

Figure 1.

Therefore, the epithelium is chafed and squashed by the lens centrally while the epithelium is free to thicken paracentrally where the lens is not so tightly fitted.

After myopic LASIK, we have previously shown that the epithelial thickness continues to change during the first 3 months, after which it remains completely stable.[12] Overnight, there is central epithelial thickening of approximately 1 to 2 µm, but paracentral epithelial thinning of approximately 4 to 6 µm—we postulated that this thinning was in response to edema. Between 1 day and 1 month, the epithelium thickened across the entire 7-mm diameter zone by up to 5 µm, with more pronounced thickening within the central 4 mm. Between 1 month and 3 months, the epithelium continued to thicken in the central 7-mm diameter zone by approximately an additional 1 µm. These epithelial changes partially explain the regression seen after myopic LASIK in the first 3 months and agree with the common finding that refractive stability is attained after 3 months.[26]

Applications of Epithelial Thickness Mapping

Epithelial changes such as those described above will have an impact on the ocular refraction; however, the biggest clinical impact of epithelial changes is to corneal front surface topography—since the epithelium compensates for stromal irregularities, the presence of an irregular stromal surface is either partially or totally masked from corneal front surface topography. Therefore, corneal front surface topography does not always tell the whole story, and in some cases does not provide the necessary information to establish a correct diagnosis.

1. Keratoconus screening

In keratoconus, the epithelium remodels follow a distinctive epithelial donut pattern, characterized by a localized central zone of thinning surrounded by an annulus of thick epithelium, demonstrating that the epithelium compensates for the underlying stromal cone by thinning over the cone and thickening around the cone.[21-23] In early keratoconus, the epithelial doughnut pattern will act to minimize the extent of the cone on the front corneal surface and potentially fully compensate the stromal surface irregularity and render a completely normal front corneal surface.[27] Therefore, epithelial thickness mapping has the potential to exclude the appropriate patients by detecting keratoconus earlier or confirming keratoconus in cases where topographic changes may be clinically judged as being "within normal limits." Secondly, epithelial thickness profiles may be useful in excluding a diagnosis of keratoconus despite suspect topography; epithelial thickening over an area of topographic steepening implies that the steepening is not due to an underlying ectatic surface.

2. Limits for hyperopic steepening

It is currently assumed that hyperopic LASIK should be limited according to postoperative curvature, as too much steepening can result in epitheliopathy or apical syndrome; it is generally accepted that the postoperative curvature should not exceed 49.00 to 50.00 D.[28] However, we have previously suggested that central epithelial thickness may be a more useful indicator, as it is a direct measurement of the potential risk of apical syndrome, which occurs once the epithelium is too thin (less than 25 µm).[13] Therefore, using epithelial thickness measurements, hyperopic re-treatments might be performed without risk of apical syndrome while also allowing some patients to have re-treatment who would otherwise have been rejected for further surgery due to high keratometry postoperatively.

3. Transepithelial PTK / stromal surface topography-guided custom ablation

Despite all the advances in corneal topography and ocular wavefront measurement, it is not always possible to diagnose the cause of subjective visual complaints by these means alone because the compensatory epithelial thickness changes act to partially mask the true stromal surface irregularity (described

above). In 1994, we coined Reinstein's Law of Epithelial Compensation for irregular astigmatism:[29] "Irregular astigmatism results in irregular epithelium." If a patient presents with stable irregular astigmatism, by definition the epithelium has reached its maximum compensatory function by thinning over peaks and thickening over troughs in the stromal surface. As mentioned earlier, the epithelium can compensate almost completely for very localized irregularities. Therefore, topography or wavefront-guided treatments may lead to a suboptimal treatment plan and potentially make things worse.[20]

Instead, we need a method to target the irregularities masked by the epithelium, something that is achieved, by definition, by transepithelial PTK.[17,19,20] The only disadvantage of transepithelial PTK is that it is limited to treating only the proportion of the stromal irregularities compensated for by the epithelium, so more than one procedure is often required. The final solution in repair treatments is going to be a custom ablation profile based on stromal surface topography, something that can be measured by subtracting the epithelial thickness profile from the front corneal surface topography.

4. Improved IOL power calculation after corneal refractive surgery

Given the lenticular nature of epithelial remodeling after corneal refractive surgery, the postoperative epithelium will make a contribution to the refractive effect of the cornea. However, the epithelial thickness profile after a myopic ablation will have the opposite effect as that after a hyperopic ablation, while also being correlated to the amount of correction—and studies have demonstrated this exact result of undercorrection in post-myopic eyes and overcorrection in post-hyperopic eyes.[30] Therefore, taking into consideration epithelial thickness profiles in IOL power calculation formulae has the potential to further improve accuracy.

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Interactive Consultations—Corneal Refractive Surgery

NOTES

The Ideal Surface Ablation: Laser, Scraping, Alcohol?

Marguerite McDonald MD

Upon an analysis of the peer-reviewed literature, all 3 methods are safe and effective as methods for removing epithelium during surface ablation. There are pros and cons to each, however:

1. Laser removal is fast, but some skill and judgment are required because the epithelial layer differs in its thickness over the corneal surface. The surgeon must note when and where epithelial breakthrough has first occurred, and must decide when to stop the ablation. If the laser removal is halted too early, a significant amount of mechanical scraping is required; if it is halted too late, the stroma will have been ablated, which can lead to irregular astigmatism. Laser removal produces the smallest epithelial defect possible and leaves a sharp edge to the epithelial defect, which most surgeons feel is desirable because it leads to faster re-epithelialization. Some surgeons use a hybrid procedure called "laser scrape," wherein the epithelial layer is removed to approximately 80%-90% depth, purposely avoiding breakthrough; the remaining epithelial cells are then removed mechanically.
2. Scraping remains a popular method for epithelial removal; it was the first technique used in the earliest days of PRK (photorefractive keratectomy, the original iteration of surface ablation). It is "low tech," inexpensive, and effective, though it generally takes a little longer than the other 2 methods, laser and alcohol. Studies have shown, however, that even experienced surgeons may leave behind basement membrane and nests of epithelial cells, which can lead to irregular astigmatism. It is also quite easy to nick the stroma, particularly when using a sharp instrument; these nicks can also lead to irregular astigmatism and perhaps to haze. A semiblunt instrument such as a Tooke knife is ideal for scraping; it is sharp enough to get the job done but so blunt that stromal nicks are highly unlikely.
3. Alcohol is a popular method for epithelial removal as well; it is also "low tech," inexpensive, and effective. Alcohol removal is a faster method of epithelial removal than scraping, but slower than laser removal. Care must be taken to use no greater than 20% alcohol, as higher concentrations have been associated with corneal edema and inflammation. Care must also be taken to time the exposure. The peer-reviewed literature has papers documenting that alcohol-treated eyes have a higher amount of postoperative pain than those treated with the other techniques, but it also has papers stating the opposite: that these eyes have less pain.

Pinhole Corneal Inlays

Minoru Tomita MD PhD

The small-aperture corneal inlay (Kamra, AcuFocus; Irvine, Calif., USA) for the correction of presbyopia is based on the principle of changing the depth of focus. It is commercially available in 48 countries and has been implanted nearly 20,000 cases worldwide. After 7 years of being in clinical trials in the United States it is currently at the FDA for review. Ever since its efficacy and safety for the treatment of emmetropic presbyopes was reported,[1-3] there have been several advancements in the surgical implantation techniques since many patients who come for the correction of presbyopia also have some degree of ametropia.

Our group reported on inlay implantation in combination with a LASIK procedure for simultaneous correction of ametropic presbyopia and found that the combination was safe and effective.[4] Additionally, our group recently reported on the 1-year outcomes of the inlay implantation in presbyopic patients who had previously undergone LASIK surgery.[5] Now a total of over 10,000 cases have been performed at Shinagawa LASIK Center. In this presentation, I will present the results of the treatment methods using the small-aperture corneal inlay for ametropic presbyopes and post-LASIK patients.

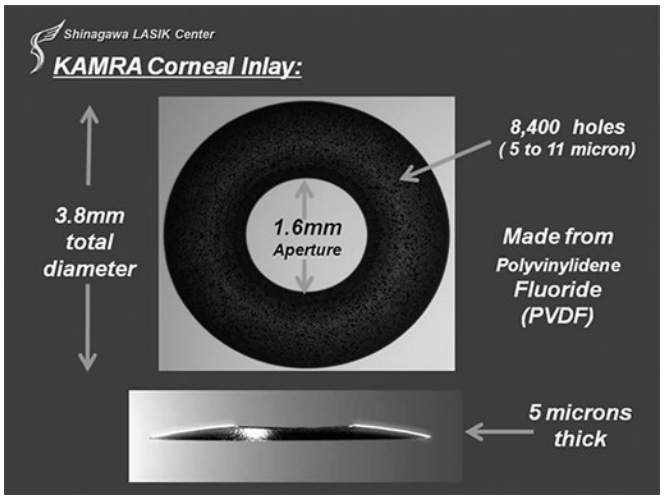

Figure 1. Characteristics of the small-aperture corneal inlay.

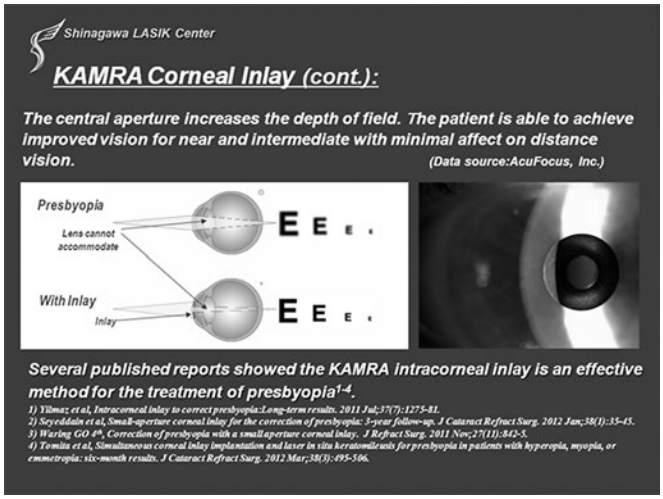

Figure 2. Principles of the inlay.

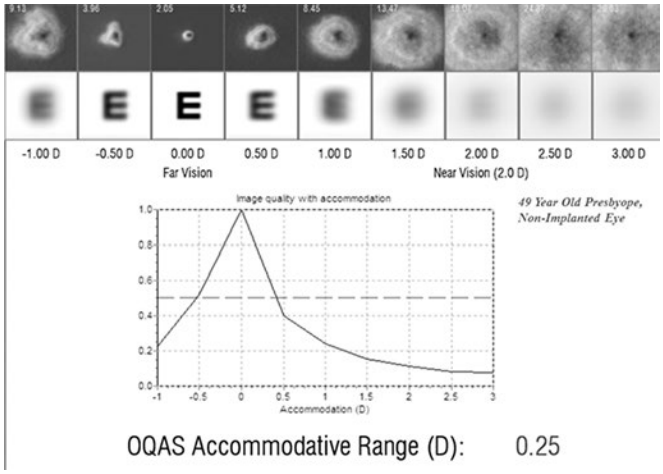

Figure 3. Accommodative range for the nonimplanted eye.

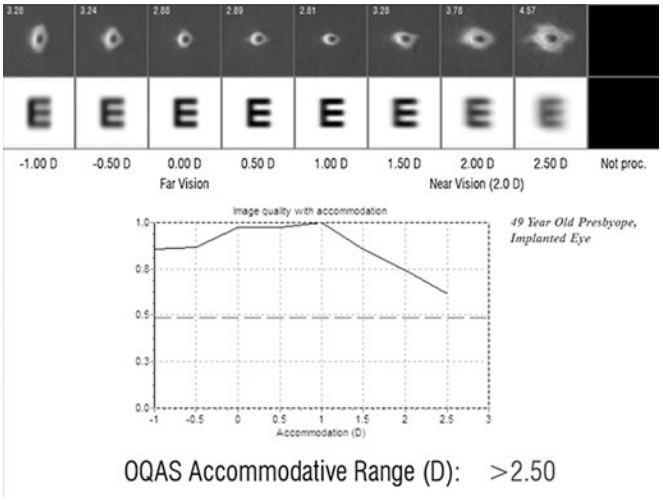

Figure 4. Accommodative range for the implanted eye.

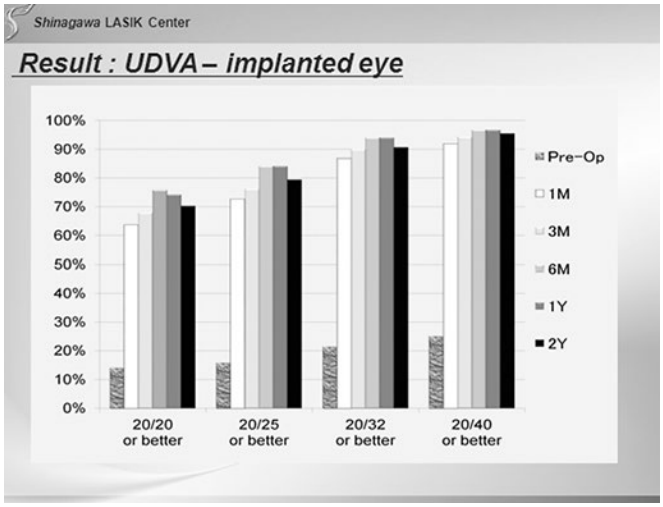

Figure 5. UDVA after combining LASIK and inlay implantation.

For all of these procedures, the inlay is implanted into the patient's nondominant eye, and if necessary, their dominant eye is treated to correct distance vision. When combining LASIK and inlay implantation, a 200-micron flap is created using a femtosecond laser. The flap is lifted and the refractive correction is performed, after which the flap is replaced. The flap is then relifted and the inlay is placed on the corneal bed, and finally the flap is replaced using a dry technique. If the position of the inlay needs to be adjusted, the flap can be lifted and the inlay repositioned.

For post-LASIK patients, a corneal pocket is created with a femtosecond laser in the nondominant eye at least 200 microns deep in the cornea and with a minimum of 100 microns between the inlay pocket and the previous LASIK flap interface. Since patients experience an average myopic shift of -0.60 D after this procedure, a small touch-up is performed if the inlay eye is not between -0.50 D and +0.25 D and the cylinder is equal to or worse than -0.75 D. This touch-up is performed by lifting the previous LASIK flap and using an excimer laser with a postoperative target of 0.00 D, and the flap is replaced in the usual fashion after the LASIK correction. The inlay is then carefully inserted into the corneal pocket.

The results for ametropic patients who had combined LASIK and inlay implantation are shown in Figures 5, 6, and 7. At 2 years postoperative, both uncorrected distance visual acuity (UDVA) and uncorrected near visual acuity (UNVA) improved, patient satisfaction increased, and their dependency on reading glasses was reduced.

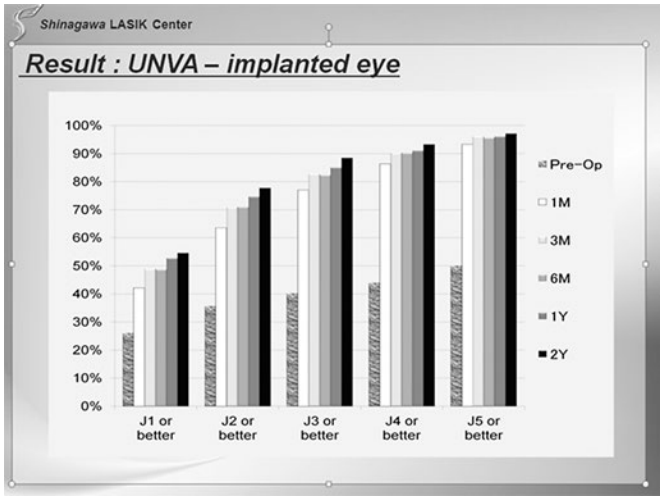

Figure 6. UNVA after combining LASIK and inlay implantation.

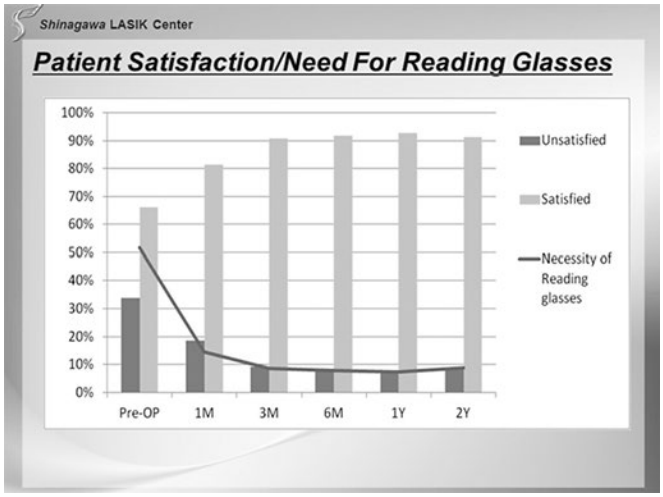

Figure 7. Subjective patient questionnaire after combining LASIK and inlay implantation.

Results for post-LASIK patients are shown in Figures 8, 9, and 10. While UDVA in the implanted eye had a minimal change at 1 year postoperative, UNVA improved, patient satisfaction increased, and their dependency on reading glasses was reduced.

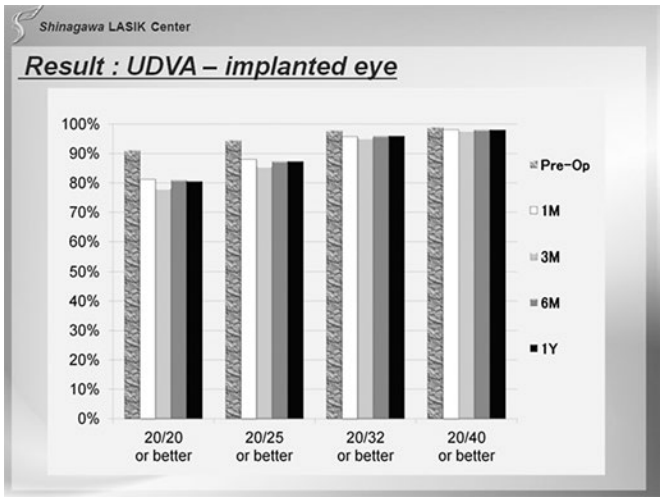

Figure 8. UDVA for post-LASIK patients.

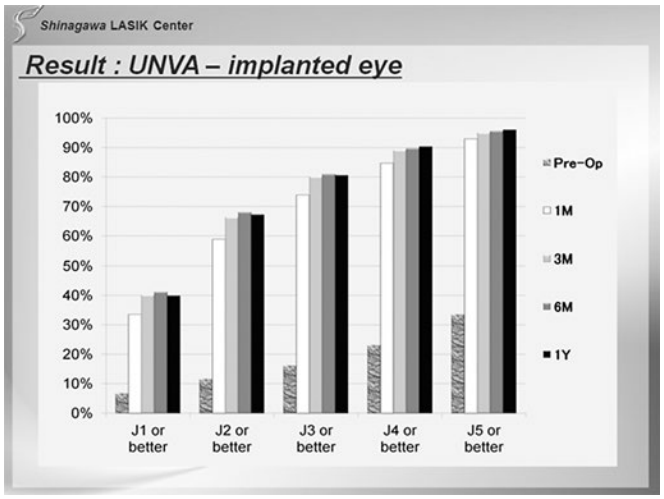

Figure 9. UNVA for post-LASIK patients.

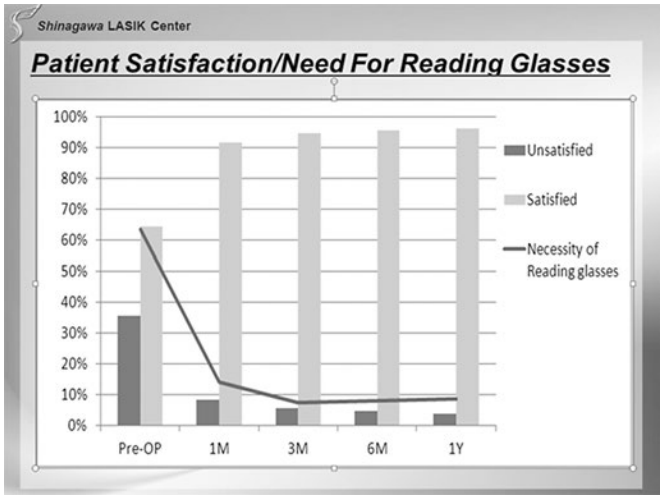

Figure 10. Subjective patient questionnaire for post-LASIK patients.

To achieve the best results and the fastest visual recoveries, surgeons should minimize surgical manipulation of the flap or inside the pocket interface. Postoperatively antibiotics, steroids, and aggressive dry eye therapy should be used to assist the healing response. It is also important to remember that all new techniques have a learning curve. Excellent results are possible from the beginning but will improve with practice.

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Refractive Corneal Inlays

Ioannis G Pallikaris MD PhD, A Limnopoulou MD MSc, G Kymionis MD PhD, D Bouzoukis MD

Abstract

The aim of this presentation is to familiarize the participants with a new technique of treating presbyopia, which is the implantation of intracorneal inlays in emmetropic presbyopic patients. A short review of the latest results of the currently used inlays will be presented, along with the presenter's personal experience with the intracorneal inlay Flexivue Microlens.

The lens was implanted inside a corneal pocket created in the nondominant eye of 45 patients using femtosecond laser. Mean UCVA for near increased from 20/100 to 20/25 and for distance decreased from 20/20 to 20/40 in the operated eye, whereas it remained stable binocularly. After surgery 92% referred no use of reading glasses. No intra/postoperative complications were found.

Final conclusions state that intracorneal lenses for presbyopia are a safe and effective method in patients aged 45 to 60 years old.

Nonrefractive Corneal Inlays

Mark T Wevill MBCHB

I. History of Corneal Inlays
II. Presbyopic Corneal Inlays: Mechanisms and Principles
III. Nonrefractive Inlays: Form and Function
IV. Studies and Results
V. Complications and Concerns

Prosecution: Inlays are Not the Ideal Solution

Michael Lawless MD

There are three forms of corneal inlays.

The Kamra small aperture inlay, which acts as an effective pinhole, has the most data. The other options are a refractive annular lenticule, which is added to the cornea, and the alternative to this—a space-occupying lenticule to create a hyper prolate cornea. These latter two have minimal data to support their use.

For a corneal inlay approach to be attractive to patients, it must provide safety and accuracy that is superior to the current alternatives of LASIK-induced monovision and/or refractive lens exchange surgery.

In my view, the literature does not support inlays as a viable alternative to these well-understood alternatives. I will use the literature and clinical examples to illustrate why we should proceed cautiously with corneal inlays in their current form.

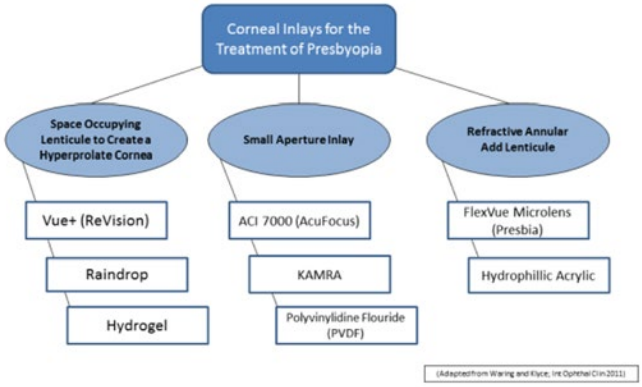

Figure 1. Flow chart depicting classification of corneal inlays based on mechanism of action.

- Most data available
- Requires induced myopia to be effective and is it slightly better than monovision?
- Will the late inflammation and induced hyperopia be managed well?
- 20% may need to be removed.

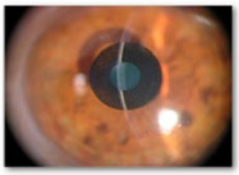

Figure 2. Kamra corneal inlay.

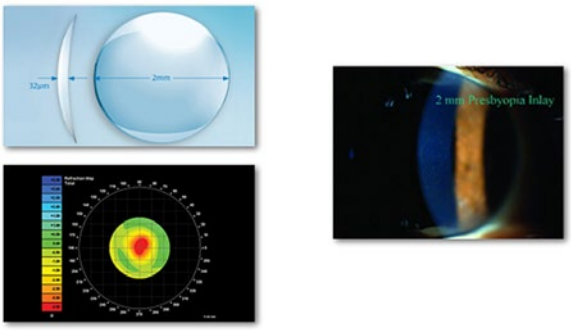

Figure 3. Raindrop corneal inlay.

- Effectively gives a central island
- Doubtful principle
- Not enough meaningful data at this stage to comment

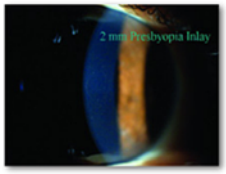

Figure 4. Raindrop corneal inlay.

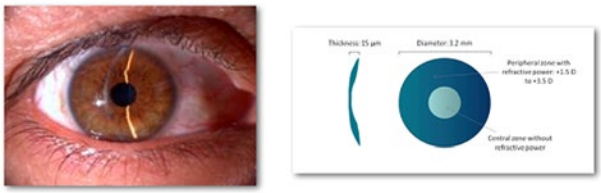

Figure 5. Presbia corneal inlay.

- Age range of reported data (45-60) too broad for meaningful interpretation of single study in literature
- Significant reduction in CS at all spatial frequencies may be too much of a compromise for normal patients

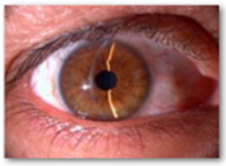

Figure 6. Presbia corneal inlay.

Table 1.

	Kamra (Acufocus)	Invue (Presbia)	Raindrop (Vue+; Revision Optics)
Company startup	2001	2008[a]	1996[b]
No. implanted	10,000	500	?
First clinical trial	2003	2009	2010
CE Mark	2005	2009	2009
FDA approval	-	-	-
Published papers	14[c]	2[c]	1

[a] Company formed by merger

[b] Original company formed

[c] Included case reports

Table 2.

	Waring. *J Refract Surg.* 2011[1]	Seyeddain. *JCRS.* 2013[2]	Yilmaz. *JCRS.* 2012[3]	Tomita. *JCRS.* 2012[4] (Hyper)	Tomita. *JCRS.* 2012[4] (Emme)	Garza. *JRS.* 2013[5] (Raindrop)	Bouzoukis. *JRS.* 2012[6] (Invue)
N	507	24	39	33	30	20	45
Follow-up (months)	18 (99)	24 (24)	48 (22)	6 (12)	6 (7)	12 (19)	12 (45)
Pocket or flap	Flap	Pocket	Flap	Flap	Flap	Flap	Pocket
Mean depth (µm)	180	230	200	180	180	150	332
Pre UDVA	20/20	20/16	20/20	0.30 ± 0.29	-0.03 ± 0.12	-	20/25
Pre UIVA	20/35	20/32	-	-	-	-	-
Pre UNVA	J8	20/63	20/50	0.90 ± 0.21	0.70 ± 0.32	-	20/50
Pre SE	-	0.06 ± 0.26	0.09 ± 0.22	1.48 ± 0.46	0.27 ± 0.46	0.07 ± 0.30	0.30 ± 0.30
Post UDVA	20/20	20/20 (79%)	20/25	-0.04 ± 0.11	-0.07 ± 0.10	20/32 or better	36% 20/25 or better
Post UIVA	20/26	20/25	-	-	-	-	-
Post UNVA	J2/3	20/25	20/20	0.18 ± 0.11	0.10 ± 0.12	20/22 to 20/23 or better	76% 20/25
Post SE	-	-0.11 ± 0.53	-0.25 ± 0.87	-0.75 ± 0.93	-0.59 ± 1.18	-	-1.20 ± 0.28

Table 3.

