The Future of Cataract & Refractive Surgery

Raymond Stein, MD, FRCSC
Bochner Eye Institute & University of Toronto

Cataract & Refractive Surgery

Past
- Intracapsular (12 mm)
- Extracapsular (10 mm)

Present
- Phaco with 2.2 mm incision & non-longitudinal energy
- Femtosecond Laser

Future

Intraocular Implants

Past
- Iris-clip Anterior Chamber
- Oval Posterior Chamber
- Non-Square Edge

Present
- Aspheric Toric
- Multifocal (Restor, Tecnis)
- Accommodative (Crystalens)

Future
- Light-adjustable Customize Asphericity
- New Accomodative IOLs

Presbyopic Procedures

Past
- Scleral inserts
- Scleral ablation
- Collagen Shrinkage

Present
- Multifocal IOLs (Restor/Tecnis)
- Accom. IOLs (Crystalens)
- Monovision
- Accom. IOLs
- Fill Capsul. Bag
- Femto on Lens
- Femto Stromal
- Corneal Inlay

Future

Myopic Refractive Procedures

Past
- Keratomileusis
- ALK
- Epikeratophakia
- RK
- Corneal Rings

Present
- Surface Ablation
- LASIK
- Phakic IOL
- Refractive Lensectomy

Future
- Microwave
- Topography-guided laser
- Flapless LASIK
- Phakic IOL
- Femto Lens
Hyperopic Refractive Procedures

Past
- Epikeratophakia
- Hexagonal Keratotomy
- Thermal Keratoplasty
- Conductive Keratoplasty

Present
- Surface Ablation
- LASIK
- Phakic IOL
- Refractive Lens Exchange

Future
- Topography-guided laser
- Phakic IOL
- Femto Lens

Myopic Refractive Surgery

<table>
<thead>
<tr>
<th>0</th>
<th>-3</th>
<th>-10</th>
<th>-30 D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Ablation + Mitomycin C</td>
<td>Phakic IOL+/- Laser</td>
<td>Refractive Lens Exchange +/- Laser</td>
<td></td>
</tr>
</tbody>
</table>

Hyperopic Refractive Surgery

<table>
<thead>
<tr>
<th>0</th>
<th>+2</th>
<th>+5</th>
<th>+15 D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface Ablation + Mitomycin C</td>
<td>Phakic IOL +/- Laser</td>
<td>Refractive Lens Exchange +/- Laser</td>
<td></td>
</tr>
</tbody>
</table>

Crystal Ball Gazing

The Future of Cataract & Refractive Surgery

- Cataract & Refractive Lens Exchange
- Presbyopia
- Laser Vision Correction

Cataract & RLE in Future
Femtosecond Cataract Surgery

Potential to Revolutionize Surgery

Cataract Surgery

- Most common procedure by ophthalmic surgeon
- North America > 3.5 million procedures/year
- Worldwide: 19 million procedures/year
- Laser cataract surgery may be mainstream in 5-10 years

Femtosecond Cataract Surgery

- Cataract Incision
- Limbal Relaxing Incisions
- Capsulotomy
- Lens Fragmentation

Femtosecond Cataract Surgery

Investigational Lasers

- LensX
- LensAR
- Optimedica
- Others

Femtosecond Laser Guided by 3 D Imaging

- Key to success is accurate real-time imaging
- Accuracy of current imaging is debatable

Cataract Incisions
Limbal Relaxing Incisions

Capsulorhexis

- Designed for precise astigmatic control

Capsulorhexis

- The size, shape, and positioning of the capsulorhexis is a key determinant for ELP
- A 0.5mm axial plane deviation from intended effective lens position (ELP) results in 1D of refractive error

Capsulorhexis

- Capsulorhexis influences ELP which effects the postop refractive error
- Consistent size, shape, and centration accomplished with Femtosecond laser

Cataract Outcomes

- Premium IOLs require refractive outcomes within 0.50 D of emmetropia
- Most surgeons generate this in approximately 50% of patients
- Femtosecond laser by creating precise capsulorhexis may enhance ELP and improve outcomes

Capsulotomy size and shape

- Manual Capsulorhexis
- Laser Capsulotomy

Capsulorhexis- Centration?

- Center over the dilated pupil?
- Center over the nondilated pupil?
- Center over the visual axis?
Capsulotomy

Lens Fragmentation
- Goal is to reduce ultrasound energy and intraocular manipulations
- May require simple irrigation to separate the lens fragments

Cataract Techniques of the Past?
- Divide & Conquer
- Nagahara Karate Chop
- Agarwal Karate Chop
- Stop & Chop
- Slice & Dice
- Tilt and Tumble

Lens Fragmentation
- Reduction in ultrasound for lenses of all nuclear density

Advantages of Laser Cataract Surgery
- Complicated Eyes
  - Posterior polar cataracts
  - Shallow anterior chambers
  - Fuch’s corneal dystrophy
  - Dense nuclear cataracts
  - Weak zonules
Femtosecond Cataract Surgery

- Will outcomes be better?
- Will it become the standard cataract procedure?
- Used only for specific indications?
- Who will fund the equipment and the extra cost per procedure?

OHIP Covers Cataract Surgery by Any Method

Cataract Surgery and Refractive Lens Exchange

- High expectations
- May not be satisfied unless 20/20 UCVA and excellent quality

Cataract Surgery and Refractive Lens Exchange

- Improve preoperative patient selection
- Measure higher-order aberrations
- Differentiate aberrations of cornea versus lens
- Determine best procedure

Cataract Surgery and Refractive Lens Exchange

- Wavefront units from the excimer laser manufacturers only measure total higher-order aberrations of the eye
- Unable to differentiate aberrations from the cornea versus lens

Is the Patient a Candidate for Lens based surgery or Laser Vision Correction?

Refractive Lens Exchange or Cataract Extraction
Definition of Cataract?

- Lens Opacification
- Wavefront Abnormality (HOA)
- Time Course: Early, Late

IOL Power Accuracy is Critical

- IOL Master allows improved outcomes over A scan
- Refractive surprises: high myopia and hyperopia, and after LASIK, PRK, RK
- We need to do better

Real-Time Feedback During Surgery

- ORange device
- Lens removed
- Intraoperative wavefront aberrometry
- Calculates refractive outcome based on intended IOL
- Surgeon modifies IOL power to be inserted

Toric IOL

- Superior predictability compared to limbal relaxing incisions
- Available in powers from 1 to 6 D
- If IOL inserted off axis will have a decrease in effect
- Can we do better?

Intraoperative Measurement of Cylinder

- ORange device
- Toric IOL inserted
- Computer calculates residual cylinder and axis
- Surgeon can refine outcome by rotation of IOL

Enhancing Outcomes with Toric IOLs

- Cyclotorsion occurs in some patients when supine
- Surgeon marks the cornea at slitlamp
- Perform topography
- Determine steep axis in degrees from the mark
Light Adjustable IOL Power & Asphericity
- Calhoun lens
- Photosensitive silicone IOL adjusted postoperatively with UV light to refine the outcome
- Correct sphere (-2 to +2 D), astigmatism (2 D), and induce multifocality
- Better than LASIK or PRK?

Improve Postop Spherical Aberration (SA)
- Average corneal SA is +0.27 um
- Post-RK, LASIK, PRK eyes usually higher degrees
- Surgeons should try to reduce SA by IOL choice
- Measure corneal SA and choose best aspheric IOL