	Waring. *J Refract Surg.* 2011[1]	Seyeddain. *JCRS.* 2013[2]	Yilmaz. *JCRS.* 2012[3]	Tomita. *JCRS.* 2012[4] (Hyper)	Tomita. *JCRS.* 2012[4] (Emme)	Garza. *JRS.* 2013[5] (Raindrop)	Bouzoukis. *JRS.* 2012[6] (Invue)
N	507	24	39	33	30	20	45
Follow-up (months)	18 (99)	24 (24)	48 (22)	6 (12)	6 (7)	12 (19)	12 (45)
Lines lost CDVA (eyes)	-	0	6 (1 line) 1 (2 lines)	0	0	10	3
Contrast, photopic	Reduced	Reduced	-	-	-	Reduced	Reduced
Contrast, mesopic	Reduced	Reduced	-	-	-	Reduced	Reduced
Visual field	-	Threshold reduced slightly	-	-	-	-	-
Removal	-	0	4	2 recentered in total	-	1 1 replaced	-
ECC	-	No change	-	-	-	-	No change
Complications	-	Epi ingrowth Iron deposit	12% epi ingrowth	Dryness Glare Haloes	(Due to LASIK flap)	1 case severe haloes	Increase aberrations

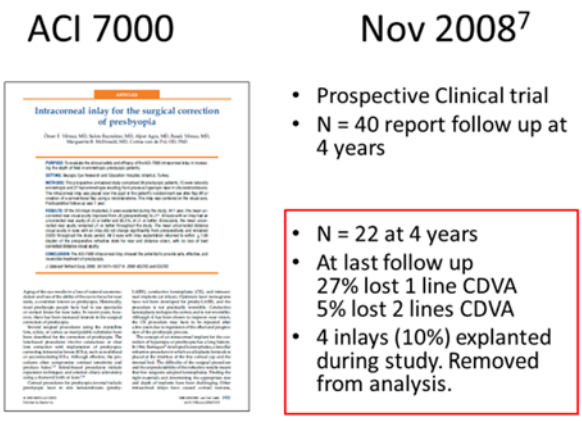

Figure 10.

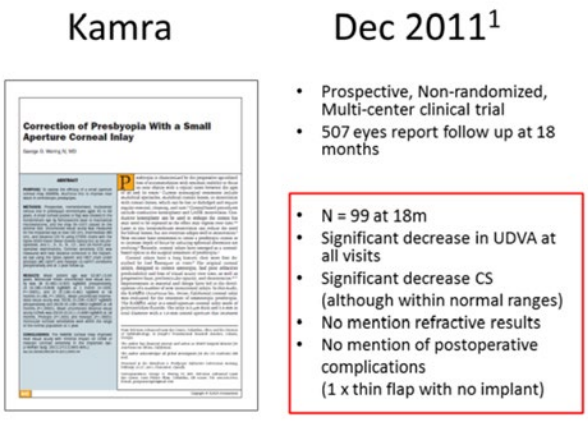

Figure 11.

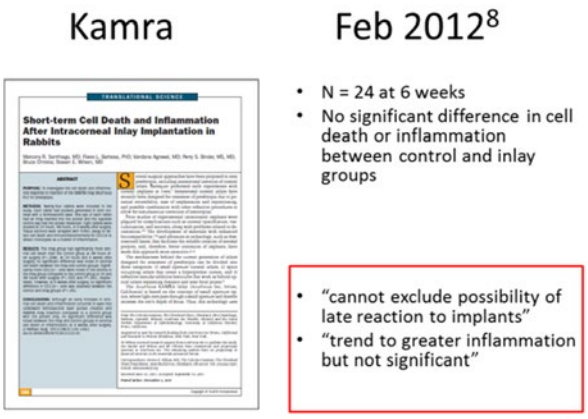

Figure 12.

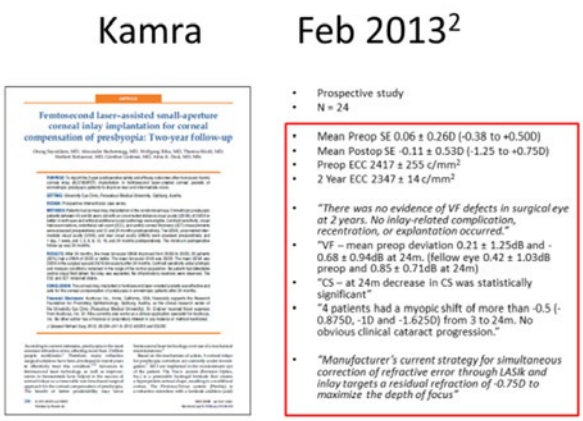

Figure 15.

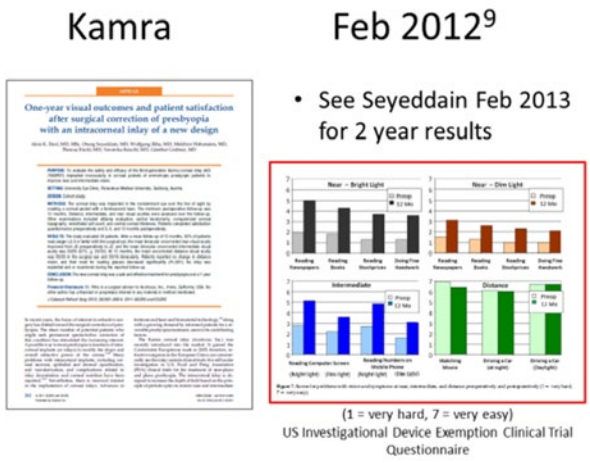

Figure 13.

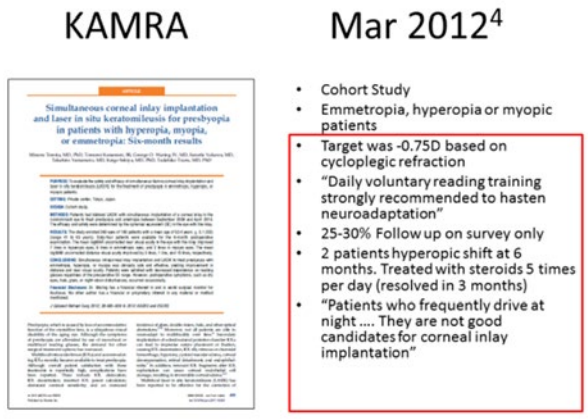

Figure 14.

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Defense: Corneal Inlays Are Excellent

Gunther Grabner MD

I. Intracorneal Implants for Presbyopia Correction

A. Intracorneal microlens systems

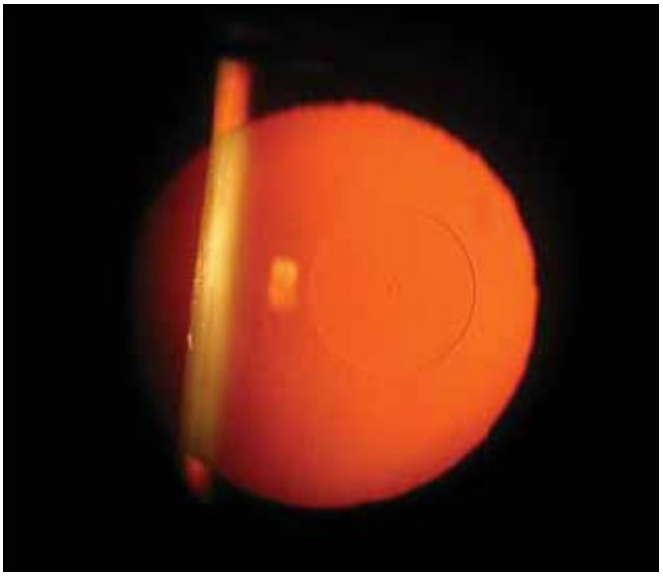


Figure 1.

1. Flexivue Microlens (Presbia; Calif., USA)
2. Raindrop (Presbylens, Vue+, ReVision Optics; Calif., USA)
3. Icolens (Neoptics, CH)
4. About 2000 implanted, small numbers published

B. "Small aperture" procedure

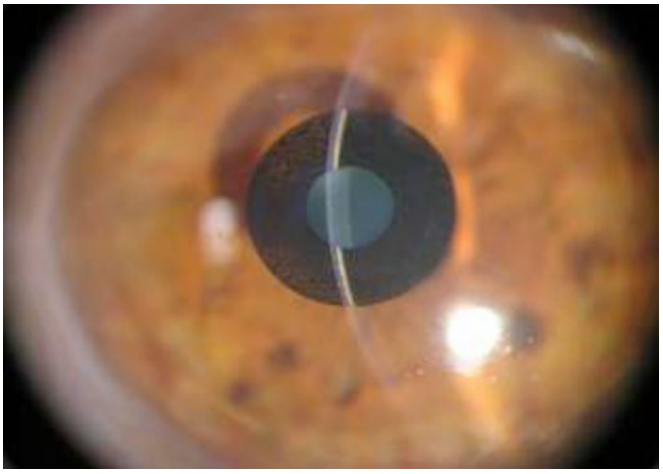


Figure 2.

1. Kamra (AcuFocus)
2. About 1000 cases published
3. 20000 (!) implanted

II. Key Points for Corneal Inlays for Presbyopia

A. Is the principle working?

B. What are the results?

C. Are they stable? Follow-up?

D. Are patients satisfied?

E. Are they safe enough?

F. Are the implants reversible?

G. Do we have enough data?

III. Is the principle working? "Pinhole Effect"

Kamra Corneal Inlay (AcuFocus; Calif., USA)

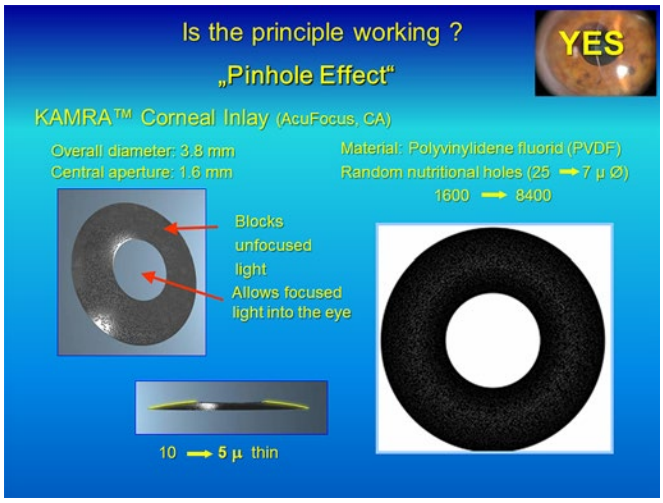


Figure 3.

IV. Depth of Focus Without Correction

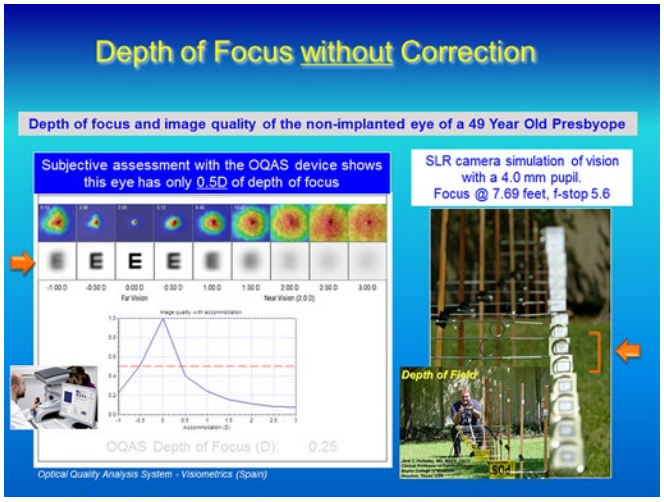


Figure 4.

V. Depth of Focus With the Inlay

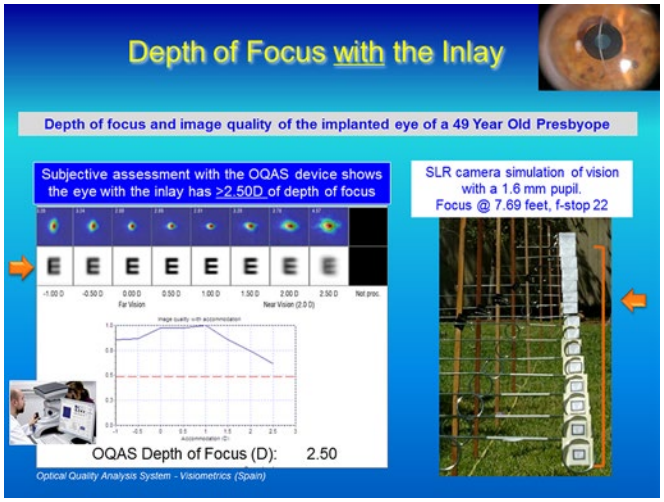


Figure 5.

VI. What are the results?

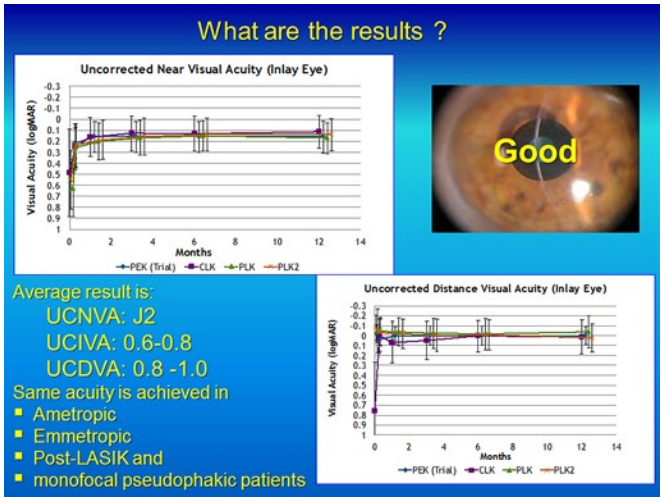


Figure 6.

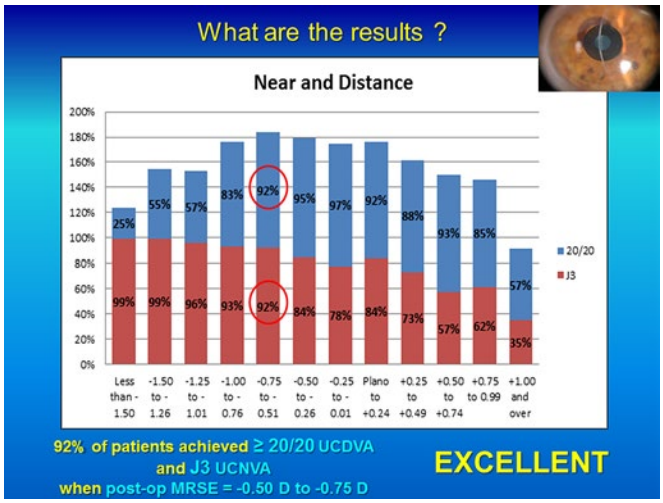


Figure 7.

VII. Are they stable? Follow-up?

A. SALZBURG Early Implant Study data

B. 32 patients; complete 5-year follow-up

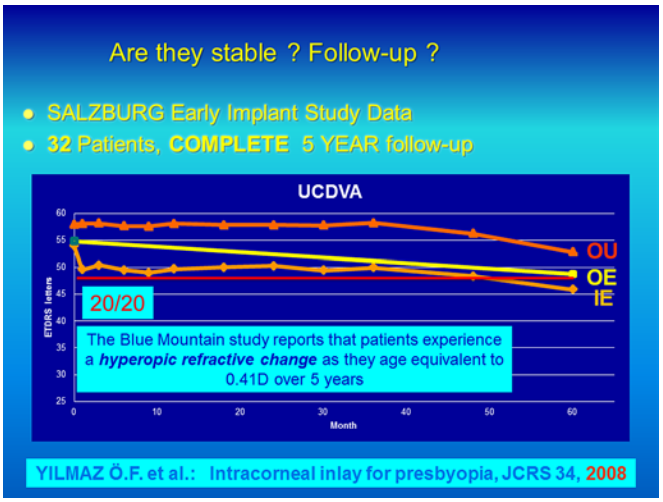


Figure 8.

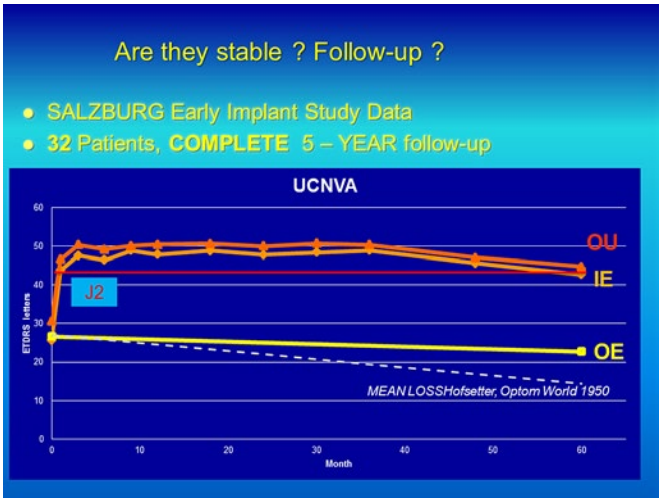


Figure 9.

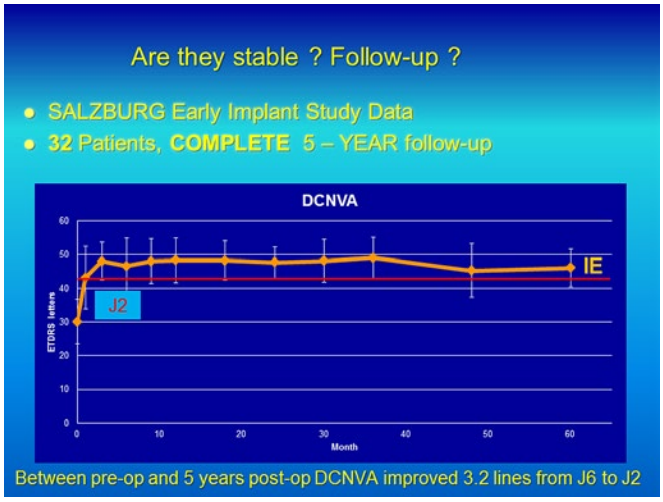


Figure 10.

VIII. Are patients satisfied?

A. Tomita et al reported 1-year satisfaction results at American Society of Cataract and Refractive Surgery 2013 (*N* = 1781)

1. 95% of patients are satisfied with their vision.
2. Reported use of reading glasses limited to:
   a. 6% said "sometimes"
   b. 2% said "often"

B. 5-year satisfaction results (*n* = 30): How would you rate the quality of your near vision? Mean 5.1 (± 1.6) (1 = bad to 7 = very good) Would you have the surgery again?

1. Yes: 26
2. Maybe: 3
3. No: 1

Figure 11.

IX. Are the implants safe enough?

Are the implants safe enough ?

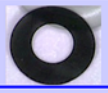
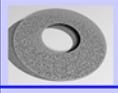
KAMRA™ Inlay Evolution				
Generation	1	2 & 3	4 & 5	FINAL
Material	Dacron	Polymide	Polyvinylidene Fluoride (PVDF)	PVDF
Thickness	25 microns	10 microns	5 – 10 microns	5 microns
Total diameter	3.8 – 4.2 mm	3.8 mm	3.8 mm	3.8 mm
Aperture diameter	1.25-1.8 mm	1.6 and 1.8 mm	1.6 mm	1.6 mm
Light transmission	N/A	10-18%	7-10%	5%
Pore size	Uniform	Uniform	Uniform	Variable
Pore pattern	Square	Hexagonal	Random	Pseudo-random

Figure 12.

A. Today's inlay are highly biocompatible and support regular corneal metabolic process.

B. Change in surgical technique:

1. Deeper implantation
2. Staged implantation
3. Better laser settings
4. Better target refraction
5. Better centration
6. Better postop treatment
   a. Steroids
   b. Lubricants

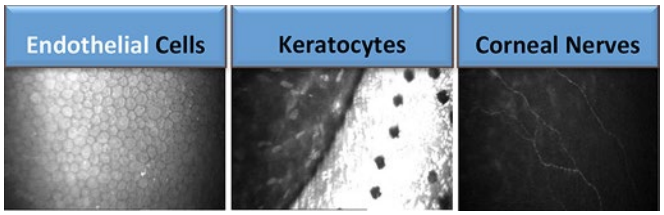


Figure 13.

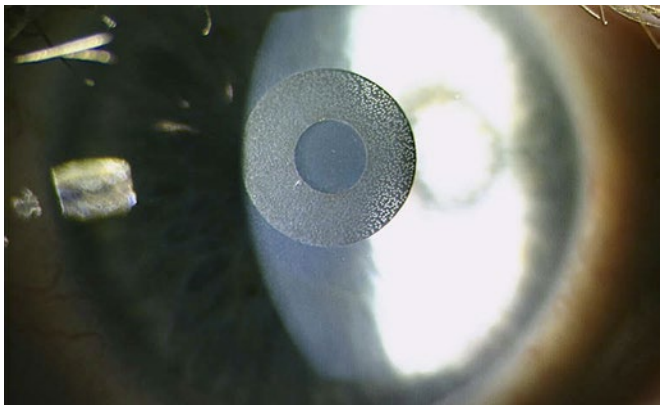


Figure 14.

X. Are the implants potentially reversible?

A. Global Kamra removal rate ~1.3%. Yilmaz et al reported all patients in their Kamra series requiring inlay removal:

1. Patients returned to within ± 1.00 D of their pre-operative refraction after inlay removal.
2. No loss of corrected acuity

B. Removability keeps future options open.

1. After inlay removal, the patient still has options for corneal or lens based presbyopia correction.
2. After PC-IOL removal, the only option for patients is a monofocal IOL.

XI. Expanded Indications

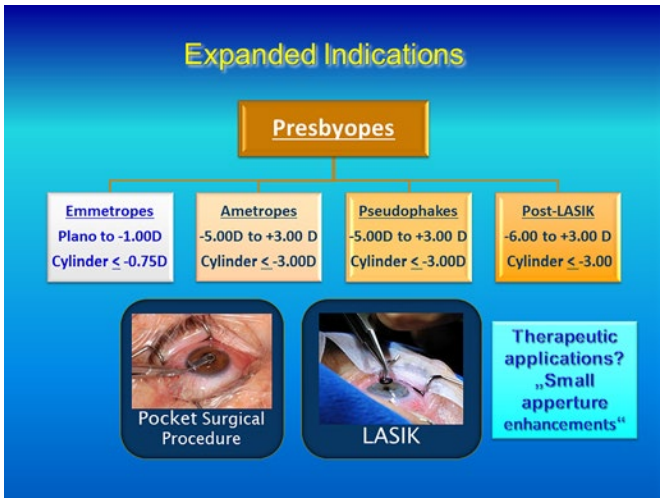


Figure 15.

Single-Optic Accommodating IOLs

Lisa Brothers Arbisser MD

I. Definition of Refractive Cataract Surgery
   A. Cataract surgery as an opportunity to provide rapid and optimal recovery of functional vision
   B. Achieving patient goals
   C. Reducing dependence on spectacles appropriate to the individual risk/benefit profile of the patient

II. Currently FDA-Approved Accommodative Lenses
   A. Crystalens 5-0
   B. Crystalens HD
   C. Crystalens AO
   D. Not approved: Tetraflex

III. Crystalens AT-45: The First FDA-Approved Accommodating IOL (Nov. 2003)
   A. Hinged optic to increase movement
   B. Lengthened haptics to maximize amplitude
   C. 4.5-mm optic to maintain 10.5-mm plate length
   D. 11.5-mm overall length

IV. Crystalens 5-O (Nov. 2006)
   A. 5-mm optic diameter
   B. Parallel plate design
      1. Greater plate coverage
      2. Enhanced optic and plate translation
   C. Square edge
   D. Two lengths
      1. 11.5 mm for powers 17.0 D and above
      2. 12.0 mm for powers below 17.0 D

V. Crystalens HD and AO
   A. Proprietary optic design modification to increase depth of focus while providing a single image to the retina
   B. Add aspheric design

VI. Mechanism of Action

   Accommodation or accommodative arching?

VII. Patient Selection

   Anyone who wants some range of vision without disturbing depth perception except
   A. Moderate myopes who expect near vision
   B. Those at significant risk for need of silicone oil
   C. Significant zonular pathology
   D. Reasons for abnormal ciliary body (accommodative) function
   E. High risk to perform YAG capsulotomy

VIII. Counselling
   A. Distance and intermediate without neuroadaptation
   B. May require blended vision or readers for fine print or extended reading
   C. Not immediate gratification (initial cycloplegia and building of accommodation over time)
   D. High likelihood for YAG capsulotomy early
   E. Increased risk for enhancement for emmetropia
   F. Wear sunglass protection (UV 350 only)

IX. Surgical Tips
   A. Precise continuous curvilinear capsulorrhexis (CCC) perhaps oval to cover hinge but to clear the optic
   B. Totally clean bag (anterior capsule curettes)
   C. Preferred placement 6:00 and 12:00 to get most accommodation effect
   D. Don't stretch the incision: must seal clear corneal incision and paracentesis
   E. Use atropine at close of case, +1.50 readers for 1 week or more?

X. Postop Care
   A. 1% atropine at the time of surgery
   B. Distance vision stable 1 week
   C. Near vision begins to stabilize at 2 weeks
   D. Effects of cycloplegia and dilation subside beginning 3-4 days postop

XI. Ideal Posterior Positioning

XII. CCC Size and Shape: Does It Matter?

XIII. Future
   A. Better accommodative technology? Will the FDA ever approve another?
   B. Improved multifocality? Can we prevent degradation of vision quality?
   C. Greater Depth of Focus IOLs?

XIV. Keys to Premium Channel Success
   A. Selecting the proper patients
   B. Setting realistic, achievable expectations
   C. Flawless surgery
   D. Nailing the correct refractive result
   E. Handling postop issues appropriately

Dual-Optic Accommodative IOLs

Mark Packer MD

Recognizing the limitations of the single optic, axial movement design, Hara et al proposed refilling the capsular bag with a rigid shell, described as two lenses 8 mm in diameter connected by a polypropylene coil spring.[1] This design was later replaced by a pair of inflexible polymethylmethacrylate optics, 6 mm in diameter, connected by 4 peripheral closed polyvinylidene fluoride flexible loops separating the optics by 3.0 mm. The posterior optic was assigned no optical power, and change in the conjugation power of the eye was achieved by anterior and posterior movement of the anterior lens to which was assigned the full optical power of the lens system.[2]

The Synchrony

The Synchrony IOL (Visiogen; Irvine, Calif., USA—acquired by Abbot Medical Optics, Inc.; Santa Ana, Calif., USA, in Oct. 2009) is a dual-optic, silicone, single-piece, foldable, accommodating IOL (see Figure 1).

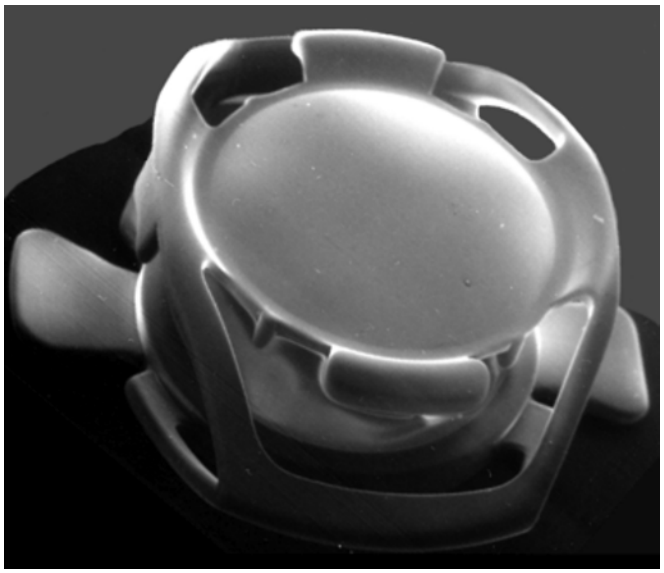


Figure 1. The Synchrony IOL, showing the plus powered anterior optic on top. In the foreground, the haptics springs connect the anterior and posterior optics.

The IOL features a 5.5-mm high-powered anterior optic connected to a 6.0-mm negative power optic by haptics. The mechanism of accommodation potential is based on a lens complex formed by two optics linked by a spring system. With accommodative effort, the zonular fibers relax, releasing the tension on the capsular bag, thus allowing release of the strain energy stored in the interoptic articulations and permitting anterior displacement of the anterior optic. The Synchrony dual optic system represents a promising surgical option for cataract surgery and may enable an extended accommodative range.

Since May 2005, the Centers for Medicare and Medicaid Services (CMS) has allowed beneficiaries to pay out of pocket for services associated with the implantation of presbyopia-correcting IOLs to reduce or eliminate the need for glasses after cataract surgery. In 2005, there were three entries in this category: the Crystalens, a single optic accommodative lens subsequently acquired by Bausch + Lomb; the ReZoom, a refractive multifocal IOL from AMO (now Abbott Medical Optics); and the ReSTOR, a diffractive multifocal IOL from Alcon.

The most complete data on the Tecnis Multifocal demonstrates that 88% of patients implanted in both eyes never wear glasses 4 to 6 months after surgery;[4] a similar study of the ReSTOR +3 and +4 D implants reveals that 76% of patients implanted in both eyes with either design never wear glasses.[5] The original FDA data from the Crystalens AT-45 investigation (completed in 2003) showed that 73% of patients never or rarely wore glasses. The FDA recently approved a toric modification, the Trulign, for improved uncorrected vision at near, intermediate, and distance.

The Synchrony promises to deliver a percentage of spectacle independence closer to that of the Tecnis and ReSTOR without the loss of contrast sensitivity and unwanted optical side effects like halos around lights at night that are part and parcel of multifocal IOL technology. A large body of data from experience outside the United States has demonstrated that the Synchrony may offer a successful alternative here as well. These studies will be reviewed further below. I will also describe imaging studies that have demonstrated movement of the anterior optic of the Synchrony corresponding to the clinical amplitude of accommodation. In addition, I will demonstrate the Synchrony preloaded injector that delivers the dual optic implant through a 3.8-mm clear corneal incision.

The IOL features a 5.5-mm high-plus powered anterior optic connected to a 6.0-mm variable negative power optic by haptics that have a spring-like action. In order to respond to ciliary body action, energy must be stored and released in the system. The mechanism of action of this lens is based on a lens complex formed by 2 optics linked by a spring system that, at rest outside of the confines of the capsular bag, produce an outward force separating the axes of the optics by approximately 3.7 mm. When implanted within the capsular bag, intracapsular tension compresses the optics, reducing the interoptic separation; that is, the resting ciliary body maintains zonular tension that is transmitted to the bag producing outward circumferential movement of the equator, axial shortening of the capsular bag, and thus compression of the lens complex, resulting in the storage of strain energy in the connecting arms. Elements are incorporated to control minimum separation, thus setting the resting distance refraction at emmetropia. With accommodative effort, the zonules relax, releasing the tension on the capsular bag, thus allowing release of the strain energy stored in the interoptic articulations and anterior displacement of the anterior optic. The posterior element is designed with a significantly larger surface area than the anterior, thus reducing the tendency toward posterior axial excursion and maintaining stability and centration within the capsular bag during the accommodation-disaccommodation process.

The optical power of the anterior optic is +32.0 D, well beyond that required to produce emmetropia; the posterior optic

is assigned a variable diverging power in order to return the eye to emmetropia. The overall length of the device is 9.5 mm and its width is 9.8 mm. When compressed, the total lens thickness is 2.2 mm. The optical principle behind this lens design relies on axial displacement of the anterior optic.

Ray tracing analysis software (ZEMAX, Focus Software, Inc.; Tucson, Arizona, USA) using a theoretical eye model has been used to analyze the expected optical effect of axial movement of this IOL when positioned at the posterior capsule plane.[3] Ray tracing analysis suggested that anterior movement of the anterior optic of a dual optic IOL design with a high-power anterior converging lens and a compensatory posterior diverging lens produces significantly greater change in object distance compared to similar displacement of a single optic IOL. For example, a 1-mm anterior axial movement of a single optic 19 D IOL would produce a refractive power change of the eye of approximately 1.2 D. However, for a dual optic system placed in the same model eye, assuming an anterior +32 D lens separated by 0.5 mm from a posterior -12 D lens, 1 mm forward displacement of the anterior convex lens is calculated to produce a refractive change of approximately 2.2 D. Based on the optical calculations described above, it is evident that a greater change in refractive power per unit axial displacement can be generated by choosing a more powerful anterior lens, but the advantages of increased accommodative range must be weighed against the increased optical sensitivity of the system. The power of the IOL is calculated by means of proprietary algorithms based on axial length, keratometry, anterior chamber depth, and lens thickness. These algorithms have been constantly improved in order to decrease deviation from target refraction.

Studies performed in laboratory settings using rabbit and human cadaver eyes demonstrated that this lens could be implanted without distortion or ovalization of the capsulorrhexis and the capsular bag. Folding and implantation into human cadaver eyes via a 4-mm clear cornea wound was confirmed. In one such experiment, a standard phacoemulsification clear corneal incision was created in a cadaver eye. A metal blade was used to create a 4.0-mm groove at the limbus and a shelved 2-mm entry into the anterior chamber created using a metal 3.2-mm keratome. This opening was then widened to approximately 4.0 mm by side-to-side motion of the keratome, and the dimensions of the opening were confirmed with calipers. Without removal of the crystalline lens, ophthalmic viscosurgical device (OVD) was injected to deepen the anterior chamber. The two optics of the IOL were brought together with lens forceps, and the lens was depressed and folded around the forceps into a taco configuration and then guided through the wound into the anterior chamber. The wound width was then remeasured with calipers and found to be approximately 4.0 mm. In two subsequent experiments, phacoemulsification was performed on cadaver eyes, and using the procedure described above, the lens was unfolded within the capsular bag via a 4-mm clear cornea wound.

Recent clinical studies address both the effectiveness and safety of the Synchrony IOL. Galvis et al have presented 5-year follow-up data on 17 eyes of 12 patients implanted with an earlier version of the Synchrony.[4] The follow-up period ranged from 58 to 64 months. Mean age at time of implant was 64.7 years (41-77). All subjects had postoperative UCVA of 20/40 or better for distance and intermediate, whereas 88% achieved this same level of uncorrected vision for near. Using best distance correction, average intermediate acuities measured 20/25 at 6, 12, and 58-64 months, with all eyes better than 20/32. Sequential evaluation demonstrated stability of intermediate acuities. Distance corrected near visual acuities were better than 20/40 in all patients at all study time points over the first 5 years. The mean distance corrected near visual acuity measured 20/25 at 6 and 12 months, and 20/32 at 58-64 months.

The YAG capsulotomy rate for this cohort was 5.8% (1 of 17 eyes) over the span of the study period. There was no evidence of interlenticular opacification on slitlamp exam. The single YAG capsulotomy was required in 1 eye close to the third year of follow-up. This capsulotomy was performed according to the protocol as a small, rounded, low energy capsulotomy. Following capsulotomy the distance corrected acuities measured 20/20 at distance, 20/25 at intermediate, and 20/32 at near, showing persistence of the accommodative effect.

Ossma et al recently presented a multicenter randomized prospective double masked clinical trial of cataract patients 40 years or older undergoing bilateral surgery.[5] Patients were randomized to receive bilateral implantation with the Synchrony dual optic accommodating IOL (Group I, $n = 44$) or a diffractive apodized multifocal IOL (Group II, $n = 48$). Follow-up visits included 1 day, 1 week, and 1, 3, 6, and 12 months postoperative. At each of the follow-up visits standardized visual testing was undertaken at 30, 40, 50, 60, 80, 100, 200, and 400 cm with and without correction. Reading speed was measured with the Spanish MN Read chart, and contrast sensitivity was determined using the Optec 6500 device. Near uncorrected acuity was 20/40 or better in 88% and 91% of subjects in Groups I and II, respectively. There were statistically significant differences in mean binocular best-distance corrected acuities at 60, 80, 100, and 200 cm (at 80 cm: -0.03 and 0.23 logMAR [$P < .01$] respectively). Similar inference values were obtained for this analysis at 60, 100. and 200 cm. See Figure 2.

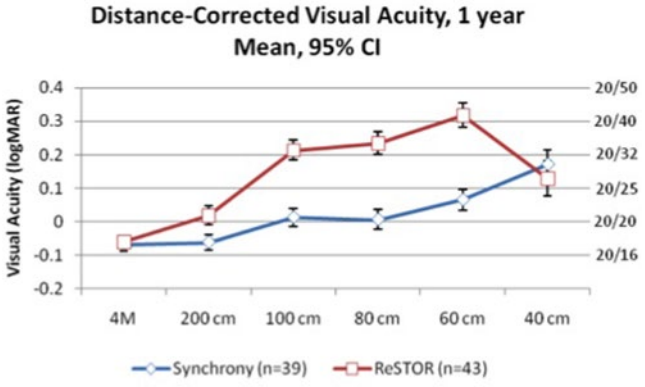


Figure 2. Mean binocular distance corrected visual acuities for subjects implanted bilaterally measured at a range of viewing distances for Synchrony and ReSTOR (+4 D).

Contrast sensitivity showed differences at all spatial frequencies for all lighting conditions between the two groups ($P < .01$). Reading acuity in Group I was significantly better than in Group II at 60, 80, and 100 cm ($P < .01$) and similar at other distances.

Bohorquez et al have presented data on reading speed at 1 and 2 years in patients implanted binocularly with the Synchrony dual optic accommodating IOL.[6] In their prospective, noncomparative series of cases, a high-contrast reading speed chart in Spanish based on the MN Read chart was used. Font size and style were maintained. Sentences contained 60 characters divided into 3 text lines, 10 standard words per sentence. Patients were tested at 40 cm, at a constant luminance (85 cd/m2). Distance

corrected near visual acuity (DCNVA) and reading speeds without near add were evaluated in 19 bilateral Synchrony patients at 1 and 2 years. Reading acuity, critical print size and maximum reading speed were assessed. A 2-way ANOVA showed a significant effect of print size ($P < .05$) and year of testing (2 year better than 1 year; $P < .05$), while the interaction effect was not significant ($P = .14$). Reading acuity was significantly better at 2 years (0.07 logRAD) than at 1 year (0.11 logRAD) (paired t test, $P < .05$). See Figure 3.

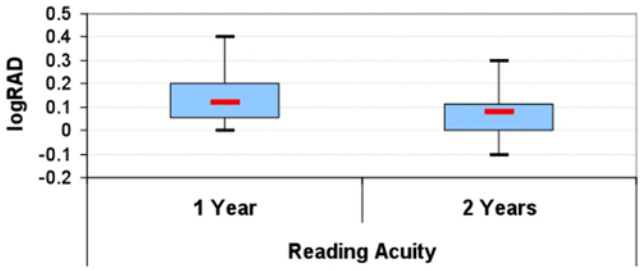


Figure 3. Reading acuity with the Synchrony, showing improvement over the 1 to 2 year interval.

The authors concluded that the Synchrony IOL provides excellent reading ability, which improves over time. This study demonstrates long-term effective functional vision of the dual optic accommodating IOL.

Ultrasound biomicroscopy (UBM) analysis for distance and near has shown evidence of movement of the anterior optic of the IOL after stimulation of accommodation.[7] In a retrospective analysis of 5 Synchrony patients, DCNVA ranged from 0.0 to 0.20 logMAR (20/20 to 20/32 Snellen acuity), push-down accommodative amplitude ranged from 2.76 to 3.22 D, and defocus curve accommodative amplitude ranged from 1.50 to 2.75 D. Objectively, UBM confirmed axial forward movement of the front optic, while iTrace showed dynamic power change in refraction. See Figure 4.

Because of the potential impact of capsular contraction and opacification on the function of the Synchrony, Galvis et al undertook a study to compare the long-term rate of objective posterior capsule opacification between dual optic accommodating and single optic monofocal or multifocal IOLs.[8] The structural design of the Synchrony dual optic accommodating IOL theoretically fills the capsular bag and should therefore reduce the appearance of posterior capsule opacification (PCO) by permitting continuous circulation of aqueous through the interior of the lens capsule. However, PCO or other elements of bag fibrosis could significantly hinder the function of an accommodating IOL. In their prospective clinical study of 139 eyes implanted with the dual optic accommodating IOL (Group I, $n = 43$) a hydrophobic acrylic monofocal IOL (Group II, $n = 54$), or a hydrophobic acrylic diffractive apodized multifocal intraocular lens (Group III, $n = 42$), digital retroillumination slitlamp photographs were taken by a trained technician under a standardized protocol at 6, 12, and 24 months after IOL implantation. PCO severity was analyzed using the Aslam Analysis System.[9] A subjective grading system was employed to assess anterior capsule opacification (ACO) in the 3 groups.

The mean Aslam Scores at 6 months were 0.343, 0.69, and 0.78 in Groups I, II, and III respectively ($P = .67$, Mann Whitney

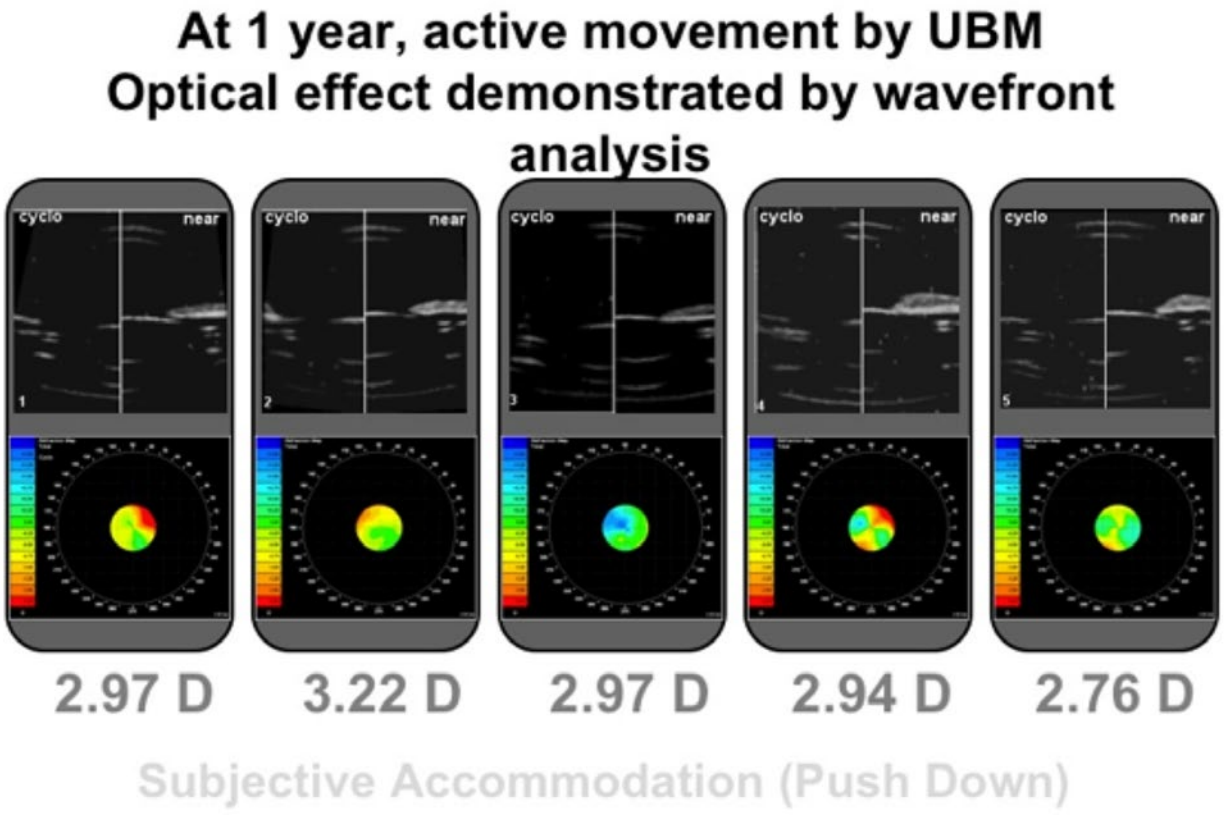


Figure 4. UBM demonstrates consistent movement of the anterior optic of the Synchrony posteriorly with cycloplegia and anteriorly with accommodation. Corresponding changes in total ocular refractive power are documented with wavefront aberrometry.

test). At 24 months, mean PCO scores were comparable for all 3 groups (1.61, 2.32, and 2.49, respectively; $P = .41$, Mann-Whitney test). The incidence of moderate or severe ACO was higher in Groups II and III (16.7% and 19%, respectively) compared to Group I (9.3%).

Galvis concludes that capsule compatibility of the dual optic accommodating IOL is comparable to that of monofocal and multifocal hydrophobic acrylic IOLs. The incidence of fibrotic changes in the anterior capsule is lower for the dual optic accommodating IOL, which could benefit the persistence of the long-term effect of this technology. See Figure 5.

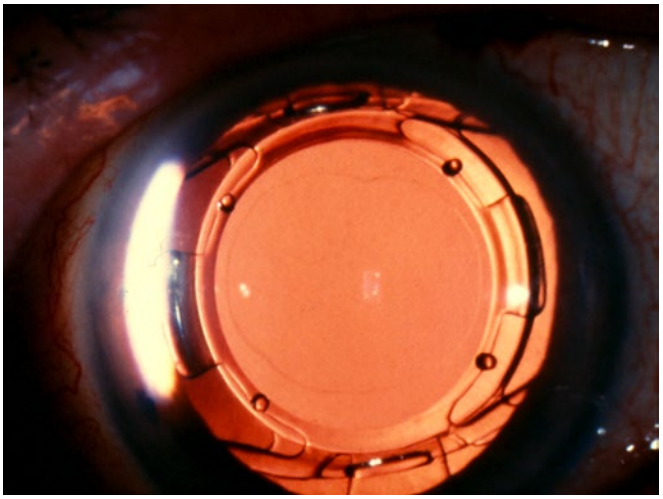


Figure 5. Retroillumination of the Synchrony demonstrates a typically clean capsule at 3 years postop.

Current accommodating IOLs might be expected to provide superior image quality compared to multifocal lenses since competing retinal images are avoided, but as described above, the accommodative range of a single rigid optic design that depends upon axial displacement of the optic is limited by the range of excursion generated. The Synchrony dual optic accommodative IOL allows the extremes of distance and near focus characteristic of multifocal designs, but additionally offers improved function at intermediate distances, and offers superior image quality at all object distances. It is important to emphasize the significance of a properly sized and intact continuous curvilinear capsulorrhexis, meticulous cortical cleanup, and in-the-bag placement of the IOL to achieve the levels of accommodation reported in the various studies summarized here.

The Synchrony IOL is a new alternative for presbyopia correction in the setting of cataract surgery and in the field of refractive lens exchange. Refractive lens exchange is increasingly seen as an advantage over cornea-based refractive procedures, especially in those over 45.[10] The function of the dual optic offers the opportunity to achieve accommodative amplitude of 3-4 D by virtue of its increasing power. This represents a huge technological leap in the advancement of cataract and refractive surgery for the worldwide aging population. To optimize surgical outcomes with the dual optic IOL design (as with any other new IOL technology), I would emphasize the importance of careful patient selection, adequate and consistent biometry method for accurate power calculation, and the implementation of a consistent surgical technique: CCC size and shape, complete cortical cleanup, anterior capsule polishing, in-the-bag IOL implantation, and rigorous postoperative regimen. Further large number studies with longer follow-up are necessary for final estimation.

Conclusion

Emmetropia and full accommodation remain the goal of refractive cataract and lens surgery. Already we've witnessed dramatic advances in the field, from a time a little over 10 years ago when just a single zonal refractive multifocal IOL was available in the United States, to today's array of refractive and diffractive multifocal and single and dual optic accommodative designs. In addition, innovative designs continue in development. We're fortunate to have the opportunity to investigate and provide these lenses to our patients; our patients truly reap the rewards of a spectacle-free life style.

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New Designs
New Accommodative IOLs

Jorge L Alio MD PhD

Presbyopia is a physiological degradation of the accommodation process, and its surgical correction remains as one of the last frontiers of refractive surgery. The complexity of the accommodation process and the multifactorial basis for the development of presbyopia makes it difficult to manage adequately. The population who reach presbyopic age, especially in western countries, is continuously increasing in number, making many hundreds of thousands and millions around the world candidates for this surgery. Therefore, presbyopic surgery must be considered as one of the most important challenges that a refractive surgeon faces today and also in the immediate future.

The "real" surgery of accommodation still does not exist today. Accommodation is the change of power of the crystalline lens associated with the active action of the ciliary body. Pseudoaccommodation is any other method that changes the power of the whole optical system of the eye or changes partly the way in which it functions to relieve patients for near. However, this is not a real and complete restoration of accommodation.[1,2] For the above-mentioned reasons, all the surgical techniques that have been proposed today for the surgical correction of presbyopia are based on the induction of pseudoaccommodation.[1]

Accommodating IOLs have been approached for a long time, but with limited success. Different models were developed with the aim of providing some accommodative capability and some functional near vision after cataract extraction. These IOLs were designed without near addition power and multifocality technology to reduce the photic phenomena induced by multifocal IOLs. The first developed and marketed accommodating IOLs were positional, and there are two main types: single optic and dual optic accommodative IOLs. Single-optic IOLs are based on the forward movement of the optic with ciliary muscle contraction to provide near focus.[3-5] Several single-optic IOL models and one dual-optic accommodative IOL has been developed, but with very little or no success. In independent studies preferred by us it was shown that the near visual outcomes with the IOL model more recently available were very limited when compared to a monofocal IOL.[6,7] So the development of new accommodating IOL models based on new technological approaches is still an unsolved challenge.

At present, the development of new accommodative IOLs is following two different approaches: those lenses still using in-the-bag support and those using sulcus support.

In-the-Bag Accommodative IOLs

In-the-bag accommodative IOLs involve projects such as the Flex-Optic IOL (Advanced Medical Optical), the Fluid Vision Lens (Power Vision, Inc.), and the Electroactivable Zaphir lens of the Elenza Project (Elenza Co.) The outcome of all these lenses may be affected by the same problems of the previous in-the-bag models, which both dual-optic and single-optic have been presenting: the lack of adequate control of anatomical behavior of the capsule, once it is opened and emptied, which leads to fibrosis and the blockade of the performance of the lens. These problems seem to be the major limitation of these IOL technologies. The Elenza project may be the one with a greater potential for success, as its electroactivated mechanism does not involve active ciliary body action. None of these lenses have provided data about clinical outcomes.

Sulcus-Based IOLs

Those IOL projects based on sulcus implantation may be free from capsular problems. These technologies are at this moment able to provide data corresponding to clinical studies on humans. These technologies are the Nulens Dynacurve and the Akkolens Lumina.

Sulcus-based lenses are using the forces generated by the ciliary body and transmitted to the anterior capsule, and they work independently from posterior capsule integrity. Basically, the vectorial forces used can be making the lens accommodate either changing power by increasing the pressure or by a silicone chamber, creating the change in the curvature of a silicone membrane, located posteriorly (Nulens technology)[8,9] or causing a shift of two optics by displacing one onto the other on the frontal plane (Akkolens technology). Both these IOL technologies have offered recent clinical data on outcomes obtained in clinical studies.

During this presentation, the most recent achievements of these technologies will be summarized, along with the most recent data of the latest ongoing clinical studies.

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Prosecution: Accommodating IOLs Are Not the Ideal Solution

Oliver Findl MD

Accommodating IOLs based on the concept of optic shift were introduced to restore accommodation after cataract surgery. Currently, several types of accommodating IOLs are commercially available, most of which have 1 optic.

Of these trials, most were performed on the 1CU (HumanOptics) and the AT-45 Crystalens (B+L). In a meta-analysis of the peer-reviewed literature, data from studies of these IOLs that use optic-shift measurements and visual acuity as the main outcome measures was extracted (Findl et al., *J Cataract Refract Surg*. 2007; 33:522-527).

In 6 randomized controlled studies, 5 of which studied the 1CU IOL, the visual acuity results showed moderate to no improvement in near visual acuity compared with control IOLs and a statistically significant, but small and interpatient variable anterior shift of the IOL optic after pilocarpine stimulation.

More clinical trials with randomized, controlled, and patient- and examiner-masked study designs that follow the guidelines of evidence-based medicine are needed to prove a benefit of accommodating focus-shift IOLs.

Defense: Accommodating IOLs Are Excellent!

Steven J Dell MD

Accommodating IOLs offer a favorable risk–benefit equation for a large portion of individuals seeking spectacle independence after cataract surgery. Options for pseudophakic presbyopia correction include multifocal IOLs, accommodating IOLs, monovision correction with standard IOLs, and various combinations of all the above. Multifocal IOLs typically demonstrate superior distance-corrected near acuity when compared to accommodating IOLs; however, this is always at the expense of visual quality. The optical function of a multifocal requires that incoming light be split into near and distance foci, inevitably leading to degradation of optical quality when compared to a monofocal IOL. Accommodating IOLs utilize a monofocal optic. While these IOLs do not match the degree of near acuity found in a multifocal, accommodating IOLs provide optical quality that matches a standard IOL, while providing improved near function.

Accommodating IOLs have been commercially available for over a decade, and they are currently available in both toric and nontoric varieties. The only USFDA-approved accommodating IOLs are the Crystalens and the Trulign IOL (Bausch + Lomb). The mechanism of action of accommodating IOLs remains controversial. The initial hypothesis regarding the function of these lenses centered on anterior-posterior translational movement. Studies of the degree and even the direction of this translational movement have yielded conflicting results. Other investigators have concluded that accommodating IOLs provide their added near function through a combination of translational movement, tilting of the optic, and flexion of the optic itself. Regardless of the actual mechanism of action, it seems clear that these lenses outperform standard IOLs with regard to near vision.

Long-term data suggest that the accommodation function of the Crystalens persists for many years. In a study examining patients who had been implanted up to 7 years prior, 98% of bilaterally implanted Crystalens patients could read J3 or better. These results surpass the original performance of the Crystalens during the FDA trial, suggesting improved function over time.

Multifocal IOLs function suboptimally in patients with compromised macular function from AMD, diabetic maculopathy, or epiretinal membranes. Reduced contrast sensitivity from advanced glaucoma is another relative contraindication to multifocal IOL use, as is irregular astigmatism from severe dry eye syndrome or various other conditions. Thus, of patients seeking presbyopia-correcting IOLs, a meaningful percentage of potential patients are either currently noncandidates or will become noncandidates for multifocal IOLs in the future. It is impossible to identify those individuals who currently seek presbyopia correction now who will become noncandidates later. In this regard, accommodating IOLs provide a stark contrast to multifocals in terms of optical quality.

A valid criticism of accommodating IOLs is the inability of current designs to provide sustained near reading ability when both eyes are targeted for distance. For example, most clinicians using the Crystalens feel that their patients achieve approximately 1 to 1.5 D of sustained accommodation. While this provides quite good intermediate vision, it is not sufficient for high grade near reading. To achieve sustained near reading, it is necessary to use approximately 0.75 D of defocus, typically in the nondominant eye. Using this strategy provides a very high degree of spectacle independence while preserving excellent optical quality.

Selected Readings

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Diffractive Multifocal IOLs

Bonnie A Henderson MD

I. Background and Evolution
   A. First generation of multifocal IOLs, introduced in 1987 by 3M
      1. Convex-concave initial design
      2. Later became biconvex design
   B. Apodization of diffractive multifocal IOL
   C. Aspheric optic with multifocal

II. Types of Diffractive Multifocal IOLs
   A. Apodized central zone
   B. Full optic zone
   C. Asymmetric
   D. Brands
      1. Alcon ReSTOR
      2. Abbott Medical Optics Tecnis MF
      3. Carl Zeiss Meditec AG Acri.Lisa 366D
      4. Hanita SeeLens MF
      5. Physiol IOL
      6. FineVision IOL
      7. Ari. Tec TwinSet

III. How They Work
   A. Separates light into 2 different focal points for distance and near
   B. Different distributions of energy
   C. Generates interference pattern based on Fresnel principle

IV. Associated Problems
   A. Loss of contrast sensitivity
   B. Dysphotopsias
   C. Focal length
   D. Decentration
   E. Pupil size

Refractive or Zonal Multifocal IOLs

Jan A Venter MD

I. Presbyopia-Correcting IOLs
   A. What IOLs are available?
      1. Diffractive
      2. Refractive
      3. Hybrid refractive-diffractive
      4. Pseudo-accommodating
   B. Problems with presbyopia correcting lenses
      1. Unwanted optical side effects, glare, halos, reduced contrast sensitivity[1,2]
      2. Careful patient selection necessary

II. New Concept of Rotational Asymmetry: Zonal (Segmental) Refractive IOLs
   A. Traditional concept of rotationally symmetric IOLs
      1. Images generated in circles over 360°
      2. Scattering of light, approximately 20% loss of energy
      3. Overlapping images, glare and halos
   B. Rotationally asymmetric IOLs
      1. Only one inferior sector for near vision; the rest of the lens is monofocal.
      2. Presence of only one transition zone between the aspheric distance vision zone and the inferior sector-shaped near-vision zone
      3. In theory, the new concept should provide better contrast sensitivity, less duplication of images, and decreased night vision phenomena.
      4. Two available models on the market
         a. Lentis Mplus
         b. Lenstec SBL-3 (no clinical studies available yet)

III. Results With Zonal Refractive IOLs: Lentis Mplus Lens
   A. Over 12,000 Lentis Mplus lenses implanted in our practice
      1. Unaided near visual acuity (UNVA) 0.154 logMAR (binocularly), 0.213 logMAR (monocularly) at 3 months; 92.1% binocular UNVA of J3 or better
      2. Mean monocular UDVA 0.049 logMAR at 3 months; 80.1% achieved binocular UDVA of 6/6 or better
      3. Severe difficulty with night driving reported in 4.6% of patients.
      4. IOL exchange due to severe night vision phenomena in 0.5% of eyes.
   B. Comparison with other multifocal IOL designs
      1. Summary of literature on multifocal lenses[3] used in the past decade found mean UNVA of 0.082 logMAR for diffractive IOLs and 0.217 logMAR for refractive IOLs and 0.064 logMAR for ReSTOR lens analyzed separately. Lentis Mplus IOL has reading performance similar to refractive lenses with the mean monocular UNVA 0.213 and mean binocular UNVA of 0.154 at 3 months.
      2. Mean UDVA in the same study[3] was 0.105 logMAR for diffractive IOLs, 0.085 logMAR for refractive IOLs, and 0.067 logMAR when the ReSTOR lens was analyzed separately. The mean monocular UDVA with Lentis Mplus was 0.049 logMAR, which is slightly superior to previously published studies.

IV. Published Literature on Lentis Mplus
   A. Reported range of mean UNVA: 0.08 logMAR to 0.3 logMAR[4-13]
   B. Reported range of mean UDVA: 0.00 to 0.26 logMAR[4-13]
   C. Adequate intermediate vision confirmed in previous studies
      1. 76% of eyes with Lentis Mplus lens had intermediate visual acuity of at least 6/12 or better at 3 intermediate distances (70 cm, 1 m, 2 m).[4]
      2. Good range of vision at defocus levels equivalent to intermediate vision found with bilateral Lentis Mplus,[5] with the mean value of 0.3 logMAR.
   D. Contrast sensitivity
      1. Comparison of monofocal IOL and Lentis Mplus found no difference in contrast sensitivity under photopic and low mesopic conditions.[6]
      2. A study comparing Lentis Mplus and Acri.Lisa[7] found significantly better values in photopic contrast sensitivity at high spatial frequencies with the Lentis Mplus IOL.
      3. Study[8] comparing contrast sensitivity of the Lentis Mplus and the AcrySof ReSTOR SN6AD1 (+3.00 near add) found statistically significantly better contrast sensitivity with the ReSTOR IOL under photopic conditions but no difference under mesopic conditions. On the other hand, another study[9] compared the Lentis Mplus IOL with the ReSTOR SN6AD3 IOL (+4.00 near

add) and found photopic contrast sensitivity was significantly better with the Lentis Mplus IOL.

V. Summary

A. There is no ideal IOL model that provides excellent near, intermediate, and distance visual acuity without possibility of glare, halos, and reduced contrast sensitivity.

B. Continuous improvements in IOL technology try to minimize unwanted optical side effects but are unable to eliminate them completely.

C. Development of zonal refractive IOLs brings a new concept to the presbyopia-correcting IOLs.

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Trifocal IOLs

Damien Gatinel MD

Justification of Trifocality

Bifocal diffractive IOLs allow operated patients to some spectacle independence for distance and near (between 35 and 40 cm) vision. These lenses, however, have not been shown to provide satisfactory intermediate vision. Studies assessing visual acuity as a function of viewing distance in patients implanted with bifocal IOLs have shown a characteristic V-pattern, with 2 peaks corresponding to near and distance vision, plus a gap in between for intermediate vision.[1,2] Low-addition bifocal IOLs improve intermediate vision relative to higher-addition bifocal IOLs, but despite this improvement, the intermediate-distance range in such bifocal IOLs is still penalized.[1,2]

Intermediate vision relates to activities such as computer work, car driving (instrument panel), music playing (musical chart), etc. In these activities for which good uncorrected vision is required for distances comprising between 60 and 80 cm, glasses may be required despite satisfactory near and distance uncorrected vision.

A pioneering solution was proposed in 2010 with the introduction of the first trifocal diffractive lens (FineVision, Physiol; Belgium).[3] This 25% hydrophilic acrylic IOL has, in addition to a near foci (+3.50 D), a foci for intermediate vision (+1.75 D) to provide treated patients with a full range of correction. A second diffractive IOL model (+3.33 D near add and +1.66 D intermediate add at the IOL plane) was introduced later in 2012 (AT LISA tri 839MP, Zeiss; Germany).

Trifocal Diffractive Design

The FineVision lens has a patented trifocal design, which combines 2 different apodized bifocal diffractive profiles that result in 3 foci. This IOL comprises 2 embedded kinoform patterns: the first one is designed with a +3.50 D addition (for near vision) at the first diffraction order, and the second one is designed with a +1.75 D addition (for intermediate vision) at the first diffraction order, and +3.50 D at the second order (which contributes to the near vision) (see Figure 1).

Therefore, the second order of the second diffractive pattern is used to reinforce approximately 5% of near vision (add +3.5 D), as afforded by the first order of the first diffractive pattern. As a result, the percentage of lost energy, which is usually 20% for standard diffractive bifocal lenses, is reduced with this IOL to approximately 14%. The relative gain in terms of saved energy is approximately 25% when compared with standard diffractive IOLs.

The IOL profile is also gradually attenuated throughout the entire optic, resulting in a continuous modulation of the light energy distribution directed to the 3 primary foci. As the step height decreases toward the periphery (apodization), when the pupil aperture becomes larger, the peripheral steps are progressively exposed. This results in an increasing amount of light dedicated to the distance vision. Hence, less light is recruited for the near and intermediate focal points. This gradual decrease of the step height from center to periphery has been shown to reduce halos, which are generated by defocalized light under dim conditions.

The light scattering on the step edges can be decreased by their smoothing. Theoretically this can be done by adding a mathematical smoothing function, called "convolution." This function was optimized to fit the lens profile as manufactured, according to the geometry of the cutting tool used in current lathing technology.

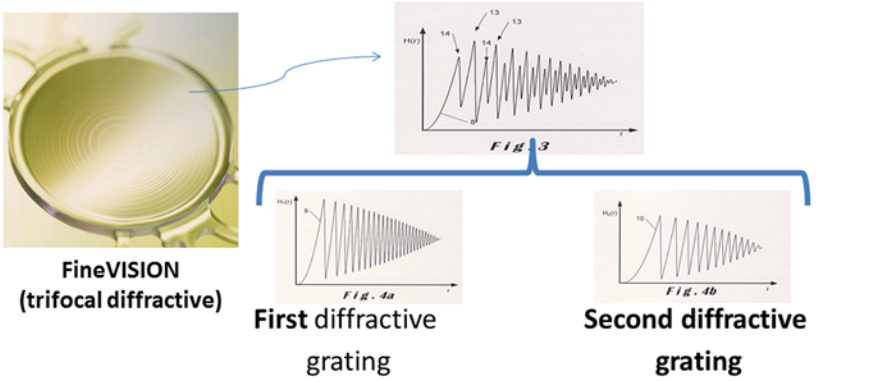

Figure 1. In this IOL design (FineVision), the first kinoform pattern is designed with an add of 3.50 D as the first diffraction order. Therefore, the second diffraction order occurs at a vergence of 7.00 D, which corresponds to lost light. The second kinoform pattern has a vergence of +1.75 D in the first order, providing an add of 1.75 D; the second order has a vergence of 2×1.75, that is, 3.50 D. The vergence of the first order of the second profile is half of the first profile add power; hence, its first order contributes to intermediate vision and its second order enhances near vision. Therefore, the second order of the second diffractive pattern is used for near vision (add +3.50 D), as afforded by the first order of the first diffractive pattern. As a result, the percentage of lost energy, which is usually 20% for standard diffractive bifocal IOLs, is reduced with this IOL to approximately 15%. The relative gain in saved energy over standard diffractive IOLs is approximately 25%. The IOL profile is gradually attenuated throughout the entire optic (the step height decreases toward the periphery), resulting in a continuous change of the light energy distribution directed to the 3 primary foci.

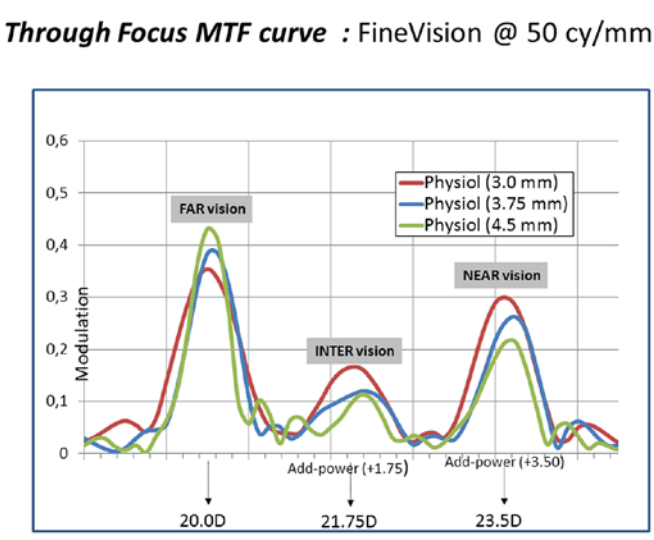

Figure 2. A third peak appears in the FineVision IOL through-frequency at +1.75 D, which corresponds to the foci allocated for intermediate vision. As a result of apodization, the percentage of light energy allocated to the far vision increases with larger apertures at the expense of the percentage of light energy allocated to the near and intermediate vision.

The lens has a biconvex-aspheric optics with a spherical aberration induction of -0.11 µm for a 6.0-mm pupil. The IOL's overall diameter is 10.75 mm, whereas the optic zone's diameter is 6.15 mm. The lens is available from +10.0 to +30.0 D in steps of 0.50 D. The FineVision IOL also incorporates a UV and blue-light blocker.

The AT LISA tri 839MP IOL has a trifocal diffractive design, the working principles of which have not been disclosed. It is claimed to provide a +3.33 D near add and a +1.66 D intermediate add at the IOL plane, with an asymmetric light distribution for far, intermediate, and near focal points. The IOL optic distributes light energy among the 3 focal points within the central 4.34-mm optical zone. Beyond the 4.34-mm zone, the AT LISA tri 839MP IOL's diffractive optic structure is exclusively bifocal (near and distance vision). The lens has an aspheric aberration-correcting design with an overall diameter of 11.0 mm, and a 6-mm optic zone diameter. The IOL is available from +0.0 to +30.0 D in steps of 0.50 D, and it includes a UV blocker.

Image Quality Assessment

The FineVision IOL has been tested using optical benches. Through-focus modulation transfer functions (MTFs) were compared with those obtained with various bifocal IOLs, and the image of the United States Air Force (USAF) target was taken while each IOL was recorded at far, intermediate, and near focal points.[4,5] The through-focus MTF of the trifocal IOL showed a peak in the intermediate range that was not present with monofocal and bifocal IOLs (see Figure 2). The USAF target images showed similar resolution with all IOLs for far focal points. Diffractive IOLs showed better resolution for near focal points, and the only sharp image in the intermediate range was obtained using the trifocal IOL. These results confirm that intermediate vision is more prominent with the trifocal IOL.

Clinical Evaluation

The clinical outcomes and subjective experience 2 months after bilateral implantation of the FineVision diffractive trifocal IOL have been reported.[6] The mean monocular corrected visual acuity (CDVA) was 0.08 logMAR ± 0.08 (SD) and the mean binocular CDVA was 0.06 ± 0.08 logMAR. Defocus curve testing showed an extended range of clear vision from +1.00 to -2.50 D defocus, with a significant difference in acuity between photopic conditions and mesopic conditions at -1.50 D defocus only. Photopic contrast sensitivity was significantly better binocularly than monocularly at all spatial frequencies. Halometry showed a glare scotoma of a mean size similar to that in previous studies of multifocal and accommodating IOLs; there were no subjective complaints of dysphotopsia. Patient satisfaction with uncorrected near vision was assessed using the Near Activity Visual Questionnaire (NAVQ): the mean NAVQ Rasch score for satisfaction with near vision was 15.9 ± 10.7 logits, echoing high level of satisfaction of the patients with their uncorrected near vision.

Conclusion

Trifocality maintains distance and near vision performance while adding a third foci for improving outcomes for intermediate vision. Binocular implantation of trifocal IOLs produces good distance visual acuity and near and intermediate visual function.

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Prosecution: Multifocal IOLs Are Not the Ideal Solution

Thomas F Neuhan MD

NOTES

Defense: Multifocal IOLs Are Excellent

Beatrice Cochener MD

At this time, in the absence of an efficient procedure that could restore accommodation, all the available procedures that could improve near vision are offering only a compensation of the accommodation loss. Multifocal lenses have taken the first place in this strategy of presbyopia management despite their unpopularity, which is based on their poor reputation, especially in quality of vision.

We will defend the concept in showing that the latest generation of multifocal lenses has nothing to do with the initial models in terms of quantitative and qualitative visual performances. Literature nowadays reports a capacity for these lenses to provide spectacle independence in 80% of cases. Thanks to the latest refinements such as the toric version, trifocal optic, this value has even increased up to 90%. We will discuss the advantages and limits of the different concepts, including piggy back implantation, and will try to demonstrate that inadequate results are related to inappropriate indications and poor patient information.

Advantages and Limitations of Corneal Laser Surgery in Presbyopia

Robert Edward Ang MD

The Need

All patients will eventually develop presbyopia. And all of us ophthalmologists will encounter patients in our clinic who want their presbyopia treated. In my practice, approximately 40% of new consultations are 40 years old and above. This population can be divided into three subgroups. About half of my new patients would have eye diseases such as cataract, glaucoma, retina, or other problems. Approximately 20% are looking for a solution to get rid of their eyeglasses. The last 30% came because they want an eye checkup but have normal findings or have minor issues such as fitting for new glasses, dryness, or nonspecific discomforts. The last two subgroups of presbyopic patients present an opportunity that can become a significant revenue driver for any refractive practice. There is no question there is a gap in refractive offerings for presbyopia treatment that is waiting to be filled. The market is there, and it will keep on growing. So to have a relevant refractive practice today, we should be able to offer a safe and effective presbyopia treatment.

The Alternatives

Surgical presbyopia options can be divided into corneal-based treatments, scleral spacing procedures, and lens-based treatments. For corneal laser treatments, we have multifocal ablations such as Supracor (Bausch + Lomb Technolas; Munich, Germany), PresbyMAX (Schwind Eye-Tech-Solutions GmbH and Co.; Kleinostheim, Germany), and pseudoaccommodative cornea (PAC; Nidek Co. Ltd.; Gamagori, Aichi, Japan), or monofocal ablations such as classic monovision LASIK and laser blended vision (Carl Zeiss; Germany). Corneal inlays include the Kamra (Acufocus; California, USA) and Raindrop (Revision Optics; California, USA). Lens-based options entail removing the natural lens (with or without a cataract) and implanting multifocal or accommodating IOLs.

I have had the opportunity of implanting the Acufocus Kamra inlay for the past 4 years and using the Supracor presbyopic algorithm for the past 2 years. I am sharing my experience with Supracor as a corneal laser surgery for presbyopia in this symposium.

Supracor creates a near addition zone 3 mm wide, with approximately 12-µm elevation, surrounded by an aspheric-optimized midperipheral zone. The Supracor LASIK procedure aims to improve near and intermediate vision while maintaining or improving distance vision because it corrects refractive error and presbyopia in a single procedure. From my experience, the ideal refractive target is -0.50 D spherical equivalent, which gives a simultaneous vision of 20/25 for distance and J2 for near vision.

The Advantages

There are numerous advantages of corneal laser surgery as a treatment for presbyopia. First, Supracor and the other multifocal ablations are LASIK-based procedures. Patient awareness is high that LASIK is a high-tech laser procedure that can get rid of their eyeglasses. We are merely extending it to the presbyopia age group. It is accepted as a quick, safe, and painless procedure and thus is easy to market and explain. Second, in terms of surgical technique, there is no learning curve for refractive surgeons. Third, the safety profile is the same as LASIK in terms of risks such as infection and flap problems. Fourth, it is not as invasive as removing the natural lens and implanting an IOL. Fifth, we do not leave a foreign body within the cornea so we do not have to worry about long-term effects of scarring or corneal melt. Sixth, there is a broad application for LASIK-based presbyopia treatments in phakic, pseudophakic, and post-LASIK eyes. Lastly, like conventional LASIK, the presbyopic treatment can be adjusted or even reversed. We have submitted a manuscript detailing a Supracor reversal procedure that we have performed on one of our patients.

The Limitations

The limitations of the corneal laser procedure for presbyopia are important to study if you would like to incorporate these procedures into your practice. First, not all presbyopia algorithms are the same. They are specific to a brand of laser, and the algorithms are proprietary. Performance and outcomes may be variable. And each algorithm may be in different stages of product development. Second, we use standard criteria for LASIK qualification in terms of corneal thickness and topography. If the cornea is thin or suspicious, we disqualify the patient. We have not tried photorefractive keratectomy (PRK) with Supracor. Third, since it is LASIK, therefore, it is possible that regression of refractive outcome or multifocal effect may occur over time. Long-term follow-up is necessary. Fourth, patients will eventually have cataracts. Therefore, the IOL calculation formula would need to be developed. Currently, we take optical biometry readings on all patients to anticipate the need for this data in the future. Fifth, presbyopes are older and therefore are prone to dry eye. This can affect visual outcomes and comfort and can eventually affect patient satisfaction. Lastly, centration of the treatment is critical. We center the treatment either over the Purkinje reflex or in between the pupil center and the Purkinje reflex. There is no firm recommendation of where best to center a multifocal presbyopia LASIK treatment.

Conclusion

There is much more to learn and develop as the algorithms become more refined. Just like IOLs, each corneal laser presbyopia option has its advantages and limitations. There is no perfect solution yet for presbyopia. I believe that having a broad range of presbyopia treatment options (cornea-based and lens-based) works to the advantage of the patient because we can tailor the treatment according to their eye condition and their lifestyle.

Free Paper Session

A Comparison of Corneal Sensation and Self-reported Dry Eye Symptoms in Eyes Undergoing Femtosecond LASIK Flap Creation With an Inverted vs. a Conventional Side C

Presenting Author: Edward E Manche MD
Coauthors: Christopher S Sales MD, Jennifer S Kung MD

Purpose: To prospectively compare corneal sensation and dry eye symptoms after femtosecond LASIK using an inverted side cut in one eye and a conventional side cut in the fellow eye. **Methods:** 122 eyes of 61 patients underwent LASIK—one eye with a 150-kHz femtosecond with a 130 degree inverted side-cut and the fellow eye with a 60-kHz femtosecond with a 70 degree side-cut. Cochet-Bonnet esthesiometry (CB) measured corneal sensation preoperatively and at Months 1, 3, and 6. **Results:** Postop CB values were greater with inverted vs. conventional side-cuts, with means of 1.45 > 1.32, $P = .08$ at 1 month, 2.49 > 1.84, $P < .01$ at 3 months, and 5.12 > 4.26, $P < .01$ at 6 months. **Conclusion:** Eyes treated with an inverted side-cut had faster recovery of corneal sensation. There were no differences in dry eye symptoms between the 2 groups.

Evolution of Corneal Epithelium With High-Resolution OCT Following Myopic LASIK Surgery

Presenting Author: Georges D Baikoff MD
Coauthor: Esteban Fuentes

Purpose: To study with the high-resolution OCT (HR-OCT) corneal epithelial thickness modifications following myopic LASIK. **Methods:** Using a 6-mm OCT scanning zone, 145 post-LASIK myopic eyes were studied. Parameters analyzed were postop refraction and central and peripheral corneal thickness. **Results:** After myopic LASIK, there is an increase of central epithelial thickness, which is related to the degree of treatment. Preoperative central keratometry does not influence epithelial variations. With regression, there is a greater increase of the central epithelium thickness. **Conclusion:** An increase in central epithelial thickness was noticed after myopic LASIK and following regression. Similar studies will be done in hyperopes.

Comparison of Corneal Epithelial Mapping With Anterior Segment OCT in Normal vs. Dry Eyes

Presenting Author: George Asimellis PhD
Coauthor: A John Kanellopoulos MD

Purpose: To assess safety and efficacy of epithelial mapping with anterior segment OCT (aOCT) in dry eyes. **Methods:** Control vs. dry eye cases ($n = 70$ each) were studied for UCVA, corrected distance visual acuity (CDVA), full eye examination, Schirmer, tear breakup time (TBUT), and epithelial mapping with aOCT. **Results:** Central epithelial thickness was 53.00 ± 2.68 µm in normal (average: 53.09 ± 2.71 µm). For the dry eye: 59.46 ± 4.18 µm and 59.34 ± 3.40 µm, respectively. Paired tests between normal and dry eye groups showed statistical difference ($P < .05$). **Conclusions:** Increased epithelial thickness and variability in dry eyes demonstrated that aOCT epithelial mapping may be a simple objective diagnostic tool for dry eye.

Three-Dimensional OCT Epithelial Thickness Mapping in Keratoconus

Presenting Author: George Chatzilaou MD
Coauthor: A John Kanellopoulos MD

Purpose: To evaluate safety, efficacy, and clinical ease of epithelial OCT mapping in keratoconus (KCN). **Methods:** Fifty-five untreated KCN (Group A) and 55 controls (Group B) were evaluated for epithelial thickness and distribution. Statistical analysis of patterns and variability was performed. **Results:** Mean overall epithelial thickness was 55.65 ± 1.22 µm (Group A) compared to 51.97 ± 0.70 µm (Group B). Variability of topographic mapping was ±9.80 ± 0.41 µm (Group A), and ±1.53 ± 0.21 µm (Group B). All differences were statistically significant ($P < .002$). **Conclusions:** OCT imaging in KCN suggests significant overall epithelial increase.

Asymmetric Centration for Excimer Custom Treatment: Integration of Pupil and Corneal Vertex Information

Presenting Author: Paolo Vinciguerra MD
Coauthors: Fabrizio I Camesasca MD, Samuel Arba Mosquera, Riccardo Vinciguerra MD

Purpose: Excimer lasers usually feature centration on the pupil center (pupil rim) or on the coaxial light reflex (corneal vertex). **Methods:** A new ablation profile, Asymmetric Offset (AO), was developed with Schwind CAM aspheric profiles combining high-order aberrations (HOA) referred to pupil center (line-of-sight) and manifest refraction referred to corneal vertex (visual axis). **Results:** With AO, sphere and cylinder are centered on corneal vertex, and the ablation axis on the visual axis. When combined with HOA ablation plan, AO leads to spherical components influencing coma, while astigmatic components influences trefoil. With AO, HOA are referenced to the pupil center and will not be shifted, with an ablation concentric to the pupil. **Conclusion:** AO ablation provides a method to combine pupil and corneal vertex information.

Lamellar Perforating Keratoplasty: New Surgical Technique

Presenting Author: Cesar C Carriazo MD

Purpose: To introduce lamellar perforating keratoplasty (LPK) for the treatment of corneal pathologies with weakened stroma and healthy endothelium such as keratoconus. **Methods:** The patients were treated with an excimer laser-guided circular photoablation of 8.0 mm removing the anterior stroma and leaving a 100-micron stromal bed. Using an interrupted photoablation ring, multiple microperforations were made at the periphery of the receptor stromal bed. An 8.0-mm donor graft without endothelium was obtained and sutured to the receptor cornea, using 16 nylon 10-0 interrupted sutures. **Results:** At 3 months postoperative UCVA improved from 20/400 to 20/100; BCVA, from 20/80 to 20/60. The endothelial cell loss was 10%. **Conclusion:** LPK is an alternative surgical treatment in patients with keratoconus.

Pocket Corneal Collagen Crosslinking Using Corneal Pocket Formation With Intrastromal Delivery of Riboflavin

Presenting Author: D James Schumer MD

Purpose: To demonstrate corneal crosslinking (CXL) efficacy, in keratoconus, equivalent to epithelium-off (epi-off) technique via riboflavin delivery through intrastromal channels, while maintaining intact corneal epithelium. **Methods:** Prospective clinical study performed on 20 eyes. Overall change in average keratometry, induction of haze using corneal OCT, manifest refraction, uncorrected visual acuity (UCVA), and best corrected visual acuity (BCVA) will be assessed over a 6-month period. **Results:** At the time of the 2013 Refractive Surgery Subspecialty Day, we will have 1-month postoperative data on at least 20 patients. **Conclusion:** We are confident that we will show equivalency to epi-off CXL, currently considered the standard for CXL treatment, in addition to reduced discomfort and infection risk and more rapid healing.

Evaluation of Combined Intracorneal Rings Implantation by Femtosecond Laser and Crosslinking in Keratoconus Management

Presenting Author: Osama I Ibrahim MD PhD
Coauthors: Amr Said, Ahmed A K El-Massry MD, Moones Abdalla MD

Purpose: To evaluate safety and efficacy of combined intracorneal rings (ICR) implanted using femtosecond laser and crosslinking in keratoconus patients. **Methods:** Prospective noncomparative case series carried out on 58 eyes of 43 keratoconus patients treated with combined femtosecond laser ICR and crosslinking. Uncorrected visual acuity (UCVA), best spectacle-corrected visual acuity (BSCVA), and corneal curvature (K readings) were measured before surgery and after 3 and 6 months and 1 and 2 years of follow-up. **Results:** Preoperative UCVA, BSCVA, and K reading showed statistically significant change after surgery ($P < .01$). No statistically significant changes exist between different follow-up periods. **Conclusion:** ICR implanted using femtosecond laser and crosslinking is a safe, effective, and durable management of keratoconus.

One-Year Follow-up of Implantable Collamer Lens in Anisometropic Amblyopia of Children

Presenting Author: Ahmed A K El-Massry MD
Coauthors: Amr Said, Osama I Ibrahim MD PhD

Purpose: To evaluate the safety and efficacy during 1-year follow-up of implantable collamer lens (ICL) to correct high anisometropia in amblyopic children with no compliance with spectacles or contact lenses. **Methods:** Prospective study of 12 eyes of 12 children with anisometropia who had ICL implantation. Patient age at the time of implantation ranged from 7 to 10 years. Mean preoperative spherical equivalent was -10 (range: -8 to 15). Mean uncorrected visual acuity (UCVA) was 0.03 (range: CF - 0.1) and corrected distance visual acuity (CDVA) mean was 0.3 (range: 0.1-0.6). Occlusion was done after surgery. **Results:** UCVA and CDVA improved in all children. At 12 months, mean UCVA and CDVA were 0.5 and 0.7, respectively ($P = .01$). No loss of CDVA was detected in any patient. **Conclusion:** ICL is a safe and effective treatment for childhood anisometropic amblyopia.

Implantable Collamer Lens Complications

Presenting Author: Alejandro Navas MD
Coauthors: Martha Jaimes, Diana F Rodriguez-Matilde MD, Arturo J Ramirez-Miranda MD, Enrique O Graue Hernandez MD, Arturo Gomez Bastar MD

Purpose: To report the complications of phakic posterior chamber implantable collamer lens (ICL) implantation. **Methods:** Retrospective review of consecutive clinical case series. **Results:** 407 eyes with mean follow-up around 60 months were included. Fourteen eyes presented complications (3.43%): 8 eyes presented surgical-related complications (1.96%) including endophthalmitis, toxic anterior segment syndrome, accidental anterior capsule rupture; and 6 eyes presented complications related with high myopia and/or trauma as ICL dislocation or retinal detachment (1.47%). **Conclusion:** While complications after ICL phakic IOL implantation can occur, most are solvable favorably.

Quality of Vision With Presbyopia-Correcting IOLs

James T Schwiegerling PhD

I. Types of Presbyopia-Correcting IOLs
   A. Zonal refractive
   B. Zonal diffractive
      1. Full aperture
      2. Apodized
      3. Bifocal/trifocal
   C. Sector-based
   D. Extended depth of focus
II. Visual Artifacts With Presbyopia-Correcting IOLs
   A. Contrast reduction
   B. Rings
   C. Halos
   D. Flare
III. Measures of Vision Quality With Presbyopia Correcting IOLs
   A. Through-focus modulation transfer function
   B. Defocus curves

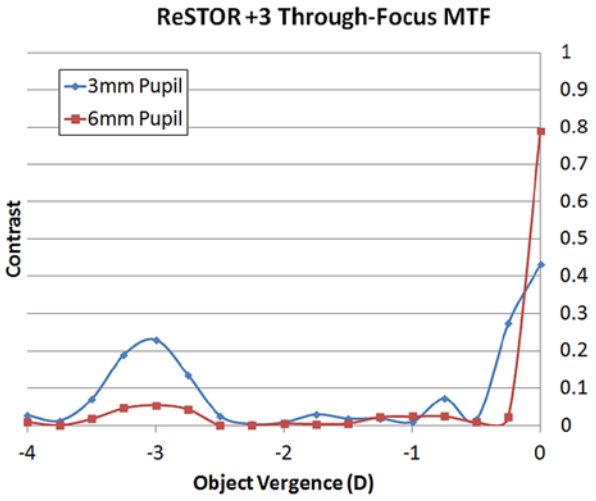

Figure 1. ReSTOR +3 Through-focus modulation transfer function.

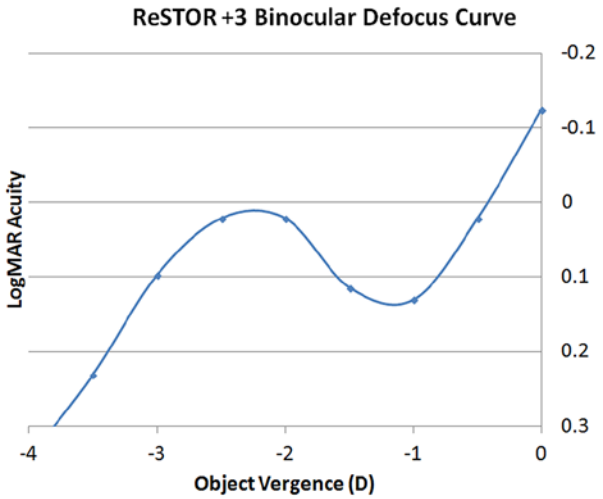

Figure 2. ReSTOR +3 binocular defocus curve.

C. Stray light analysis

D. Image simulations

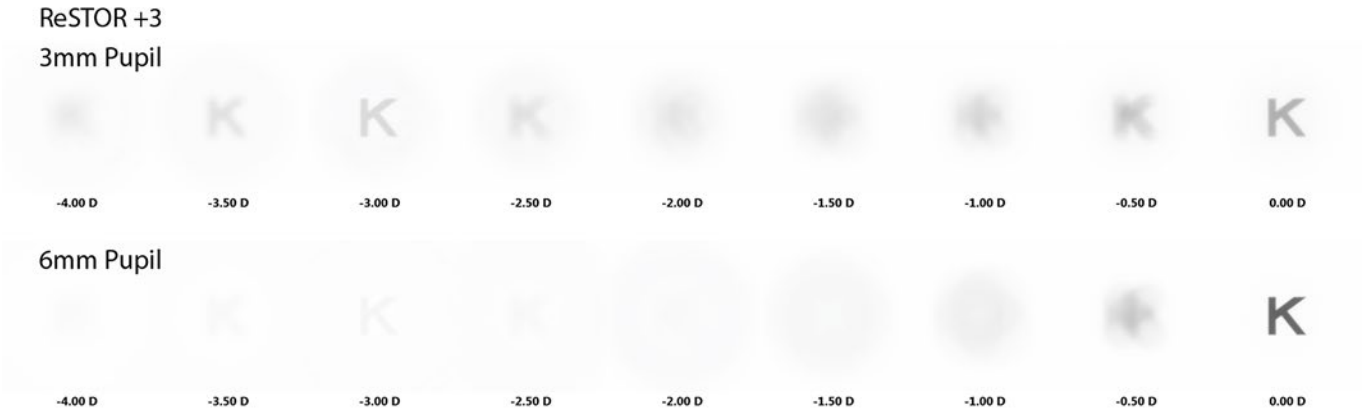

Figure 3.

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Influence of the Reference Surface Shape for Discriminating Between Normal Corneas, Subclinical Keratoconus, and Keratoconus

David Smadja MD, Marcony R Santhiago MD, Glauco R Mello MD**, David Touboul MD, Ronald R Krueger MD

Purpose

To compare the discriminating ability of corneal elevation calculated with different reference surfaces for distinguishing normal corneas from keratoconus (KC) and subclinical keratoconus (FFKC).

Methods

A total of 391 eyes of 208 patients were prospectively enrolled in the study and divided into 3 groups: 167 eyes of 113 patients with KC, 47 contralateral topographically normal eyes of clinically evident KC in the fellow eye, and 177 eyes of 95 refractive surgery candidates with normal corneas. All eyes were measured with a dual-Scheimpflug analyzer. Maximum elevation values were recorded within the central 5-mm diameter in both anterior (MAE) and posterior (MPE) elevations maps. Discriminating ability of corneal elevation measurements obtained by best fit toric and aspheric (BFTA) and best-fit sphere (BFS) reference surfaces were compared by receiver operator characteristic curves (ROC).

Results

ROC analysis showed that corneal elevation measured by a BFTA had a significantly better ability than with a BFS for distinguishing normal corneas from KC and FFKC. Posterior elevation measured by a BFTA had a significantly higher predictive accuracy for FFKC than anterior elevation with an area under ROC curves of 0.88 and 0.80, respectively. The sensitivity and specificity achieved with the MPE for detecting KC and FFKC were 99% and 99% for KC and 82% and 80% for FFKC by setting the cutoff value at 16 µm and 13 µm, respectively.

Conclusion

The ability to discriminate between normal and FFKC with elevation parameters was significantly improved by using a BFTA instead of a BFS reference surface.

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

Spectral-Domain OCT Analysis of Regional Epithelial Thickness Profiles in Keratoconus, Postoperative Corneal Ectasia, and Normal Eyes

Karolinne Maia Rocha MD, Claudia Perez Straziota MD, R Doyle Stulting MD PhD, J Bradley Randleman MD

***J Refract Surg*. 2013; 29(3):173-179.**

In this study we used spectral domain OCT (SD-OCT) to evaluate and compare the regional corneal epithelial thickness profiles in patients with keratoconus (KC), postoperative corneal ectasia (ectasia), and normal eyes to determine the relative thickness consistency and predictability for each condition.

Regional corneal epithelial thickness profiles of eyes with KC and ectasia were measured with anterior segment SD-OCT high-resolution cross-line scans (Optovue RTVue-100, Optovue, Inc.; Fremont, CA) and compared retrospectively to those of normal eyes (control group). Anatomical landmarks for the epithelium and Bowman layer were identified by direct visualization of the area of increased reflectivity corresponding with the epithelium-Bowman interface. Epithelial thickness was assessed at 21 points, 0.5 mm apart, across the central 6 mm of the corneal apex in the horizontal and vertical meridians.

One hundred twenty eyes were evaluated, including 49 eyes from 29 patients with KC, 32 eyes from 16 patients with ectasia, and 39 eyes from 21 control patients. Average epithelial thickness at the corneal apex was 41.18 ± 6.47 µm (range: 30-51 µm) in eyes with KC, 46.5 ± 6.72 µm in eyes with ectasia (range: 34-60 µm), and 50.45 ± 3.92 µm in normal eyes (range: 42-55 µm). Apical epithelial thickness was significantly thinner in eyes with KC ($P < .0001$) and ectasia ($P = .0007$) than it was in controls. Epithelial thickness ranges in all other areas varied widely for KC (SD, range: 21-101 µm) and ectasia (SD, range: 30-82 µm) compared to controls (SD, range: 43-64 µm), $P = .0063$.

Central epithelial thickness was, on average, significantly thinner in ectatic corneas compared to controls; however, both central and regional epithelial thickness was highly irregular and variable in corneas with keratoconus and postoperative corneal ectasia. These thickness variations may alter preoperative topographic features and measurements in unpredictable ways, especially steepest K-values. Regional epithelial thickness cannot be assumed to be uniform in ectatic corneas and therefore may require direct measurement when considering treatments for which underlying stromal thickness is particularly important, such as corneal collagen crosslinking or topography-guided excimer laser ablation (see Figure 1).

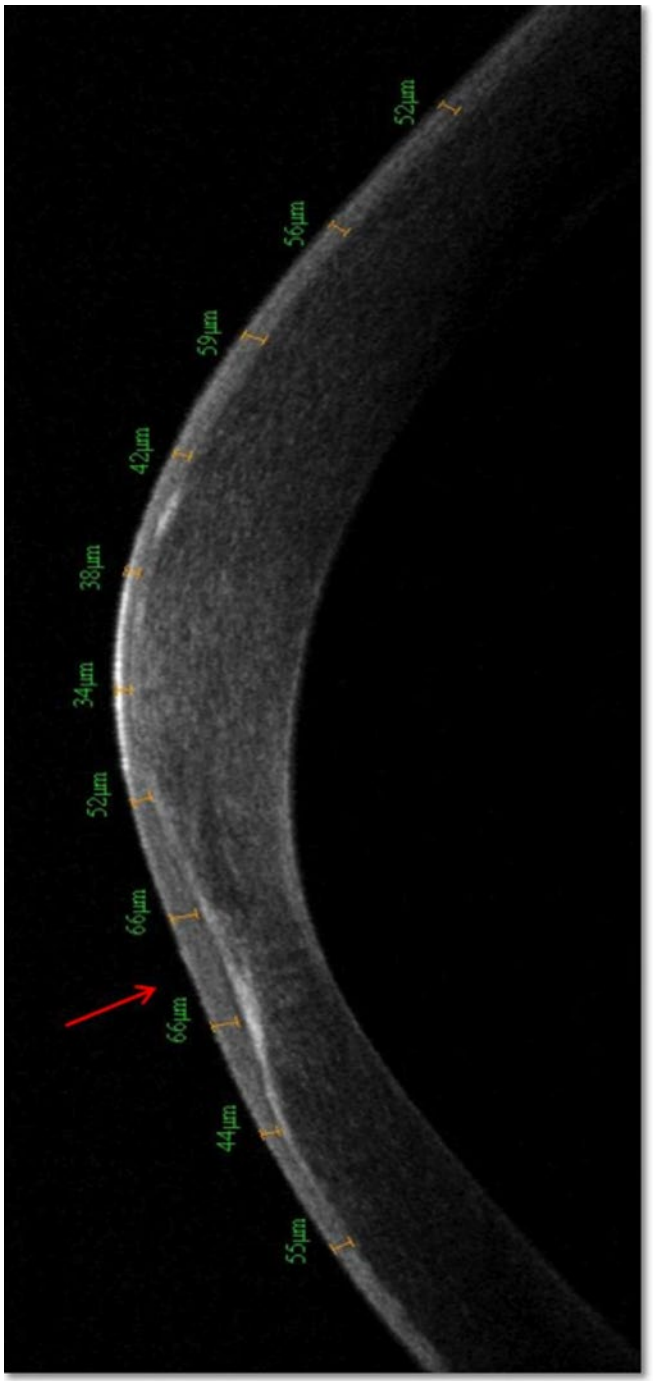

Figure 1. Spectral-domain OCT cross-sectional high-resolution scan across the central 6 mm of the corneal apex in the vertical meridian in keratoconus (arrow shows area of epithelial remodeling).

Effect of Femtosecond Laser Fragmentation on Effective Phacoemulsification Time in Cataract Surgery

Burkhard Dick MD PhD

I. The Price of Using Ultrasound
   A. High ultrasound power and time are the most important intraoperative factors leading to endothelial cell loss.[1,2]
   B. Implicated in the pathogenesis of cystoid macular edema[3]

II. Laser cataract surgery fragmentation capability is defined by laser specific features.
   A. 3-D OCT with image guidance
      1. Full volume 3-D OCT captures images of eye through the posterior capsule.
      2. OCT informs surgical decision making.
      3. Automatic algorithms calculate maximum fragmentation volume.
   B. Laser capabilities are important for reduction in ultrasound.
      1. Extensive grid fragmentation pattern creates capability to eliminate ultrasound energy.
      2. Laser pulses delivered based on image-guided algorithms

III. 1900 Consecutive Case Controlled Trial
   A. Capsulotomy, lens fragmentation, cataract and/or arcuate incisions
   B. Endpoints
      1. Effective phacoemulsification time (EPT) during lens removal
      2. Intra- and postoperative complications
      3. BCVA
      4. Endothelial cell loss
      5. Irrigation fluid volume
      6. Surgical time
   C. Study of numerous adjustments
      1. Reduction in grid size
      2. Reduction in safety zone
      3. Switching away from flared tip

IV. Results
   A. Previously, showed 96% reduction in EPT.[4,5]
   B. Analysis of 1900 case consecutive series showed > 40% requiring zero ultrasound.
   C. Low complication rate
   D. Only 9% of last 200 cases used any ultrasound.[6]
   E. Reduced endothelial cell loss and faster visual recovery [7]
   F. Comparable irrigation fluid and surgical time[7]
   G. Improved BCVA

V. Conclusions
   A. Method development optimizes capability for ultrasound reduction.
   B. Lens fragmentation results in elimination of ultrasound in large percentage of cases.
   C. Reduction in endothelial cell loss and faster visual recovery with Catalys

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Progression of Keratoconus and Efficacy of Pediatric Corneal Collagen Crosslinking in Children and Adolescents

Farhad Hafezi MD PhD

Introduction

In past years, corneal collagen crosslinking (CXL) with riboflavin and UV-A has been used to stop the progression of postoperative ectasia and keratoconus.[1-5]

Whereas in postoperative ectasia the age of onset depends on the age of the patient at the time of surgery, keratoconus starts in the teenage years and shows the most aggressive progression in the second and third decade of life.[6] Most studies published so far have focused on CXL in adult corneas. In this study, we have investigated two factors: 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.

Methods

Retrospective interventional cohort study. We included 59 eyes of 42 children and adolescents with confirmed keratoconus. Main outcome measures were refraction, slitlamp examination, Placido-based corneal topography, and Scheimpflug imaging preoperatively and at 6 and 12 months postoperatively. Follow-up was up to 36 months (mean follow-up: 26.3 months).

Results

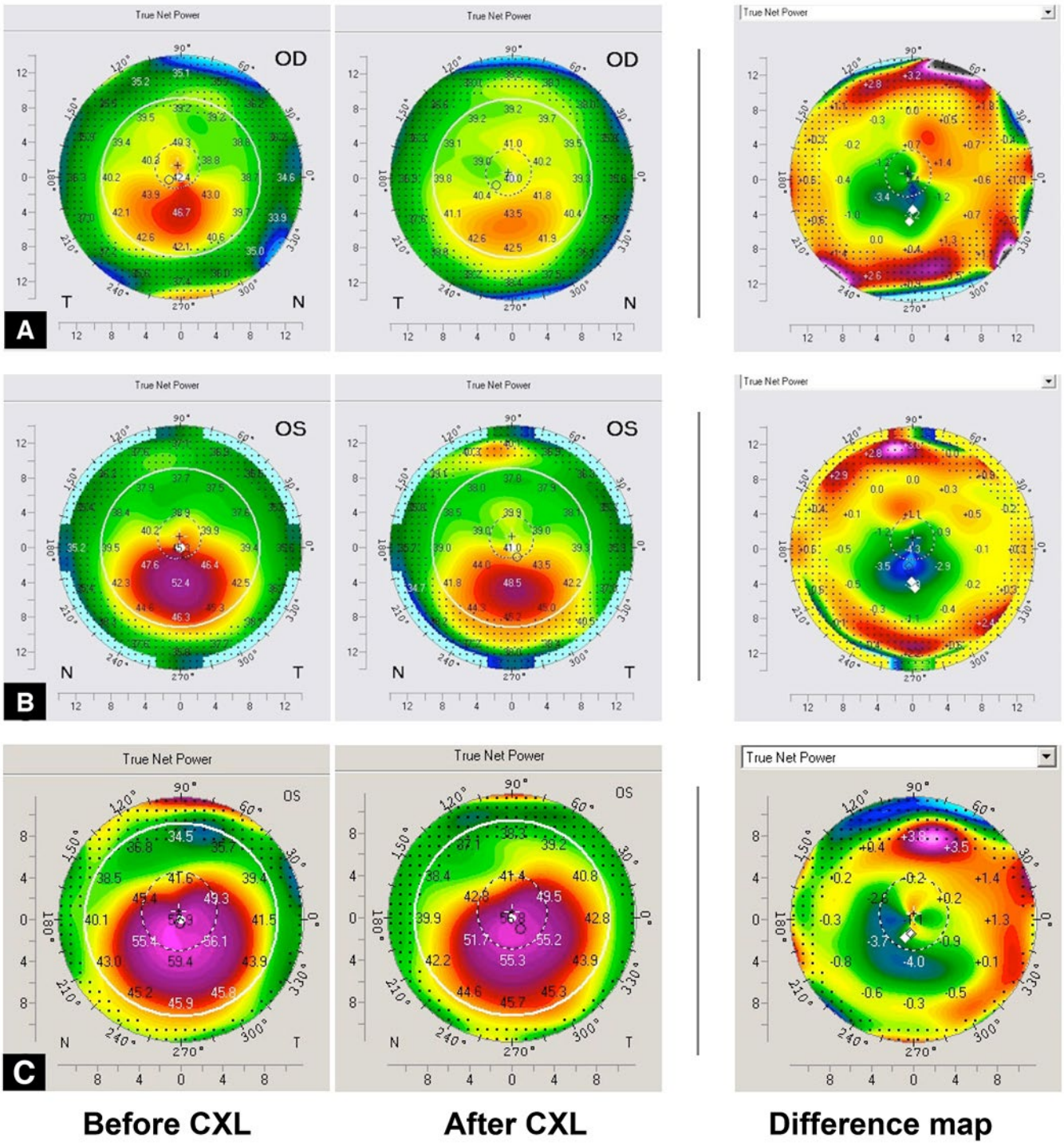
Patients showed the flattening effect typical for CXL at 12 months after the procedure (see Figure 1).

CDVA showed a significant improvement over the entire follow-up of 36 months. K_{max} reduction was significant at 12 and 24 months after CXL but lost significance at 36 months after CXL (see Figure 2).

Fifty-two of the 59 eyes enrolled in this study showed progression of keratoconus, corresponding to a progression rate of 88%.

Discussion

At 12 and 24 months after CXL, pediatric corneas showed a response similar to the one known from the studies in adults. However, at 36 months, K-max did not show a significant reduction of readings when compared to the preoperative values, but rather stable readings. In conclusion, CXL seems to be safe in children and adolescents. The effect of CXL might not be as long-lasting as in adults, and longer follow-ups are needed to verify this trend. Progression of keratoconus occurred in 88% of children and adolescents. We therefore adopted the attitude of treating progressive keratoconus as soon as the diagnosis has been made, without awaiting confirmation of progression.



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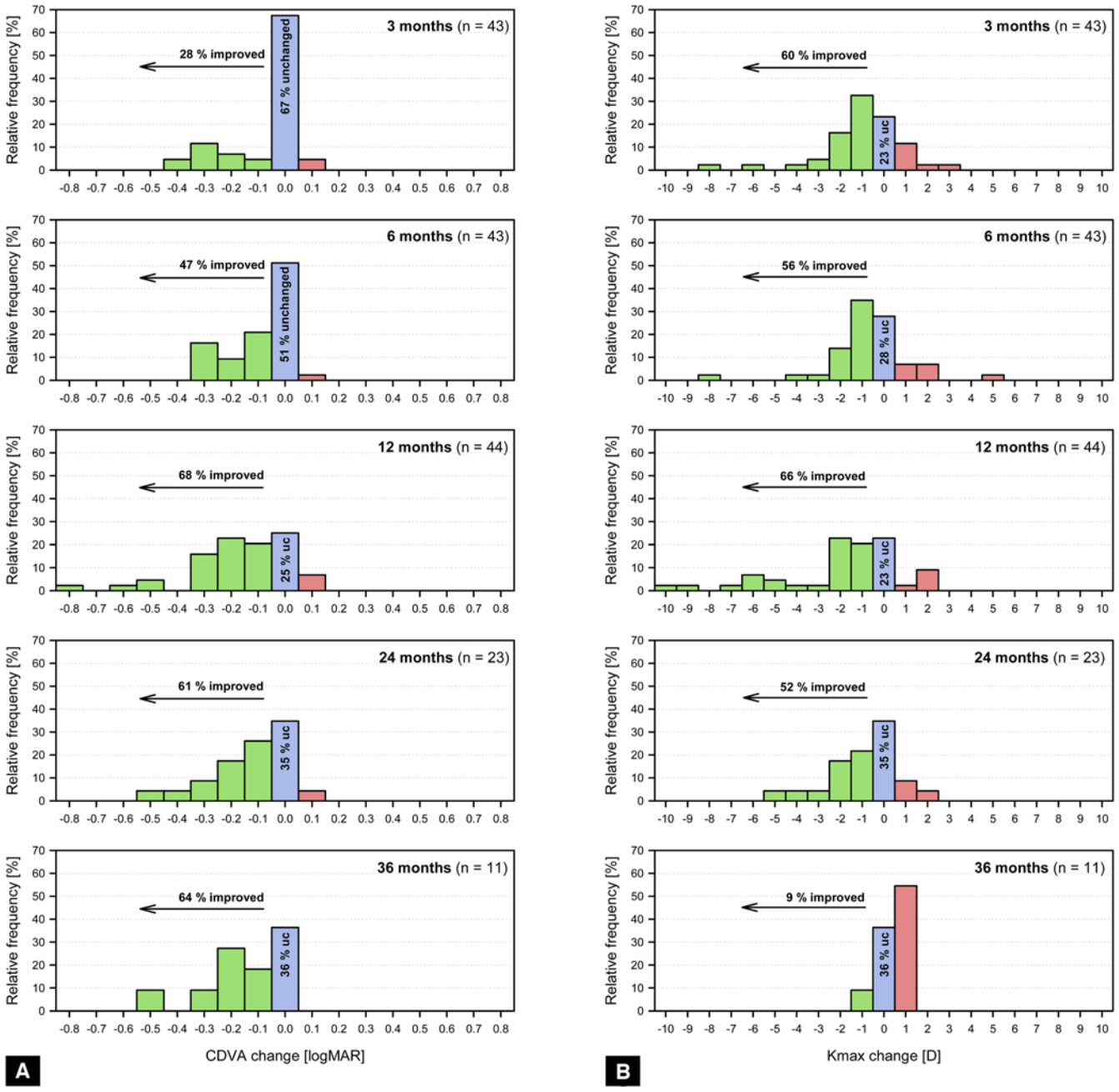

Figure 2. Reprinted with permission from SLACK, Inc. 2013.

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Corneal Confocal Microscopy Following Conventional, Transepithelial, and Accelerated Corneal Collagen Crosslinking Procedures for Keratoconus

David Touboul MD

Introduction

The corneal collagen crosslinking (CXL) procedure shows progressive and subtle morphological tissue changes during the corneal healing process and has been shown to minimize ectasia in progressive keratoconus.[1,2] In the "conventional" CXL procedure the epithelium is removed from the central 8 to 10 mm of the cornea to facilitate diffusion of riboflavin into the anterior stroma. This is followed by the installation of riboflavin 0.1% in 20% dextran drops to the cornea every 3 to 5 minutes for 30 minutes. The cornea is then irradiated for 30 minutes with an ultraviolet A (UVA) light-emitting diode light source that has an irradiance of 3 mW/cm^2. During this period of irradiation, an additional drop of riboflavin is instilled every 5 minutes, resulting in total UVA delivered of 5.4 J/cm^2. After CXL, the epithelium generally heals in a few days without any adverse effects; however, microbial keratitis and vision loss have been reported following this procedure.[3,4]

As an alternative to disrupting the epithelium during conventional CXL, transepithelial formulations are being developed. These transepithelial CXL protocols and formulations are being used to expedite passage of riboflavin through epithelial tight junctions so as to enhance absorption intensity for the treatment.[5,6] The goal of this approach is to reduce unwanted side effects from epithelial debridement and patient discomfort. Conventional CXL is a time-consuming procedure, lasting more than 60 minutes. Accelerated CXL has recently been proposed as an alternative means of speeding up the procedure by delivering higher irradiance to the cornea, thus reducing the required light exposure time.[7,8]

Purpose of the Study

The aim of this study is to document and compare the morphological changes of the cornea by confocal microscopy following conventional, transepithelial, and accelerated CXL using commercially available protocols, formulations, and systems.

Methods

Twenty-four patients with progressive keratoconus were divided into 3 groups to receive conventional, transepithelial, or accelerated CXL. In vivo corneal confocal microscopy was performed on each patient preoperatively and at 1, 3, and 6 months postoperatively.

Summary

In vivo corneal confocal microscopy analysis of the postoperative impact of CXL on the cornea revealed clear differences among conventional, accelerated, and transepithelial CXL protocols. Accelerated CXL had a greater impact than conventional CXL on the anterior cornea, whereas transepithelial CXL did not appear to alter corneal morphology.

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Predictors for the Outcome of Small-incision Lenticule Extraction for Myopia

Jesper Hjortdal MD

Purpose

Refractive lenticule extraction is a fairly new laser refractive procedure whereby an intrastromal lenticule is cut by a femtosecond laser.[1,2] In femtosecond lenticule extraction, a full traditional flap is also created and opened in order to ease removal of the refractive lenticule.[3] In small-incision lenticule extraction, the lenticule is removed through a small, 2-mm wide tunnel incision.[4] In the present study, the influence of patient- and surgery-related parameters on the predictability, efficacy, and safety of small-incision lenticule extraction (ReLEx smile) for treatment of myopia was examined.[5]

Methods

335 patients with myopia up to 10 D (spherical equivalent refraction) and astigmatism up to 2 D were treated with small-incision lenticule extraction in both eyes (670 eyes) and followed for 3 months. The study was considered a prospective clinical quality control study.

Results

Preoperative spherical equivalent averaged -7.19 D ± 1.30 D. In eyes with emmetropia as target refraction, 84.0% obtained an uncorrected distance visual acuity ≤ 0.10 (logMAR) at 3 months. Mean corrected distance visual acuity improved from -0.03 to -0.05 (logMAR) ($P < .01$). 2.4% (16 eyes) lost 2 or more lines of corrected distance visual acuity. The achieved refraction was 0.25 ± 0.44 D less than attempted after 3 months, and 80.1% (537 eyes) and 94.2% (631 eyes) were within ± 0.5 and ± 1.0 D of attempted, respectively. Multiple linear regression analyses revealed that spherical equivalent undercorrection was predicted by increasing patient age (0.1 D per decade; $P < .01$) and steeper corneal curvature (0.04 D per D; $P < .01$). The safety and efficacy of the procedure was minimally affected by age, gender, and simultaneous cylinder correction.

Conclusion

The findings of an undercorrection of 0.25 D and small effects of patient age and corneal curvature suggest that the standard nomogram needs only minor adjustments. This study suggests that safety and efficacy are not influenced to any clinically significant degree by easily discernible patient factors.

A new cohort of +500 consecutive eyes operated with small-incision lenticule precision for myopia will be analyzed in order to validate these findings, and the results will be presented at the meeting.

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One-Year Safety and Efficacy Results of a Hydrogel Inlay to Improve Near Vision in Emmetropic Presbyopes

Enrique Barragan MD

I. Purpose

To assess the safety and efficacy of Raindrop Near Vision Inlay (ReVision Optics, Inc.; Lake Forest, Calif., USA) when implanted in the nondominant eye of emmetropic presbyopes.

II. Methods

A. IRB-approved 2-site prospective study

B. 52 emmetropic presbyopes were monocularly implanted with the Raindrop Near Vision Inlay.

C. Emmetropia was defined as stable manifest spherical equivalent refraction between -0.5 and +1.00 D.

D. The Optec 6500 Vision Tester was used to record visual acuities.

E. Ability to perform everyday tasks (5 tasks for each of 3 distance ranges) without additional visual aid was ascertained using a questionnaire.

III. Results

A. In the inlay eye UCVAs at 12 months showed 94% of eyes were 20/25 or better at near, 100% of eyes were 20/32 or better at intermediate, and 81% of eyes were 20/32 or better at distance.

B. Binocular UCVAs at 12 months averaged a +4 line increase at near, +2 line increase at intermediate, and no change to distance.

C. Visual performance scores showed most patients improved and could easily perform tasks at near (88%), intermediate (87%), and distance (98%).

D. No patients were dissatisfied after 12 months.

IV. Conclusions

A. Significant improvements were found at near and intermediate UCVAs.

B. There was a corresponding increase in ability to perform everyday tasks without additional visual aid.

C. The Raindrop Near Vision Inlay is an effective tool to improve vision and visual task performance in emmetropic presbyopes.

Nonpenetrating Femtosecond Laser Intrastromal Astigmatic Keratotomy in Patients With Mixed Astigmatism After Previous Refractive Surgery

Jan Venter MD

I. Astigmatic Keratotomy (AK)

A. Manual AK

1. Fairly standardized and effective procedure to reduce naturally occurring and surgically induced astigmatism[1-3]
2. Used for several decades
3. Generally performed by freehand or mechanical techniques
4. Disadvantages
   a. Result more "surgeon dependent"
   b. Risk of corneal perforation and wound dehiscence
   c. Lower incision predictability and topographic stability

B. Femtosecond AK

1. Introduced in recent years with the development of femtosecond laser technology
2. Surgeons able to better customize the depth and placement of AK incisions
3. Improved predictability, faster procedure and recovery
4. Previously published literature: femtosecond AK mainly used to reduce high amount of astigmatism, such as following keratoplasty[4-6]

II. Nonpenetrating Intrastromal Femtosecond AK Technique

A. In previous reports on femtosecond AK, intrastromal arcuate incisions were opened after surgery.

B. We reported our initial experience with nonpenetrating femtosecond AK in patients with a low mixed astigmatism and a history of refractive surgery[7] with the following technique:

1. Two paired symmetric incisions created on the steepest axis of the manifest cylinder
2. 60 microns from epithelium to 80% depth
3. Intrastromal, nonpenetrating incisions

C. Due to a "coupling effect," AK flattens the incised meridian while steepening the opposite meridian[8] and is therefore the ideal option for treatment of mixed astigmatism.

III. Our Experience With Nonpenetrating Intrastromal Femtosecond AK

A. To date, treated 194 eyes with this technique, with follow-up of 9.6 ± 3.1 months

B. Indication: eyes with previous refractive lens exchange, phakic intraocular surgery, LASIK/PRK with a low amount of postoperative mixed astigmatism – unsuitable for excimer laser enhancement for various reasons such as dry eye syndrome, central corneal thickness not allowing further ablation, etc.

C. Unaided distance visual acuity improved from 0.19 ± 0.16 logMAR to 0.01 ± 0.14 logMAR

D. The mean absolute cylinder decreased from 1.29 ± 0.41 D preoperatively to 0.52 ± 0.37 D postoperatively. Sphere decreased from +0.67 ± 0.39 D to +0.13 ± 0.41 D.

E. A coupling ratio (ratio between flattening of the incised meridian and steepening of the opposite meridian) of 0.91 ± 0.39

F. No intraoperative or late postoperative complications were recorded.

IV. Summary

Nonpenetrating intrastromal femtosecond AK is a promising technique for treatment of mixed astigmatism.

A. Precise arcuate incisions, outside of visual axis, minimal change to higher-order aberrations

B. Intrastromal incisions: no epithelial injury, no worsening of dry eye syndrome, minimal risk of infection

C. Faster recovery than with manual technique

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Mathematical Model to Compare the Relative Tensile Strength of the Cornea after PRK, LASIK and Small-Incision Lenticule Extraction (SMILE)

Dan Z Reinstein MD

Introduction

Ever since femtosecond lasers were first introduced into refractive surgery, the ultimate goal has been to create an intrastromal lenticule that can then be removed in 1 piece manually, thereby circumventing the need for incremental photoablation by an excimer laser. Early work was done in 1996-1998 using picosecond and femtosecond lasers;[1-5] however, these initial studies were not followed up with further clinical trials.

After the introduction of the VisuMax femtosecond laser (Carl Zeiss Meditec; Jena, Germany) in 2007,[6] the intrastromal lenticule method was reintroduced in a procedure called femtosecond lenticule extraction (FLEx), with the first results reported in 2008.[7-9] Following the successful implementation of FLEx, a new procedure called small-incision lenticule extraction (SMILE) was developed. This procedure involves passing a dissector through a small, 2-3 mm, incision to separate the lenticular interfaces and allow the lenticule to be removed, thus eliminating the need to create a flap. The results of the first prospective trials of SMILE have been reported,[10-12] and there are now more than 50 surgeons routinely performing this procedure worldwide.

Consequences of Leaving the Anterior Stroma Uncut

The absence of a flap and the fact that the stromal tissue is removed from within the stroma means that the anterior-most stromal lamellae remain intact after the procedure (except for the region of the small incision). This is in contrast to both LASIK, where the anterior stromal lamellae are severed by the creation of the flap and also by the excimer laser ablation, and surface ablation (PRK), where the anterior stromal lamellae are severed by the excimer laser ablation.

Randleman et al[13] published a study in 2008 in which they demonstrated that the cohesive tensile strength (ie, how strongly the stromal lamellae are held together) of the stroma decreases from anterior to posterior within the central corneal region. In an experiment in which the cohesive tensile strength was measured for strips of stromal lamellae cut from different depths within donor corneoscleral buttons, a strong negative correlation was found between stromal depth and cohesive tensile strength. The anterior 40% of the central corneal stroma was found to be the strongest region of the cornea, whereas the posterior 60% of the stroma was at least 50% weaker. A number of other authors have reached this conclusion by other indirect means.[14-19]

In addition to cohesive tensile strength, tangential tensile strength (ie, stiffness along the stromal lamellae) and shear strength (ie, resistance to torsional forces) have both been found to vary with depth in the stroma. Kohlhaas et al[20] and Scarcelli et al[21] found that the tangential tensile strength was greater for anterior stroma than posterior stroma, each using different methodology. There was a strong correlation between the results for cohesive tensile strength by Randleman et al[13] and the results for tangential tensile strength by Scarcelli et al,[21] such that the curves are almost interchangeable. Petsche et al[22] found a similar result for transverse shear strength to decrease with stromal depth.

Therefore, given that SMILE effectively leaves anterior corneal stroma intact, while the keratomileusis takes place in the deeper and therefore weaker portion of the cornea, it is reasonable to assume that for any given refractive correction SMILE will leave the cornea with greater tensile strength than either LASIK or PRK.

Comparison of Tensile Strength After PRK, LASIK and SMILE

We have now developed a mathematical model based directly on the Randleman[13] depth-dependent tensile strength data to calculate the postoperative tensile strength and to compare this between PRK, LASIK, and SMILE.[23] We performed nonlinear regression analysis on this data and found that a fourth-order curve maximized the fit to the data with the R^2 of 0.930, demonstrating the very high correlation achieved by a nonlinear fit. The total tensile strength of the untreated cornea was then calculated as the area under the regression line by integration (see Figure 1). The total tensile strength of the cornea after LASIK was derived by calculating the area under the regression line for all depths below the residual stromal bed thickness (assuming the flap does not contribute to the tensile strength of the postoperative cornea[24]). This value was divided by the total tensile strength of the untreated cornea to represent the relative total tensile strength as a percentage. Similarly, the total tensile strength of the cornea after PRK was derived by calculating the area under the regression line for all depths below the stromal thickness after ablation. Finally, the total tensile strength of the cornea after SMILE was calculated as the area under the regression line for all depths below the lower lenticule interface added to the area under the regression line for all depths above the upper lenticule interface or within the stromal cap.

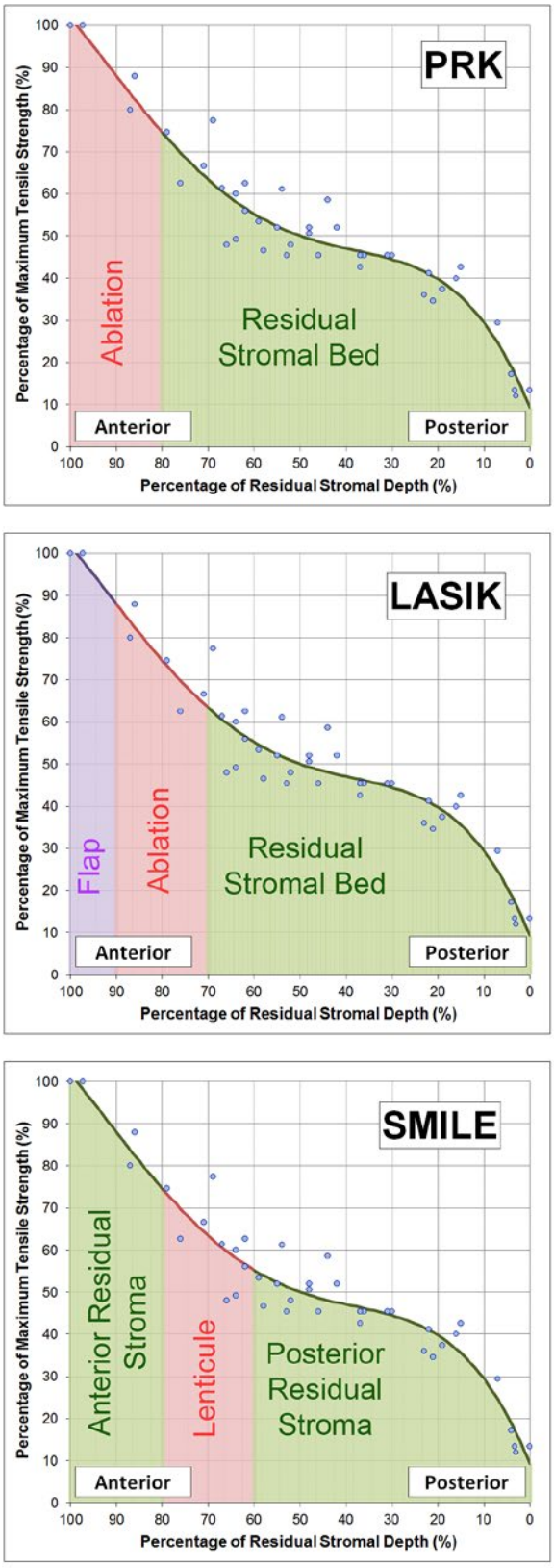

Figure 1. A fourth-order polynomial regression was applied to the depth-dependent stromal tensile strength data by Randleman et al.[13] The regression equation was integrated in order to calculate the area under the curve for the relevant stromal depths after PRK, LASIK and SMILE as demonstrated by the shaded regions. Reprinted by permission from Reinstein DZ, Archer TJ, Randleman JB. Mathematical model to compare the relative tensile strength of the cornea after PRK, LASIK, and small incision lenticule extraction. *J Refract Surg*. 2013; 29(7):454-460.

The model was then applied to a variety of different scenarios and a number of conclusions could be drawn from the analyses:

1. The postoperative tensile strength was greater after SMILE than after PRK: in SMILE, the refractive stromal tissue removal takes place in deeper and relatively weaker stroma, leaving the stronger anterior stroma intact, meaning that for any given refractive correction SMILE will leave the cornea with greater tensile strength than PRK.
2. The postoperative tensile strength was greater after SMILE than after LASIK: because the anterior stroma is left intact, SMILE will (by definition) leave the cornea with greater tensile strength than LASIK for any given refractive correction.
3. The postoperative tensile strength increased for SMILE with increasing cap thickness: if SMILE is performed deeper in the cornea, more of the stronger anterior stroma will remain and hence the postoperative tensile strength will be greater; this is in contrast to LASIK, where deeper ablation results in lower postoperative tensile strength given the minimal contribution of the flap to corneal biomechanics after healing.

These results can be quantified in the example scenario represented in Figure 2, which shows the relative total tensile strength after LASIK (purple), photorefractive keratectomy (PRK) (blue), and SMILE (green) plotted against a range of ablation depths for a fixed central corneal thickness of 550 µm, a LASIK flap thickness of 110 µm, and a SMILE cap thickness of 130 µm. The orange lines indicate that the postoperative relative total tensile strength reached 60% for an ablation depth of 73 µm in LASIK (approximately -5.75 D), 132 µm in PRK (approximately -10.00 D), and 175 µm in SMILE (approximately -13.50 D), translating to a 7.75 D difference between LASIK and SMILE for a cornea of the same postoperative relative total tensile strength. The red lines indicate that the postoperative relative total tensile strength after a 100-µm tissue removal would be 54% in LASIK, 68% in PRK, and 75% in SMILE.

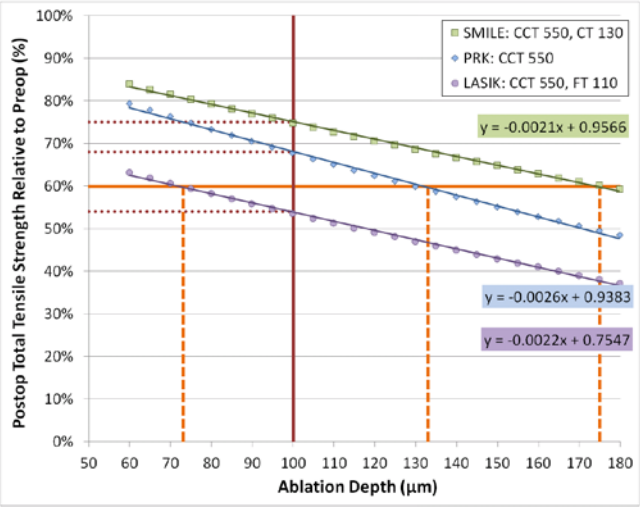

Figure 2. This graph shows the relative total tensile strength after LASIK (purple), PRK (blue) and SMILE (green) plotted against a range of ablation depths for a fixed central corneal pachymetry of 550 µm, a LASIK flap thickness of 110 µm, and a SMILE cap thickness of 130 µm. Reprinted by permission from Reinstein DZ, Archer TJ, Randleman JB. Mathematical model to compare the relative tensile strength of the cornea after PRK, LASIK, and small incision lenticule extraction. *J Refract Surg*. 2013; 29(7):454-460.

This model does not take into account the fact that the Bowman layer remains intact after SMILE, which is not true in either LASIK or PRK. The Bowman layer has been shown to have very different biomechanical properties to stromal tissue, as demonstrated by Seiler et al,[25] who showed that removing the Bowman layer with an excimer laser reduced the Young modulus by 4.75%. Leaving Bowman layer intact may further increase the corneal biomechanical stability after SMILE compared with LASIK and PRK.

Conclusion

Considering the safety of subtractive corneal refractive surgical procedures in terms of tensile strength represents a paradigm shift away from classical residual stromal thickness limits. The residual thickness-based safety of corneal laser refractive surgery should be thought of at least in terms of total residual uncut stroma—ie, in SMILE, the sum of the posterior stroma and the uncut anterior stroma. Ideally, a parameter such as total tensile strength, which takes the nonlinearity of the strength of the stroma into account, seems more appropriate. For example, the residual stromal bed thickness under the interface in SMILE could easily be less than 250 µm due to the additional strength provided by the untouched stromal lamellae in the cap, as long as the total remaining corneal tensile strength is comparable to that of the postoperative LASIK 250-µm residual stromal bed thickness standard. In this new case of using remaining total tensile strength, the minimum would evidently be defined as the total tensile strength remaining after LASIK with a residual stromal bed thickness of 250 µm.

In summary, a mathematical model derived from depth-dependent stromal tensile strength data quantified the difference in postoperative relative total tensile strength between SMILE, PRK, and LASIK. The flapless intrastromal SMILE procedure brings the advantage of leaving the strongest anterior stromal lamellae intact to maximize the strength of the cornea after the procedure compared with PRK and LASIK. This model demonstrates that SMILE does not follow the same criteria as LASIK for residual stromal calculations and hence can be expected to correct higher levels of myopia within the cornea than is currently possible by LASIK or PRK.

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E-Poster Index

E-Posters will be available for viewing during the meeting in the La Nouvelle Orleans Foyer, outside the session room, and after the meeting on the Academy's website: www.aao.org/2013

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* Indicates that the presenter has financial interest.
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E-Poster Abstracts

Visual, Contrast Sensitivity Outcomes and Aberration Changes After Transepithelial PRK in High Myopia: A 9-Month Follow-up Study

Abstract #: RP30037102

Presenting Author: Soheil Adib Moghaddam MD
Coauthors: Amir-Houshang, Omidvari MD MPH

Purpose: To evaluate visual, contrast sensitivity (CS) outcomes and aberrations after transepithelial PRK (Trans-PRK) in high myopia. **Methods:** Seventeen eyes with high myopia were recruited in a prospective study at Bina Eye Hospital, Iran. All cases underwent Trans-PRK using the Schwind Amaris 500. Follow-up visits were performed up to 9 months. Visual acuity (VA), CS, and aberrations were evaluated. **Results:** The mean of uncorrected distance VA and best spectacle-corrected VA improved significantly, from 0.14 to 1.01 and 0.74 to 1.09, respectively. Mean trefoil aberrations increased, but it was not clinically significant. The mean coma aberration and mesopic CS didn't change significantly. The mean of photopic CS improved significantly, from 2.27 to 1.42. **Conclusion:** This study shows that Trans-PRK could improve VA and CS, while it wouldn't change aberrations significantly.

Combination of Intracorneal Ring Segments (Ferrara and Intacs) in the Care of Patients With Keratoconus

Abstract #: RP30037076

Presenting Author: Roberto G Albertazzi Sr MD
Coauthors: Leonardo Ferlini Sr MD, Rao Guillermo Sr MD, Luciano D Perrone MD, Jesus M Merayo-Lloves MD, Jose F Alfonso MD

Purpose: Outcome analysis of a combination of intracorneal ring segment (ICRS), both Ferrara and Intacs, for tectonic and refractive correction of paracentral keratoconus. **Methods:** Forty-three eyes of 33 patients were divided in 2 groups according to the coincidence of axis of astigmatism and coma. K-minimal, K-maximal, uncorrected distance visual acuity (UDVA), best corrected visual acuity (CDVA), and refractive error reduction were measured. **Results:** After 6 months the improvement in keratometric values groups (especially in K-max), UDVA, CDVA, myopia, and astigmatism were significant ($P < .01$) in both groups. **Conclusions:** The combination of Ferrara and Intacs ICRS implantation achieve good tectonic and refractive outcome in the care of patients with keratoconus.

Accommodation Amplitude and Visual Acuity With the New Accommodative IOL: The Akkolens Lumina

Abstract #: RP30037116

Presenting Author: Jorge L Alio MD PhD
Coauthors: Alfredo Vega-Estrada MD, Alexander Angelov**, Michiel Rombach

Purpose: To compare accommodation amplitude and visual acuity of the Akkolens with a monofocal IOL. **Methods:** Prospective study of 16 eyes that were divided into Group 1—11 eyes implanted with the Akkolens—and Group 2—5 eyes implanted with the AcrySof SN60AT. After implantation, refractive status and defocus responses were measured. **Results:** Corrected vision was not different between groups ($P = .72$). Defocus response of Group 1 was significantly higher ($P < .01$), with a mean visual acuity of 0.64 ± 0.22 for a reading distance of 33 cm. The defocus response for 66 cm was not significantly different between groups (0.81 vs. 0.67 for Group 2; $P = .07$). **Conclusion:** Preliminary results show that the Akkolens provides sufficient accommodation to allow sharp vision for reading and intermediate vision.

3-D LASIK Flap Variability Assessment, in Flaps Created by a Mechanical Microkeratome (M2) and Two Femtosecond Lasers (FS60 and FS200)

Abstract #: RP30037056

Presenting Author: George Asimellis PhD
Coauthors: A John Kanellopoulos MD

Purpose: To evaluate programmed vs. achieved flap thickness variability. **Methods:** 110 LASIK eyes of 3 groups had high-frequency ultrasound biomicroscopy (HF-UBM). Topographic flap and epithelial thickness variability (FTV) were computed. **Results:** Average central thickness: M2 (mean ± standard deviation), 138.33 ± 12.38 µm; FS60, 128.46 ± 5.72 µm; and FS200, 122.00 ± 5.64 µm. Topographic flap thickness variability: M2, 9.73 ± 4.93 µm; FS60, 8.48 ± 4.23 µm; and FS200, 4.84 ± 1.88 µm (statistically significant to M2 and FS60). **Conclusions:** HF-UBM study revealed femtosecond LASIK (FL) reduced FTV compared to keratome (M2); also possible significant difference in FTV between the two FL groups.

Clinical Outcomes of Premium IOL Implantation in Post-LASIK Cataract Eyes

Abstract #: RP30037156

Presenting Author: Navaneet S C Borisuth MD PhD
Coauthors: Darshan S Hullon, Sahiba K Chailertborisuth

Purpose: To evaluate the outcomes of post-LASIK cataract eyes undergoing phacoemulsification (PE) with toric (t-IOL) ($n = 6$) or multifocal lens (m-IOL) ($n = 15$). **Methods:** Twenty-one eyes of 19 patients underwent t-IOL or m-IOL implantation using the American Society of Cataract and Refractive Surgery IOL Calculator to optimize IOL powers. We analyzed the postoperative manifest refractive spherical equivalent (MRSE), uncorrected distance and near visual acuity (UDVA and UNVA), and the rate of excimer laser enhancement (ELE) to obtain the target refraction. **Results:** After PE, the MRSE was -0.21 ± 1.19 D. UDVA improved to 0.22 ± 0.21 ($P = .01$). In the m-IOL group, UNVA improved from 0.50 ± 0.10 to 0.07 ± 0.1 ($P < .001$). Sixty-two percent of eyes were within ±0.5 D of target outcomes, and 100% were within ±2.0 D. ELE was performed in 43% of eyes. **Conclusion:** Implantation of premium lenses in post-LASIK cataract eyes results in excellent UDVA and UNVA but is associated with a high rate of ELE.

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

Comparison of Topographic and Tomographic Metrics for the Distinction Between Eyes With Keratoconus and Normal Eyes

Abstract #: RP30037067

Presenting Author: Jens Buehren MD
Coauthors: Karl Henpel MD, Thomas Kohnen MD PhD FEBO

Purpose: To compare the discriminative ability of different keratoconus detection metrics. **Methods:** Twenty-nine keratoconus (KC) and 97 normal eyes were examined with the Pentacam Scheimpflug system. The area under the receiver operating characteristics curve (AzROC) was computed for different KC detection metrics. **Results:** Discriminant functions constructed from Zernike coefficients yielded the maximum AzROC (0.93, 0.95, and 0.95, respectively) followed by C3-1 (0.90), and a discriminant function based on anterior elevation data (Df, 0.89). The discriminant function based on posterior corneal elevation data (Dp), coma root mean square and the index of vertical asymmetry (IVA) had the highest specificity values, however, at the cost of sensitivity. **Conclusions:** The Zernike method yielded excellent results for the detection of early KC with the Pentacam.

Reliability of High-Order Aberrations Measurements With 2 Wavefront Aberrometers: Ray Tracing vs. Dynamic Skiascopy

Abstract #: RP30037137

Presenting Author: Florence Cabot MD
Coauthors: Alain Saad MD, Sonia H Yoo MD, Siobhan Williams, William J Feuer MS, Damien Gatinel MD

Purpose: To assess repeatability of high-order aberrations measurements with 2 wavefront aberrometers, one using ray tracing technology; the other, dynamic skiascopy. **Methods:** Three consecutive aberrometric measurements were obtained with iTrace (Tracey Technologies) and OPD-Scan III (Nidek; Japan). In keratoconus, post-refractive surgery, and healthy eyes, repeatability was assessed with intraclass correlations (ICC) and device differences were examined with Bland-Altman plots. **Results:** For high-order aberrations, in keratoconic and post-refractive surgery eyes, ICCs were excellent (> 0.9) for both iTrace and OPD-Scan III. Bland-Altman plots revealed no systematic differences between devices. **Conclusion:** These 2 wavefront aberrometers provide reliable measurements in both healthy and aberrated eyes.

Stromal Lenticule Surface Quality After Femtosecond Small-Incision Lenticule Extraction (ReLEx SMILE)

Abstract #: RP30037155

Presenting Author: Florence Cabot MD
Coauthors: Noel Ziebarth, William W Culbertson MD, Rehan Hussain MD, Sander Dubovy MD, Sonia H Yoo MD

Purpose: To evaluate stromal lenticule surface quality after femtosecond small-incision lenticule extraction (ReLEx SMILE). **Methods:** VisuMax (Carl Zeiss Meditec; Dublin, Calif., USA) femtosecond laser was used to perform the lenticule extraction. Settings were: spot/tracking distance of 3x3 microns and energy level index of 25. Light microscopy and electron microscopy analysis were performed on 17 stromal lenticules removed after ReLEx SMILE procedure. **Results:** Electron microscopy revealed that 64.7% of extracted lenticules presented a smooth anterior and posterior surface. **Conclusion:** Stromal lenticules extracted from ReLEx procedure have good surface quality.

Monofocal Toric IOL Implantation and Alignment With an Empirical Method: Subjective and Objective Refractive Results

Abstract #: RP30037077

Presenting Author: Fabrizio I Camesasca MD
Coauthors: Massimo Vitali, Paolo Vinciguerra MD

Purpose: We evaluated subjective refraction (SR) and objective refraction before and after implantation of a toric aspheric monofocal (TAM) IOL. **Methods:** Thirty-six eyes received a TAM IOL. Preoperatively, reference limbal vessels close to the website software alignment axis were photographed. IOL was aligned with these vessels, checking software angle and corneal topography astigmatism. **Results:** Mean preoperative SR was -2.29 D ± 3.63 D sph with -2.19 D ± 0.55 D cyl at 64.44° ± 72.73. Mean topographic astigmatism was -1.79 ± 0.39 at 118.88° ± 73.82°. Postoperatively (9 ± 4 months), mean SR was -0.41 D ± 0.79 D sph with -0.25 D ± 0.44 D cyl at 93.33° ± 45.09. Mean BSCVA and UCVA were -0.06 logMAR and -0.02 logMAR, respectively. Mean TA was -1.87 D ± 0.40 D at 134.25 ± 63.90. **Conclusions:** Mean TA was not influenced by surgically induced astigmatism and SR showed highly satisfactory correction of astigmatic defect.

Phakic IOLs in Keratoconus: Artiflex vs. Implantable Collamer Lens

Abstract #: RP30037082

Presenting Author: Pilar Casas de Llera MD
Coauthors: Jorge L Alio MD PhD, Pablo Pena, Fidan Guliyeva MD

Purpose: To compare results achieved with 2 different models of phakic IOLs (P-IOLs) in stable keratoconic patients. **Methods:** Forty-eight eyes were implanted (20 Artiflex, 28 implantable collamer lens, ICL). Main outcome measures: manifest refraction, uncorrected and corrected distance visual acuity (UDVA and CDVA), corneal topography. **Results:** Spherical equivalent changed from -9.31 ± 4.20 to -0.46 ± 0.88, UDVA changed from 1.24 ± 0.39 to 0.18 ± 0.20, and CDVA changed from 0.13 ± 0.15 to 0.07 ± 0.11 *(P* < .001). None of the patients lost lines of CDVA. Efficacy and safety indexes were 0.90 ± 0.26 and 1.19 ± 0.29. Stability was confirmed during the follow-up. **Conclusion:** P-IOL implantation is a safe and effective surgical option for stable keratoconus. Artiflex revealed clinically, although not significantly, better values of efficacy (*P* = .058).

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

Clinical Outcomes With a New Diffractive Multifocal IOL

Abstract #: RP30037121

Presenting Author: Pilar Casas de Llera MD
Coauthors: Ana Belen Plaza, Alfredo Vega-Estrada MD, Jorge L Alio MD PhD

Purpose: To evaluate visual outcomes in patients implanted with a new diffractive multifocal IOL. **Methods:** A study including 10 patients implanted with the SeeLens MF multifocal IOL. **Results:** A significant improvement was observed in uncorrected distance visual acuity, corrected distance visual acuity, uncorrected near visual acuity, and corrected near visual acuity ($P <$ .01). Postoperatively the uncorrected intermediate visual acuity was 0.20 ± 0.13. There was a significant reduction of the internal higher-order aberrations ($P \leq .04$). Visual Functioning questionnaire showed that patients reported high levels of satisfaction when performing daily tasks. **Conclusions:** The SeeLens MF IOL is able to restore successfully distance, near, and intermediate visual function after cataract surgery.

Premium IOL Calculations in the Post-LASIK Cataract Eye: A Comparison of the American Society of Cataract and Refractive Surgery IOL Calculator and Holladay II Formula

Abstract #: RP30037150

Presenting Author: Sahiba K Chailertborisuth MD
Coauthors: Darshan S Hullon, Darshan S Hullon, Navaneet S C Borisuth MD PhD

Purpose: To compare the accuracy of Holladay II and the American Society of Cataract and Refractive Surgery (ASCRS) IOL Calculator for premium IOL (P-IOL) power calculations in post-LASIK cataract eyes. **Methods:** Postoperative refractive data were used to compare back-calculated optimum IOL powers (BCI) to those predicted by Holladay II and the ASCRS IOL Calculator in 20 eyes of 18 patients undergoing P-IOL implantation (toric lens: $n = 6$, diffractive multifocal lens: $n = 14$) after myopic LASIK ($n = 11$) or hyperopic LASIK ($n = 9$). **Results:** BCI correlated highest with ASCRS average IOL power ($r = 0.8604$), Modified Masket ($r = 0.7439$), Masket ($r = 0.6440$), and corneal bypass ($r = 0.6007$) power calculations. **Conclusion:** The ASCRS Average IOL formula and the Masket formulae most effectively predicted postoperative refractive outcomes in premium IOL implantation of post-LASIK cataract eyes.

Compare Diazepam Oral to Midazolam Intravenous Injection for Sedation in Cataract Surgery Under Topical Anesthesia

Abstract #: RP30037070

Presenting Author: Ming Chen MD
Coauthors: Geoffrey M Hill MD, Eliot Ku, Mindy Lin Chen

Purpose: Diazepam vs midazolam in cataract surgery. **Methods:** 223 cases were in the study. **Results:** Diazepam induced less paradoxical movement and less poor cooperation (< 0.05). **Conclusion:** Diazepam is better.

Change in Refractive Error and Corneal Structure After Selective Laser Trabeculoplasty

Abstract #: RP30037119

Presenting Author: Mausam R Damani MD
Coauthors: Marlene R Moster MD, Meredith J Regina MD PhD, Husam Ansari MD PhD, Michael E Sulewski MD, Stephen E Orlin MD

Purpose: To describe the refractive and corneal changes associated with selective laser trabeculoplasty (SLT). **Methods:** Retrospective case series. **Results:** Three patients presented after SLT with substantial acute decrease in BCVA, to as low as 20/200 in the worst case. Exam revealed central corneal haze, thinning, and dramatic topographic flattening in all 3 cases, along with varying degrees of hyperopic shift, the greatest of which was 8.75 D. At 1 year follow-up, BCVA had improved to at least 20/25 in all patients; however, central corneal thinning persisted. **Conclusion:** While SLT is generally thought to be safe, significant refractive shifts and corneal changes can occur. Given the number of SLT procedures performed, studies of the causes and predisposing factors for these changes are needed.

Effects of Dry Eye on Corneal Nerve Regeneration After Refractive Surgery

Abstract #: RP30037165

Presenting Author: Mohammad H Dastjerdi MD
Coauthor: Reza Dana MD MSc MPH

Purpose: To examine the effects of dryness on corneal nerve regeneration after refractive surgery in a mouse model of dry eye. **Methods:** Dry eye was induced in a group of mice ($n = 20$). Age-matched mice ($n = 20$) served as controls. After 2 days, partial thickness trephinations were made in corneas to sever nerve bundles. Corneas were harvested on Days 3-10. **Results:** In the control group, regenerated nerves exhibited parallel growth with minor tortuosity. The corneas in the dry eye group showed scattered irregular growth, with highly focal regenerative pattern and tortuosity. **Conclusion:** Nerve regeneration in dry eye is strikingly different than in non-dry eye corneas. Patients susceptible to dry eye may be at greater risk of abnormal corneal nerve regeneration after refractive surgery that may subsequently perpetuate the dry eye disease.

Operating Times of Experienced Surgeons Beginning Femtosecond Cataract Surgery

Abstract #: RP30037107

Presenting Author: Kendall E Donaldson MD
Coauthors: Jordon G Lubahn MD, William W Culbertson MD, Sonia H Yoo MD

Purpose: To better understand how adding femtosecond (FS) technology will impact operating room efficiency. **Methods:** Time (patient-in to patient-out) was compared between conventional and FS cataract surgery (laser completed as part of the timed procedure). **Results:** Three surgeons completed 420 cataract surgeries during the first 6 months of using the laser; 162 patients (38.6%) had the FS laser. Surgeons 1, 2, and 3 had mean conventional case times of 33.1, 40.9, and 29.5 minutes, while their FS times were 45.1, 52.9, and 40.6 minutes, respectively. This resulted in a difference of 11.1-12.1 minutes longer for FS cases ($P <$ .0001). **Conclusion:** We found that, even for experienced cataract surgeons, using the FS laser resulted in longer operating room times compared to conventional cataract surgery.

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

Optical Factors and Vector Analysis in Increased Visual Acuity After Excimer Laser Surgery Performed on Mixed Astigmatic Patients Using Bitoric Ablation

Abstract #: RP30037163

Presenting Author: Uzeyir Erdem MD
Coauthor: Abdullah Ilhan MD

Purpose: To examine optical factors in eyes with increased visual acuity after bitoric ablation excimer laser surgery for correcting mixed astigmatism. **Methods:** Fifty-seven eyes of 35 patients; Nidek's Navex CXII System and bitoric ablation software (modified Chayet's) were used. Wavefront and vector analysis were done. **Results:** No eye lost corrected visual acuity (CVA); postop uncorrected visual acuity was significantly better than preop CVA ($P = .013$); CVA increases in amblyopic patients were better, although not significant ($P = .183$). There were no important increases in high-order aberrations after surgery due to the aspheric and bitoric correction and significant improvement in blurring strength. **Conclusion:** Bitoric excimer laser is effective and safe in the treatment of mixed astigmatism. Sparing the corneal asphericity and improving the optic quality after surgery results in better visual outcome.

Six-Month Results of Presbyopia Correction With a µ-Monovision Approach in Surface Ablation

Abstract #: RP30037089

Presenting Author: Erika N Eskina MD

Purpose: To investigate results of presbyopia correction using µ-monovision biaspheric PRK treatments. **Methods:** Ongoing study performed on 6+11 presbyopic patients with myopic and hyperopic refraction, respectively. Uncorrected distance and near visual acuities were investigated together with the level of anisometropia. Data were collected at 6 months follow-up. **Results:** Statistically significant differences ($P < .0008$) were observed between preop and postoperative UDVA for both groups and between preop and postoperative UNVA ($P < .0001$) for the hyperopic group. The target anisometropia of 0.75 D was reached in both groups (0.72 ± 0.14 D and 0.74 ± 0.40 D for myopic and hyperopic groups). **Conclusion:** A biaspheric µ-monovision approach allows spectacle independence in myopic and hyperopia presbyopic patients.

Accelerating Vision after LASIK

Abstract #: RP30037166

Presenting Author: Sandy T Feldman MD
Coauthors: Daniel S Durrie MD, Karl G Stonecipher MD, Stephen G Slade MD FACS, K Ashley Tuan OD PhD

Purpose: To provide immediate visual recovery using a unique shield after LASIK. **Methods:** Early visual and corneal recovery after femtosecond LASIK were studied. A cohort of patients received an ocular shield immediately after LASIK. Visual and functional data were measured in the first 4 hours and 24 hours postop and were compared with that of a control cohort. **Results:** Corneal edema and surface irregularity were responsible for transient post-LASIK visual reduction. Eyes with the shield demonstrated significantly *(P*, 0.05) faster resolution and better UCVA during the immediate and early postoperative period. As a result, more subjects reported being able to text or drive after LASIK. **Conclusion:** Placement of a shield significantly aids in maintaining vision and accelerating functional recovery following LASIK.

Perioperative Complications and Clinical Outcomes of IOL Exchange in Patients With Opacified Lenses

Abstract #: RP30037080

Presenting Author: Roberto Fernandez Buenaga MD
Coauthors: Jorge L Alio MD PhD, Laura Pinilla Cortes

Purpose: To evaluate the perioperative complications and the outcomes of IOL exchange in patients with opacified lenses. **Methods:** Retrospective consecutive series of 22 eyes that had severe late opacification of the IOL. The IOLs were explanted and replaced with new IOLs. The perioperative complications and the best spectacle-corrected visual acuity (BSCVA) before and after the explantation surgery were analyzed. **Results:** The mean time lapsed between the cataract surgery and the IOL exchange surgery was 89.1 ± 33.6 months. The mean BSCVA (decimal scale) before and after the surgery were 0.25 ± 0.23 (0.001-0.75) and 0.71 ± 0.2 (0.08-1.0), respectively ($P < .001$). Twenty eyes (90.9%) achieved a BSCVA ≥ 0.5. **Conclusion:** The IOL exchange surgery significantly improves the visual acuity of these patients.

Refractive Error After Cataract Surgery: How to Resolve It? IOL Exchange, Piggyback, or LASIK

Abstract #: RP30037081

Presenting Author: Roberto Fernandez Buenaga MD
Coauthors: Jorge L Alio MD PhD, Laura Pinilla Cortes

Purpose: To evaluate the efficacy, predictability, and safety of IOL explantation, piggyback, and LASIK to correct residual refractive error following cataract surgery. **Methods:** Retrospective study that comprised 65 eyes. Group 1 (IOL explantation: 17 eyes), Group 2 (piggyback: 20 eyes), and Group 3 (LASIK: 28 eyes) were compared. **Results:** Group 3 had a reduction in SE and refractive cylinder in comparison with Group 1 ($P < .001$) and also a significantly reduced cylinder in comparison with Group 2 ($P = .002$). In the efficacy index, significant differences were found between Groups 1 and 3 ($P = .004$) and Groups 2 and 3 ($P = .003$), favoring Group 3. The highest predictability was achieved in Group 3. **Conclusion:** Group 3 (LASIK) had the best refractive outcomes, efficacy, and predictability.

Small-Incision Lenticule Extraction vs. Femto-LASIK: Posterior Corneal Topographic Changes

Abstract #: RP30037125

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

Purpose: To compare posterior float (PF) measurements before and after small-incision lenticule extraction (SMILE) and femto-LASIK (F-LASIK) using a Scheimpflug camera with a Placido disc topographer (SIRIUS). **Methods:** Prospective, randomized, eye-to-eye study. Forty-two eyes of 21 patients were randomized to receive SMILE or F-LASIK. Posterior corneal elevation obtained with SIRIUS was measured preop and 1 day, 1 week, and 1, 3, and 6 months postop. **Results:** At Day 1, PF measured was not statistically significant ($P > .58$); however, over time, logistic regression at further follow-up visits showed that the difference in PF was statically significant ($P < .01$). **Conclusion:** There is a greater statistically significant change in the posterior corneal elevation in eyes operated with SMILE than in those of F-LASIK.

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

Long-term Efficacy and Stability of a Small-Aperture Corneal Inlay for Presbyopia Correction

Abstract #: RP30037144

Presenting Author: Gunther Grabner MD

Purpose: To report 5-year results of implantation of a small-aperture corneal inlay for correction of presbyopia in emmetropes. **Methods:** Thirty-two patients were monocularly implanted with a small-aperture inlay in their nondominant eye. Monocular uncorrected acuities for near (UNVA), intermediate (UIVA), and distance (UDVA) were assessed preoperatively and out to 5 years postoperatively. **Results:** Mean UNVA improvement of 3.2 lines to 20/25 was maintained over the 5-year follow-up. A 1-line improvement was seen in mean UIVA to 20/25, with results maintained over the course of the study. Mean UDVA remained stable from 1 month to 5 years postop with a loss of less than 1 line. **Conclusion:** Implantation of a small-aperture inlay in emmetropes provides long-term sustained improvement in near visual acuity while maintaining distance vision.

Relationship Between Anterior, Posterior, and Total Corneal Astigmatism in Highly Astigmatic Normal and Keratoconic Corneas

Abstract #: RP30037142

Presenting Author: Dilraj Grewal MD
Coauthor: Surendra Basti MBBS

Purpose: To evaluate the relationship between anterior (ACA) and posterior corneal astigmatism (PCA) in normal (N) and keratoconus eyes (K) with ≥ 3 D corneal astigmatism. **Methods:** Twenty-eight normal and 22 K eyes underwent Pentacam to calculate spherical equivalent (SEQ) of posterior cornea, total corneal SEQ, ACA, and PCA. Total corneal astigmatism (TCA) was calculated using vergence transformation. **Results:** SEQ contribution of the posterior to total corneal SEQ was 4.47% in N and 4.76% in K (P = .001). Correlation of PCA with TCA was similar (P = .4) between N (r = 0.42) and K (r = 0.63). PCA contributed 31 ± 8.5% of the TCA in N and 22.6 ± 9.2% in K (P = .02). **Conclusion:** Among highly astigmatic corneas, PCA has a greater contribution toward TCA in N compared to K.

Femtolaser-Assisted LASIK vs. Laser-Assisted Subepithelial Keratectomy for the Correction of High Myopia and Astigmatism

Abstract #: RP30037030

Presenting Author: Seyed Javad Hashemian MD

Purpose: To compare the visual, refractive outcomes and higher-order aberration changes of femtolaser-assisted LASIK (FA-LASIK) with those of LASEK in the treatment of high myopia. **Methods:** Thirty-six eyes with MRSE ≥ -6.0 D and cylinder ≤ -3.0 D were assigned to 2 groups: 26 eyes were treated with FA-LASIK and 12 eyes with LASEK. Uncorrected visual acuity (UCVA), distance corrected visual acuity (DCVA), higher-order aberration changes, and complications were evaluated over 6 months. **Results:** Preoperatively the MRSE was -6.9 D in the FA-LASIK group and -6.5 D in the LASEK group; at 1 week and 6 months it was -0.19 and -0.26, -0.25 and -0.16, respectively. There were no statistically significant differences in terms of UCVA (P = .35), DCVA (P = 1.0), cylinder (P = .99) HOA changes (P = .22), safety (P = .35), and efficacy (P = .13) in all postoperative visits between groups. **Conclusion:** Both FA-LASIK and LASEK were safe and effectively treated eyes with high myopia.

The Visual and Refractive Outcomes and Tomography Changes After Femtolaser-Assisted Intrastromal Corneal Ring Segment Implantation in Keratoconic Subjects

Abstract #: RP30037031

Presenting Author: Seyed Javad Hashemian MD

Purpose: To evaluate the visual, refractive, and tomography change after Intacs SK implantation in keratoconus. **Methods:** One or 2 rings of Intacs SK ICRS were implanted using femtosecond laser in eyes with Stage I-IV keratoconus. Visual, refractive, corneal tomography changes and complications were analyzed over 6 months. **Results:** Sixty-eight eyes were evaluated. At 6 months postoperation, the spherical equivalent decreased by a mean of 1.75 D and the mean cylinder decreased 1.10 D. The mean preop logMAR uncorrected and distance corrected visual acuities of 6.96 and 0.59 increased to 0.54 and 0.34, respectively. Keratometry K flat and K steep decreased by a mean of 2.0 D and 2.57 D, respectively. The mean posterior best fit sphere and irregularity were not changed significantly. **Conclusion:** Implantation of Intacs SK ICRS in keratoconus was safe and effective, leading to significant improvement in UDVA CDVA and refractive error.

Fibrin Tissue Glue for the Treatment of LASIK Buttonholes and Recalcitrant Epithelial Ingrowth

Abstract #: RP30037069

Presenting Author: Lingmin He MD
Coauthor: Edward E Manche MD

Purpose: To review cases where fibrin tissue glue was used for the treatment of epithelial ingrowth after LASIK. **Methods:** A retrospective chart review was conducted to evaluate outcomes of eyes treated with fibrin glue after removal of epithelial ingrowth. **Results:** Five eyes were identified. One developed epithelial ingrowth after a traumatic flap dislocation, 2 had prior multiple re-treatments, and 2 had paracentral buttonhole defects. All eyes were treated with a flap lift and scraping of the ingrowth with fibrin tissue glue used to secure the flap edges after repositioning. They were all followed for at least 3 weeks postoperatively, and 2 were seen for 6 months. None had significant recurrence. **Conclusion:** Fibrin tissue glue can be a useful adjunct for the treatment of epithelial ingrowth after LASIK.

Clinical Assessment of a Novel Color LED Topographer With Scheimpflug Tomography and Placido Topography in Normal Eyes

Abstract #: RP30037054

Presenting Author: A John Kanellopoulos MD
Coauthors: George Asimellis PhD, Ioannis Datseris MD**

Purpose: To evaluate a novel color LED topographer (Cassini, i-Optics) in comparison to established standard topographers. **Methods:** Steep and flat keratometry and surface regularity were investigated in 195 healthy corneas, age 35 ± 17 years, with color LED topography, Placido topography (Vario), and Scheimpflug (Oculyzer) topometry. **Results:** Mean keratometry was as follows: for Cassini, 43.5 ± 2.00 D; for Vario, 43.8 ± 2.3 D; and for Oculyzer, 43.7 ± 1.9 D. The differential between Cassini and Vario was -0.3 D and between Cassini and Oculyzer, -0.2 D. **Conclusions:** This novel LED-based topographer provided repeatable measurements, comparable with Placido and Scheimpflug. It may provide superior curvature measurements in the center of the cornea.

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

Novel Keratoconus Classification Based on Corneal Scheimpflug Imaging Asymmetry Indices

Abstract #: RP30037055

Presenting Author: A John Kanellopoulos MD
Coauthor: George Asimellis PhD

Purpose: To investigate Pentacam-derived anterior corneal surface topometric indices in keratoconus (KCN) classification. **Methods:** 212 KCN cases were evaluated. Correlations between keratometry (Ks), corrected distance visual acuity (CDVA), and the Scheimpflug keratoconic grading and 7 anterior derived topometric indices. **Results:** CDVA was 0.626 ± 0.244, keratometry: (K1) was 46.7 ± 5.89 D, (K2) was 51.05 ± 6.59 D. Correlations between CDVA = poor, Ks = poor, but from the 7 indices: ISV (surface variance) strongest, IHD (height decentration) second (*P*-values were < 0.001). **Conclusions:** Of the 7 TI: ISV and IHD may help aid in an early diagnosis and progression assessment of KCN and not CDVA and/or Ks.

Epithelial Profile After Corneal Ring Implantation

Abstract #: RP30037099

Presenting Author: Aylin Kılıç MD

Purpose: To evaluate epithelial thickness (ET) after corneal ring implantation in keratoconic eyes. **Methods:** Twenty-nine keratoconic eyes with ring were divided into 2 groups according to ring thickness. Corneal Module HRT II was used to measure ET 6 months after ring implantation. Group 1 had 15 eyes with thicker ring (300-350 microns), and Group 2 had 14 eyes with thinner ring (150-250 microns). **Results:** Mean ET on ring surface was 31.48 microns; mean ET at ring edge was 68.17 microns for all eyes ($P < .05$). Mean ET difference between ring location and ring edge was 44.26 microns in Group 1 and 28.57 microns in Group 2 ($P < .05$). **Conclusion:** Epithelium is thinner on the ring location, and there is more ET change in eyes with thicker segment.

Clinical Evaluation of an Aberration Corrected, Pure Diffractive Multifocal IOL in a Toric and Nontoric Version

Abstract #: RP30037092

Presenting Author: Florian T A Kretz MD
Coauthors: Anna Fitting MSc, Gerd U Auffarth MD

Purpose: Clinical evaluation of a toric and a nontoric multifocal IOL (M-IOL). **Methods:** For cataract surgery in patients with an astigmatism less than 1 D, a M-IOL with a near add of 4 D was implanted. In patients with an astigmatism of greater than 1 D, the same M-IOL model with toric correction was chosen. Subjective refraction, visual acuity (near in 30 cm and distance), contrast sensitivity, and wavefront analysis were evaluated. **Results:** Uncorrected distance visual acuity was 0.1 in both M-IOL groups, with an uncorrected near visual acuity of 0.2 in the toric and 0.1 in the nontoric M-IOL group (logMAR). **Conclusion:** The aberration corrected, diffractive multifocal IOL in a toric and nontoric version show good refractive results for near and distance visual acuity.

Evaluation of a Diffractive, Apodized, and Convoluted Trifocal Multifocal IOL: The Finevision Concept

Abstract #: RP30037093

Presenting Author: Florian T A Kretz MD
Coauthors: Anna Fitting MSc, Gerd U Auffarth MD

Purpose: Prospective study for the clinical evaluation of a new trifocal lens design. **Methods:** A trifocal diffractive, apodized, and convoluted multifocal IOL (M-IOL) with an intermediate add of +1.75 D and a near add of +3.5 D was implanted during cataract surgery in 20 eyes of 11 patients. Follow-up examinations were performed up to 6 months after surgery, including refraction, ETDRS visual acuity (VA) monocular and binocular (near at 40 cm, 80 cm, and distance), as well as defocus curve. **Results:** Median monocular uncorrected distance VA was 0.2 (logMAR) during follow-up period, compared to corrected distance VA of 0.075. Median uncorrected near VA was 0.2, compared to a distance corrected near VA of 0.2. Uncorrected intermediate VA was 0.3 compared to a distance corrected intermediate VA of 0.2. All patients were satisfied with their refractive outcome. **Conclusion:** The new M-IOL design provides good functional results with a high patient satisfaction.

Clinical Utility of Combined Placido-Scanning-Slit Mid-peripheral and Thinnest-Point Pachymetry After Myopic Ablation

Abstract #: RP30037123

Presenting Author: Miguel J Maldonado MD PhD
Coauthors: Alberto Lopez Miguel, Loreto Martínez-Almeida**, Maria Begona Coco-Martin, Maria del Val**, Maria E Correa Perez MD

Purpose: To assess the reliability of thinnest-point and mid-peripheral pachymetry after keratorefractive surgery. **Methods:** Sixty patients who underwent myopic surface ablation with no biomicroscopically detectable corneal haze were subjected to 5 consecutive topographic examinations (Orbscan-II). The within-subject standard deviation (S_w), the repeatability and coefficient of repeatability (CR = 2.77xS_w/mean) were calculated. **Results:** The repeatability (and CR) for thinnest point and mid-peripheral superior, inferior, nasal, and temporal locations was 26.5 (5.81%), 37.9 (6.29%), 31.0 (5.21%), 30.5 (5.0%), and 35.4 µm (6.26%), respectively. **Conclusions:** These estimates should help discriminate real pachymetry change, as occurs in post-laser ectasia, from pachymetry measurement noise.

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

Early Changes in Corneal Sublayer Thickness After Cataract Surgery

Abstract #: RP30037129

Presenting Author: Miguel J Maldonado MD PhD
Coauthors: Alberto Lopez Miguel, Maria Calabuig-Goena, Victoria Marques, Maria Begona Coco-Martin, Dorio Iglesias-Cortinas

Purpose: To assess changes in central and paracentral epithelial (ECT) and nonepithelial corneal thickness (NECT) after phacoemulsification. **Methods:** We measured 20 eyes with Cirrus HD-OCT at the corneal center and at the paracentral 3-mm diameter. Gauging was performed before and 7 and 30 days after surgery. **Results:** With respect to preoperative ECT, 30-day central, peri-incisional, and opposite-incisional values decreased (-4.5 ± 5.5, -4.9 ± 6.4, and -3.9 ± 5.5 µm, respectively; $P < .01$). One week postoperatively, NECT increase was maximal at the central (29.3 ± 17.2 µm) and peri-incisional (36.1 ± 28.7 µm) locations *(*$P = .02$). **Conclusions:** Corneal epithelial thinning seems to compensate for nonepithelial thickening after phacoemulsification. Changes occur more markedly in the peri-incisional area.

Contralateral Comparisons of the Shield Surface Ablation and Bandage Contact Lens Surface Ablation

Abstract #: RP30037100

Presenting Author: Marguerite B McDonald MD

Purpose: To evaluate the vision and epithelial healing rate in a cohort of patients using the Shield (Nexis Shield) and bandage contact lens (BCL) after undergoing surface ablation. **Methods:** Prospective contralateral study was conducted on 25 PRK subjects from 2 sites. Subjects were followed daily during the first 4 days and Day 7. **Results:** The vision were significantly better ($P < .05$) in UCVA and BCVA at most time points for the eyes with the Shield. On average, eyes with the Shield had 2 lines better vision than the eyes with the BCL; these eyes also healed faster ($P < .05$) than the contralateral eyes with the BCL. **Conclusion:** Placement of the Shield significantly aids in maintaining uncorrected visual acuity and accelerating epithelial healing following surface ablation.

LASIK Following Small-Incision Lenticule Extraction (SMILE) Lenticule Reimplantation: A Feasibility Study of a Novel Method of Creating Monovision in the Treatment of Presbyopia

Abstract #: RP30037126

Presenting Author: Jodhbir S Mehta FRCS FRCOphth
Coauthor: Chris Lim, Andri Riau, Shyam S Chaurasia, Donald Tan MD FRCS FRCOphth

Purpose: To investigate LASIK after small-incision lenticule extraction (SMILE) lenticule reimplantation. **Methods:** SMILE correction was performed in 9 rabbit eyes. The lenticules were cryopreserved and reimplanted. Five weeks later, 3 of these eyes underwent LASIK; 3 eyes underwent standard LASIK. Tissue responses were analyzed by immunohistochemistry, slitlamp, and in vivo confocal microscopy (IVCM). **Results:** Intrastromal irregularities and elevated reflectivity levels of the excimer-ablated plane were observed on slitlamp and IVCM. The reimplantation/LASIK and LASIK alone groups showed similar fibronectin expression levels, number of CD11b-positive cells, and apoptotic cells. **Conclusions:** The tissue responses elicited after performing LASIK on corneas that have undergone SMILE and subsequent lenticule reimplantation are similar to primary procedures.

Pachymetry, Equivalent Keratometric Readings With Zonal Changes and Pupil Diameter That Affect IOL Calculation After Laser Refractive Surgery

Abstract #: RP30037147

Presenting Author: Orkun Muftuoglu MD
Coauthor: Orhan Ayar MD

Purpose: To compare new posterior elevation parameters in diagnosing forme fruste keratoconus (FFKC) in the fellow eye of patients with unilateral keratoconus. **Methods:** Eighty eyes of 40 patients with unilateral keratoconus in one eye and FFKC in the fellow eye were included and compared with only one eye of 81 control subjects. Each eye was evaluated by Scheimpflug rotating camera imaging. Receiver-operating-characteristic (ROC) curves were used to determine the overall predictive accuracy of the test parameters. **Results:** In ROC analysis, D parameter had the highest area under curve, followed by progression and keratometric parameters, BAPE, posterior elevation, and pachymetry. The D parameter was positive (more than 1.50) in 78% of the patients. **Conclusion:** The D parameter has a good sensitivity and specificity to diagnose FFKC.

Equivalent Keratometric Readings With Zonal Changes and Pupil Diameter That Affect IOL Calculation After Laser Refractive Surgery

Abstract #: RP30037148

Presenting Author: Orkun Muftuoglu MD
Coauthor: Orhan Ayar MD

Purpose: To compare pre- and post-myopic laser refractıve surgery keratometric and pachymetrıc measurements. **Methods:** Sixty-two eyes of 31 patients underwent femtosecond and wavefront-guided LASIK with MEL 80 excimer laser for the correction of myopia or myopic astigmatism and were evaluated by Scheimpflug camera imaging (Pentacam; Wetzlar, Germany) before and after surgery. **Results:** Among different equivalent K readings under 1.0-mm, 2.0-mm, 3.00-mm, and 4.5-mm zones, the mean equivalent K readings at 1.0 and 2.0 mm were closest to the benchmark value. There was a correlation with postoperative pupil diameter and equivalent K reading diameter. **Conclusion:** The mean equivalent K readings at 1.0 and 2.0 mm were closest to the benchmark value. Postoperative pupil diameter was correlated with equivalent K reading diameter.

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

Long-term Outcomes of Implantable Collamer Lens for Stable Keratoconus

Abstract #: RP30037085

Presenting Author: Alejandro Navas MD
Coauthors: Martha Jaimes, Arturo J Ramirez-Miranda MD, Tito Ramirez-Luquin MD, Enrique O Graue Hernandez MD, Arturo Gomez Bastar MD

Purpose: To describe the long-term outcomes of patients with keratoconus treated with implantable collamer lenses (ICL). **Methods:** Of 41 eyes of 28 patients with topographic diagnosis of stable keratoconus or forme fruste keratoconus, 25 cases were treated with toric ICL and 16 with spheric ICL model. **Results:** Mean age: 30 ± 7.4 years. Paired *t*-test was used. Preoperative spherical equivalent was -12.25 ± 3.92 D; postoperative, -0.72 ± 1.07 D ($P < .001$). Preoperative uncorrected distance visual acuity was 1.77 ± 0.49 logMAR; postoperative, 0.22 ± 0.15 logMAR ($P < .001$). Mean corneal power: 47 ± 2.6 D (45-63 D). Follow-up was 45 ± 33 months, with no evidence of progression. **Conclusion:** This study provides evidence that the use of ICLs could be a long-term, safe, predictable, and efficacious strategy in patients with stable keratoconus.

Safety and Visual Outcomes with a 1-Piece Hydrophobic Acrylic IOL in Cataract Patients

Abstract #: RP30037138

Presenting Author: Mark Packer MD

Purpose: To review the safety and visual outcomes of a multicenter clinical study with implantation of a 1-piece hydrophobic acrylic IOL (enVista, model MX60, Bausch + Lomb; Rochester, NY, USA). **Methods:** Prospective, multicenter clinical study of cataract patients implanted with the enVista IOL. The final visit was on postoperative day 150 (± 30 days). **Results:** 118 patients (100%) achieved BCVA of 20/40 or better, compared with 96.7% of patients in the historical controls FDA grid data. No glistenings developed in any IOL.The lens showed excellent rotational stability. **Conclusion:** The enVista MX60 lens was associated with excellent BCVA, high rotational stability, a low incidence of posterior capsule opacification, and no glistenings. The safety and visual outcomes exceeded the historical controls of the FDA grid data.

Postop Cataract Associated With Implantable Collamer Lenses Is Reported to Range From 2.9% to 33%. Can We Possibly Narrow That Down?

Abstract #: RP30037090

Presenting Author: Gregory D Parkhurst MD

Purpose: To show physicians how to analyze the literature to accurately judge the safety of implantable collamer lenses (ICLs). **Methods:** A literature search was conducted to discover why the reported range of cataract following ICL implantation is so wide. **Results:** Several variables impact the incidence of cataract reported, including method of data reporting; definition and clinical significance of cataract; size, age, and refractive range of cohort; ICL model and manufacturer. **Conclusion:** To accurately gauge the risk of cataract associated with ICLs requires a closer look at the variables and data reported in the article.

Safety and Efficacy of Trulign Toric Presbyopia-Correcting IOL

Abstract #: RP30037027

Presenting Author: Jay Stuart Pepose MD PhD

Purpose: To determine safety and efficacy of Trulign toric IOL. **Methods:** Prospective, randomized, multicentered clinical trial. **Results:** Trulign toric IOL showed an 85% reduction in cylinder, significant difference in reduction in cylinder in the 1.25 D toric vs. the spherical control group ($P < .001$), rotational stability of < 2 degrees, 96.1% ≤ 5 degree rotation, and statistically significant improvement in uncorrected distance vision vs. spherical control ($P = .001$) with mean uncorrected vision of 20/25 distance, 20/22 intermediate, and 20/40 near. **Conclusion:** Trulign toric accommodating IOL is safe and effective, reducing the effects of preoperative corneal astigmatism while providing improved uncorrected distance, intermediate, and near vision.

Pupil Light Response in Cataractous and Pseudophakic Subjects

Abstract #: RP30037051

Presenting Author: Jay Stuart Pepose MD PhD
Coauthor: Amitava Gupta PhD

Purpose: To establish baseline metrics of pupil light response and to determine whether pupil light response measurements differ between cataractous and pseudophakic patients. **Methods:** Dual arm, parallel study using infrared pupillometry. **Results:** Multiple regression of the pseudophakic subject data showed that time elapsed since surgery was a significant factor in dark-adapted pupil size, and its effect is independent of age. ANCOVA analysis with age covariate comparing cataractous subjects only to pseudophakic subjects with elapsed time since surgery less than 2.5 years showed that dark-adapted pupil diameter was significantly smaller in those pseudophakic subjects with more recent surgery. **Conclusion:** There is an effect of cataract surgery on pupil function that persists for years after surgery but gradually diminishes.

Comparison of Optical Quality in Low and Moderate Myopic Patients Operated With PRK and Femto-LASIK

Abstract #: RP30037146

Presenting Author: Eric Perez-Campagne MD
Coauthors: Hana Landoulsi, Damien Gatinel MD

Purpose: To compare objectively the quality of vision assessed by double-pass imaging. **Methods:** Prospective comparative study of 130 eyes (PRK, $n = 76$; femto-LASIK, $n = 54$). The objective scattering index (OSI), the modulation transfer function (MTF) cut-off frequency (c/deg), and the Strehl ratio (SR) were compared preoperatively and at 3 months. The patients were divided into low myopic PRK group, moderate myopic PRK group, low myopic femto-LASIK group, and moderate myopic femto-LASIK group. **Results:** At 3 months the OSI increased more in the moderate myopic patients ($P < .05$). The MTF cut off frequency (c/deg) and the SR were higher in the low myopic patients. **Conclusion:** The low myopic patients have a better optical quality in the postoperative period as they have less scatter, better contrast sensitivity, and a larger SR.

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

Corneal Ectasia Secondary to Radial Keratotomy: Astigmatism Correction With an Additional IOL by the Piggyback Technique

Abstract #: RP30037036

Presenting Author: Joana Portelinha Padua Figueiredo MD
Coauthors: Tiago B Ferreira MD, Eduardo F Marques MD

Purpose: Two cases of high astigmatism due to corneal ectasia after radial keratotomy (RK) were managed with the implantation of an additional toric IOL. **Methods:** Two patients submitted to RK and phacoemulsification with IOL implantation presenting with progressive visual loss. Corneal tomography revealed corneal ectasia. (1) Corneal collagen crosslinking was performed. Postoperative uncorrected distance visual acuity (UDVA) was 20/200 and corrected distance visual acuity (CDVA) was 20/30 (+4.00-4.50x90°). (2) CDVA was 20/50 (-9.75x60°). Corneal ectasia was stable over 1 year. An add-on Torica-sPB IOL (HumanOptics) was implanted in both patients. **Results:** UDVA improved to 20/30 and CDVA to 20/25 (+1.00-1.00x100°). (2) UDVA and CDVA improved to 20/30 (-0.25-0.50x60°). **Conclusion:** The implantation of a secondary IOL was effective in improving VA in patients with high astigmatism due to corneal ectasia.

Ideal Pocket Position With Femtosecond LASIK

Abstract #: RP30037095

Presenting Author: Louis E Probst MD

Purpose: To determine the ideal flap position for femtosecond LASIK. **Methods:** The anatomical measurements of the corneal dimensions (retrospective video analysis) and lid position (preoperative clinical measurement) were performed on 52 patients (104 eyes). **Results:** The average corneal dimensions were 12.16 + 0.37 mm horizontally and 11.66 + 0.52 mm vertically. In over 80% of eyes, the lid margin to light reflex distance (MRD) was >10% of corneal vertical measurement or >1.2 mm. **Conclusion:** At least 1.2 mm of superior cornea is covered by the upper lid in the majority of patients, which limits its visual significance, making it the ideal position for the flap pocket and hinge.

Circular vs. Elliptical Flaps for Femtosecond LASIK

Abstract #: RP30037096

Presenting Author: Louis E Probst MD

Purpose: To compare the visual and qualitative results of elliptical and circular flaps created with the femtosecond laser. **Methods:** Flaps were created with the iFS laser and all corrections were performed with the CustomVue (both Abbot Medical Optics; Santa Ana, Calif., USA). **Results:** Preoperatively, the sphere error was -2.82 ± 1.2 D in the circular group and -3.35 ± 1.4 D in the elliptical group. The astigmatism was -0.62 D in the circular group and -0.58 D on the elliptical group (ns). Postoperatively at 90 days, in the circular and elliptical groups, respectively, 20/20 or better uncorrected vision was achieved in 100% and 90%, 20/16 or better in 84.6% and 80%, and 20/12 or better in 40.4% and 30.0% (ns). **Conclusion:** Both circular and elliptical flaps can yield excellent results for LASIK.

Corneal Ectasia Diagnosis Models Developed From Scanning Slit Videokeratography

Abstract #: RP30037112

Presenting Author: Mujtaba A Qazi MD
Coauthors: Pete S Kollbaum PhD, Ashraf M Mahmoud**, Michael D Twa OD, Cynthia Roberts PhD, Jay Stuart Pepose MD PhD

Purpose: To assess the efficacy of scanning slit videokeratography metrics to diagnose keratectasia. **Methods:** 617 slit-scanning videokeratography (Orbscan) metrics were calculated for a retrospective data set of keratoconus (n = 338), fellow keratoconus (KCF, n = 74), suspect (n = 78), and normal eyes (n = 114). For each measure, the receiver operator curve (AUC) was calculated. **Results:** Anterior curvature, anterior elevation, and posterior elevation metrics had higher AUCs (≥ 0.97) for detecting KCN than pachymetry metrics (≥ 0.92). Combining metrics improved the ability to differentiate subgroups, including for KCF (AUC ≥ 0.99). **Conclusion:** Evaluation of keratoconus and suspect corneas highlights the importance of both anterior and posterior videokeratographic analysis in the assessment of keratorefractive surgery candidates.

Small-Incision Lenticule Extraction Procedure for the Correction of Myopia and Astigmatism: Eighteen-Month Results

Abstract #: RP30037103

Presenting Author: Arturo J Ramirez-Miranda MD
Coauthors: Tito Ramirez-Luquin MD, Angie De La Mota MD, Alejandro Navas MD, Enrique O Graue Hernandez MD

Purpose: To report the visual refractive and clinical outcomes of 113 eyes treated with small-incision lenticule extraction (SMILE) to correct myopic refractive errors. **Methods:** A SMILE procedure with the VisuMax femtosecond laser (Carl Zeiss Meditec) was performed. Outcome measures were corrected distance and uncorrected distance visual acuity and manifest refraction. **Results:** The study enrolled 113 eyes of 58 patients. Mean spherical equivalent was -5.75 D (3.27 SD) preoperatively and +0.17 D (0.45 SD) 18 months postoperatively. Refractive stability was achieved within 6 weeks. Eighteen months after surgery, 97% of all cases had an uncorrected distance visual acuity of 20/25 or better. No eyes lost lines of corrected distance visual acuity. **Conclusion:** SMILE appears to be a safe, predictable, and effective procedure to treat myopia and myopic astigmatism.

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

Outcomes Including Contrast Sensitivity of High Myopic Small-Incision Lenticule Extraction Compared to Matched LASIK Controls

Abstract #: RP30037071

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

Purpose: To report outcomes of high myopic small-incision lenticule extraction (SMILE) and matched LASIK controls. **Methods:** Retrospective analysis of 38 high myopic SMILE eyes (SEQ -8.00 to -12.25 D, cylinder up to 2.50 D, and corrected distance visual acuity [CDVA] ≥ 20/20) each matched to 2 LASIK eyes for sphere, cylinder, age, and CDVA. Follow-up was 3 months. **Results:** Mean SEQ -9.67 D, cylinder 0.76 D. Median age: 31 years (19-58 years). Postop SEQ was -0.18 ± 0.45 D (74% ± 0.50 D) for SMILE and -0.35 ± 0.64 D (54% ± 0.50 D) for LASIK. UDVA was ≥ 20/20 in 78% for SMILE and 73% for LASIK. Loss 1 line CDVA in 8% for SMILE and 1% for LASIK. No eyes lost 2 lines. Contrast sensitivity was unchanged for SMILE and LASIK. **Conclusion:** Visual outcomes and refractive accuracy in high myopic SMILE were better than in a matched LASIK control group.

Evaluation of Epi-on Corneal Collagen Crosslinking at 6-Month and 1-Year Follow-up in Patients With Keratoconus or Post-LASIK Ectasia

Abstract #: RP30037149

Presenting Author: Roy Scott Rubinfeld MD
Coauthors: William B Trattler MD, Michael Mrochen PhD, Rosane Oliveira Correa MD, Gregg J Berdy MD, Ranjan Malahotra MD, Jennifer M Mercado MD

Purpose: To determine the efficacy of transepithelial crosslinking (CXL) in patients with keratoconus or post-LASIK ectasia evaluated to ensure adequate stromal riboflavin loading before proceeding to UV light application. **Methods:** Prospective clinical study performed on 390 eyes with keratoconus and 71 eyes with post-LASIK ectasia. UCVA, best spectacle-corrected visual acuity (BSCVA), and K-max measurements were compared with preop measurements at 6-month and 1-year follow up. **Results:** Respectively at 1 year, 1 or more lines of improvement in UCVA and BSCVA were found in 57.6% and 49.4% of eyes with keratoconus and 55.5% and 36.8% of eyes with post-LASIK ectasia. Average change in K-max at 1 year in eyes with keratoconus and post-LASIK ectasia was -0.80 D and -0.60 D, respectively. **Conclusion:** Transepithelial CXL appears safe and effective for keratoconus and post-LASIK ectasia.

Evaluation of Epi-on Corneal Collagen Crosslinking at 6-Month and 1-Year Follow-up in Patients Diagnosed With Keratoconus

Abstract #: RP30037162

Presenting Author: Roy Scott Rubinfeld MD

Coauthors: William B Trattler MD, Michael Mrochen PhD, Gabriela Perez , Rosane Oliveira Correa MD, Ranjan Malahotra MD, Jennifer M Mercado MD, Gregg J Berdy MD

Purpose: To determine the efficacy of transepithelial crosslinking (CXL) in patients with a diagnosis of keratoconus who were evaluated at the slitlamp to ensure adequate stromal riboflavin loading before proceeding to UV light application. **Methods:** Prospective clinical study performed on 390 patients with keratoconus. UCVA, best spectacle-corrected visual acuity (BSCVA), and K-max measurements were compared with preop measurements at both 6-month and 1-year follow-up. **Results:** At 1 year, 57.6% and 49.4% of eyes resulted in an improvement in 1 or more lines of UCVA and BSCVA, with an average change in K-max of -0.80 D. **Conclusions:** In this study, transepithelial CXL appears to be both safe and effective for the treatment of eyes with a preoperative diagnosis of keratoconus.

Apple iPad for Laser Refractive Surgery

Abstract #: RP30037133

Presenting Author: James J Salz MD
Coauthor: Leonard S Teye-Botchway MD MBChB

Purpose: To describe use of an Apple iPad for laser refractive surgery. **Methods:** An iPad modified with a camera and fixation light was used to magnify the cornea while centering a suction ring with a sapphire window over the pupil center. The laser probe with 16 fiberoptic bundles is then attached with magnets, and 16 paracentral spots are delivered in 2.5 seconds to correct low hyperopia and presbyopia. A video of the procedure will be shown. **Results:** Over 200 eyes have been treated with excellent centration of the spots and no complications. The sapphire window acts to protect the cornea so patients experience no discomfort and notice an immediate improvement in vision. **Conclusion:** The iPad allows proper centration for delivery of thulium laser spots and eliminates the need for an operating microscope.

Case Report of a Hyperopic Presbyopic Patient Who Received 9 Bilateral Thulium Laser Treatments Over a 4.5-Year Period

Abstract #: RP30037127

Presenting Author: James J Salz MD
Coauthors: William B Trattler MD, Kenneth J Rodgers MD**, Harry G Glen MD, Michael Berry PhD

Purpose: To evaluate the multiple-repeatability of laser vision correction by noninvasive keratoplasty. **Methods:** Retrospective case study of a hyperopic presbyopic patient treated 9 times over 4.5 years. **Results:** *Safety*. No adverse events occurred. Corneal health was excellent as determined by corneal diagnostics and slitlamp examination. Faint noncosmetically notable opacifications were visible in treatment spots, but these did not cause ocular disturbances such as glare and halo. *Effectiveness*. After each treatment, binocular uncorrected distance and near visual acuities were 20/25 or better. Additional treatments were given as needed for maintenance of functional near vision. **Conclusion:** Noninvasive keratoplasty is multiply repeatable, with negative sequelae, as needed to compensate for age-related changes in vision.

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

Femtolaser Intracorneal Ring Segment Implantation Based on a Nomogram Modification in Type 1 and Type 2 Ectasia

Abstract #: RP30037074

Presenting Author: Mouamen Mostafa Sayed Seleet FRCS MD
Coauthor: Ashraf Hassan Soliman MD

Purpose: To evaluate the visual and corneal changes in keratoconic eyes treated by femtolaser Keraring implantation following a proposed nomogram modification. **Methods:** Keraring implantation was performed in 10 eyes of 7 patients with keratoconus. All cases were followed up for 6 months. **Results:** At 6 months there was an improvement in UCVA ($P < .05$), BSCVA ($P \leq .001$), and refraction ($P < .001$). Keratometric readings changed ($P < .001$), with flattening of the cornea. Corneal aberrations showed significant reduction when analyzed by Zernike ($P < .001$) and Fourier analysis ($P \leq .001$; $P < .001$). Corneal asphericity (Q value) also showed improvement ($P < .05$). **Conclusion:** Femtolaser Keraring implantation using the proposed modification in the nomogram showed promising results.

Keratoconus Match Index and Keratoconus Match Probabilities in Normal and Keratoconic Eyes

Abstract #: RP30037143

Presenting Author: Youjia Shen MD
Coauthors: Tahra Ali Almahmoud MBBS, Eser Adiguzel PhD, Mark J Cohen MD, Avi Wallerstein MD

Purpose: To determine the distribution of the Ocular Response Analyzer (ORA) keratoconus match index (KMI) and keratoconus match probabilities (KMP) to 5 KMPs: normal, suspect, mild, moderate, and severe keratoconus (KC). **Methods:** Normal and diagnosed suspect KC (sKC) and obvious KC (oKC) eyes were examined with ORA. **Results:** KMI was 0.95 ± 0.25, 0.83 ± 0.24, and 0.84 ± 0.26 in normal ($n = 8848$), sKC ($n = 50$), and oKC ($n = 60$) eyes. 100%, 96%, 83%, 6%, and 0.01% of normal, 100%, 98%, 90%, 12%, and 2% of sKC, and 100%, 97%, 92%, 15%, and 0% of oKC matched to some degree to normal, suspect, mild, moderate, and severe KC KMPs, respectively. 83% of normal matched to multiple KC KMPs while 28% of sKC and 33% of oKC had ≥ 75% match to normal KMP. **Conclusion:** KMI and KMP had large overlaps in all eyes, indicating KMI and KMP alone are not adequate for detecting subclinical KC.

Improvement in Refractive Outcomes in Post-Radial Keratotomy Eyes Undergoing Cataract Surgery With Toric IOL Implantation

Abstract #: RP30037124

Presenting Author: Jonathan D Solomon MD

Purpose: To determine whether intraoperative aberrometry is useful in the selection and positioning of toric IOLs in eyes with prior incisional surgery. **Methods:** Results were evaluated in a series of 10 eyes with prior radial keratotomy (RK), with or without astigmatic keratotomy (AK). All of the eyes had 8 or fewer total incisions and were implanted with an AcrySof Toric IOL (SN6AT3-T8). Power selection and positioning were guided by intraoperative aberrometry using the ORA System. **Results:** Mean preop topographic cylinder was 3.32 ± 1.88 D. Three months postop, mean refractive cylinder was 0.41 ± 0.29 D. **Conclusion:** Intraoperative aberrometry contributed to better refractive results than typically experienced in post-RK eyes with standard IOL power selection criteria.

Femtosecond Laser-Assisted On-Axis Intrastromal Arcuate Keratotomy

Abstract #: RP30037128

Presenting Author: Jonathan D Solomon MD

Purpose: To report the results of femtosecond laser on-axis intrastromal clear-corneal incisions (fsOACCI). **Methods:** Patients with regular corneal astigmatism were treated to perform opposite fsOACCI on the steep axis. Patients were followed for 2 months. Preoperative and intraoperative examinations along with aphakic aberrometry were measured prior to incision titration. **Results:** Fourteen patients were enrolled. All incisions were placed on the steep axis. Mean (SD) intraoperative aphakic cylinder was reduced from topographic astigmatism of 1.19 (0.37) D to 0.75 (0.32) D (P-value 0.004). Postop refractive cylinder was 0.51 (0.39) D ($P < .001$). **Conclusion:** Precise and reproducible intrastromal arcuate incisions can be made with the Lensar femtosecond laser without the inherent risk associated with breaching the Bowman membrane.

Optimizing Femtosecond Laser Lens Fragmentation Pattern for Improving Phaco Efficiency

Abstract #: RP30037105

Presenting Author: Kerry D Solomon MD
Coauthor: Helga P Sandoval MD

Purpose: To demonstrate improvement in phaco efficiency with new femtosecond laser fragmentation patterns. **Methods:** Cataract patients with nuclear density of 2-3+ were evaluated. Measurements collected were fragmentation pattern, phaco power, time, and cumulated dissipated energy. **Results:** The new pattern provided small nuclear fragments that were easily aspirated with no or minimal use of phaco energy. **Conclusion:** The use of femtosecond laser in prefragmenting the lens during cataract surgery helps improve phaco efficiency by improving surgeon's overall efficiency with nucleo fractis techniques. The programmable pattern has virtually no limits to fragmentation, and it is expected that many more patterns will be developed as the technology evolves.

Numerically Modeling Stromal Expansion Pressure and Fluid Shifts to Improve Refractive Surgery Predictions

Abstract #: RP30037122

Presenting Author: Harald Patrik Studer PhD
Coauthor: Cynthia Roberts PhD

Purpose: Refractive surgery leads to stress relaxation, tissue expansion, and fluid shifts, which are investigated numerically. **Methods:** Biphasic finite element modeling, a numerical approach relating tissue tensile stresses and fluid pressure in corneal stroma, is used to simulate tissue expansion in LASIK flap incisions. **Results:** The negative imbibition pressure becomes positive in the flap, causing fluid shifts. Stress relaxation occurs in the outer layers, leading to tissue expansion. The deeper layers, taking over the relaxed load from the flap, contract. **Conclusion:** The negative imbibition pressure becomes positive in the flap, causing fluid shifts. Stress relaxation occurs in the outer layers, leading to tissue expansion. The deeper layers, taking over the relaxed load from the flap, contract.

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

Prophylactic Punctal Occlusion in Dry Eye Hyperopic LASIK Patients

Abstract #: RP30037050

Presenting Author: Mohammed A Taha MBBS
Coauthors: Eser Adiguzel PhD, Mark J Cohen MD, Avi Wallerstein MD

Purpose: To determine if preoperative punctal plugs in hyperopic patients can reduce and/or eliminate post-LASIK dry eye. **Methods:** Prospective, comparative study. Inclusion criteria of +2.0 D sphere O.U. Pre-LASIK, long-term, temporary punctal plug was inserted into inferior punctum of 1 eye. Uncorrected and corrected distance visual acuities, manifest refractive spherical equivalence, tear breakup time (TBUT), punctate epithelial erosions (PEE), and conjunctival staining were measured and Ocular Surface Disease Index (OSDI) questionnaire was administered preop and at 1 week and 1 and 3 months postop. **Results:** Forty-five patients were enrolled. No significant differences in accuracy, efficacy, safety, or stability at 3 months. No significant differences in TBUT, PEE, conjunctival staining, or subjective OSDI scores at preop, 1 week, or 1 or 3 months. **Conclusion:** Preliminary results indicate there are no significant differences between plugged and control hyperopic eyes in outcomes and dryness post-LASIK.

Corneal Wound Healing in LASIK Outcomes

Abstract #: RP30037094

Presenting Author: Jonathan CK Tovey MD
Coauthors: Rajiv R Mohan PhD, Ajay Sharma PhD, Ashish Tandon PhD, Audrey Bernstein PhD, John W Cowden MD

Purpose: LASIK can cause stromal flap complications. We tested if topical low TGFβ after flap creation prevents keratocyte loss and improves healing. **Methods:** In vivo rabbit studies used single TGFβ (40 µl) topical application after flap creation with microkeratome. In vitro studies used human stromal fibroblasts and TGFβ (0.01-1.0 ng/ml). Immunofluorescence analyzed corneal fibrosis, proliferation, and apoptosis biomarkers. **Results:** Low TGFβ in vitro stimulated proliferation and migration, and high doses led to differentiation. Equal TGFβ doses in vivo did not cause keratocyte proliferation up to 3 days after flap creation. **Conclusion:** TGFβ affects keratocyte fate in a dose- and time-dependent manner. Low TGFβ may prove effective in reducing LASIK complications by modulating corneal healing. More studies are needed.

Evaluation of 2 Formulations of Riboflavin for Transepithelial Crosslinking

Abstract #: RP30037158

Presenting Author: William B Trattler MD
Coauthors: Roy Scott Rubinfeld MD, Michael Mrochen PhD, Gabby Perez, Rosane Oliveira Correa MD, Jennifer M Mercado MD

Purpose: To evaluate the speed of loading, as well as the efficacy of 2 riboflavin formulations for use in transepithelial corneal crosslinking (CXL). **Methods:** Keratoconus or post-LASIK ectasia patients who underwent transepithelial CXL were evaluated. **Results:** 247 and 200 eyes were treated with riboflavin Formulations 1 and 2, with an average loading time of 56.3 and 22.17 minutes, respectively. At 1 year, 61% and 54% of eyes (Formulation 1) and 67% and 47% of eyes (Formulation 2) experienced 1 or more lines of improvement in UCVA and BSCVA. Patients treated with Formulations 1 and 2 experienced 0.65 D and 2.29 D of flattening in K-max at 1 year, respectively. **Conclusions:** Riboflavin Formulation 1 required a longer loading time than did Formulation 2. A remarkable flattening in K-max was noted at 1 year with Formulation 2.

The Incidence of Topographic Abnormalities in Patients Scheduled for Cataract Surgery

Abstract #: RP30037161

Presenting Author: William B Trattler MD
Coauthors: Rosane Oliveira Correa MD, Brian Frank, Shannon MC Cabe, Charles J Kaiser MD, Frank E Spektor MBChB**, Henry L Trattler MD

Purpose: To report the incidence of topographic abnormalities prior to cataract surgery. **Methods:** Consecutive patients scheduled for cataract surgery from Oct. 2012 to Feb. 2013 underwent preoperative evaluation with topography. **Results:** 120 eyes of 83 patients diagnosed with cataract were assessed. Mean age was 70 years old. Normal / symmetric bow tie was present in only 40% of eyes. Thirteen percent had an abnormal I/S index (>1.4). Corneal topography was subjectively classified as being abnormal in 60% of eyes, with findings that included asymmetric bowtie with inferior corneal steepening, and central flattening after laser corneal refractive surgery or radial keratotomy. **Conclusion:** Corneal topography was able to detect anterior corneal surface abnormalities in patients scheduled for cataract surgery.

Clinical Outcomes and Rotational Stability of a New 1-Piece Toric IOL

Abstract #: RP30037136

Presenting Author: Farrell C Tyson II MD
Coauthors: Kevin Lee Waltz MD, Donald R Nixon MD, Kristen Featherstone MS, Sanjeev Kasthurirangan PhD, Pamela J Smith MS

Purpose: Clinical evaluation of the ZCT 1-piece toric IOL. **Methods:** Multicenter, 2-arm, 6-month clinical trial. Percentage reduction in cylinder and visual acuity were compared between toric eyes and control or target values. Degree of postoperative rotation in all toric eyes was also measured. **Results:** Mean percentage reductions in cylinder were significantly greater for the toric eyes than for control or target in both study arms ($P <$ .0001). Uncorrected distance visual acuity (UCDVA) of ≥ 20/20 were significantly greater for the toric eyes than for control or target in both study arms ($P = .0026$ and $P < .0001$, respectively). Mean absolute axis change between visits for all toric eyes was 2.74°. **Conclusion:** The ZCT toric IOL effectively reduced ocular astigmatism and improved UCDVA, as well as demonstrated excellent rotational stability.

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

Regional Changes in Stromal Diffusivity Following Corneal Collagen Crosslinking

Abstract #: RP30037159

Presenting Author: George O Waring IV MD
Coauthors: Glenn Hepfer BS**, Changcheng Shi PhD, Hai Yao PhD

Purpose: To investigate regional changes in stromal diffusivity after crosslinking (CXL). **Methods:** Standard, epithelium-off corneal CXL was performed on fresh, intact porcine eyes, while controls received riboflavin without irradiation. Fluorescence recovery after photobleaching (FRAP) was performed at different stromal depths, and diffusivities were calculated. **Results:** Diffusivities of crosslinked and control corneas were significantly different (P = .026, Student test) in the anterior cornea. This difference decreased as stromal depth increased (R = -0.89). **Conclusion:** The effect of CXL is more pronounced in the anterior stroma. For the first time, we present a nondestructive ex vivo method for quantifying crosslinking effect with respect to stromal depth.

Evaluating the Correlation and Agreement Between 2 Refractive Surgery Screening Technologies

Abstract #: RP30037075

Presenting Author: Heather M Weissman MD
Coauthor: J Bradley Randleman MD

Purpose: To evaluate the correlation and agreement between the Pentacam HR Belin/Ambrosio Display and Ambrosio Relational Thickness scores and the Ocular Response Analyzer (ORA) Keratoconus Match Score Index in patients with suspicious screening parameters. **Methods:** 174 eyes from 87 patients were evaluated with Pentacam and ORA and categorized as normal, suspicious, or abnormal. Pearson correlation coefficient (r) was used for statistical analysis. **Results:** Pentacam and ORA indices showed poor correlation (r = 0.338 and r = -0.254). There was agreement between the machines in 31 normal eyes (18%), 20 suspicious eyes (11%), and 2 abnormal eyes (1%). **Conclusion:** Pentacam and ORA indices did not correlate with one another. There is limited agreement between these screening algorithms in evaluating patients at risk.

Evaluation of Corneal Flaps Created With 2 Femtosecond Laser Platforms

Abstract #: RP30037140

Presenting Author: Jeffrey Whitman MD OCS

Purpose: To use anterior segment OCT to evaluate the accuracy of LASIK corneal flaps created with 1 of 2 femtosecond laser platforms. **Methods:** Twenty eyes of myopic and hyperopic LASIK patients (10 eyes in each laser group). At 1 month postop, anterior segment OCT was performed to measure flap thickness and uniformity. Femtosecond lasers used were the Victus (Bausch + Lomb; Rochester, NY, USA) and the Intralase (Abbott Medical Optics; Santa Ana, Calif., USA). **Results:** Four OCT measurements were done per eye. The mean postop flap thickness was 126.5 µm (deviation of 0.48 µm) with Victus and 127.88 µm (deviation of -0.88 µm) with IntraLase. **Conclusion:** The Victus and IntraLase femtosecond lasers show similar results with respect to the predictable creation of corneal flaps with good thickness and uniformity.

Screening Subclinical Keratoconus With Color LED Technology-Based Corneal Topography

Abstract #: RP30037118

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Purpose: To assess performance of color LED corneal topography (CLCT) in normal (N), keratoconus (KC), and KC suspect (KCS) eyes. **Methods:** 15 N, 8 KC, and 8 KCS were examined with Keratron (Optikon; Italy), Pentacam (Oculus; Germany), and Cassini CLCT (i-Optics; Netherlands). KC indices SRI, SAI, I-S, and third- and fourth-order corneal aberrations (CA) @ 6-mm zone were compared using the Student t-test. **Results:** KC indices agree well in KC. Pentacam measured different third- and fourth-order CA for N and KC (P < .012 and P < .033, respectively). Cassini SRI was higher (P < .002 and P < .028, respectively) than Keratron for N and KCS. For SAI on N, Cassini was higher (P < .000001) than Keratron. **Conclusion:** Pentacam, Keratron, and Cassini agree well for KC but less so for KCS and N. SRI measurements of the Cassini on N and KCS suggest that the CLCT is more sensitive in corneal irregularity.

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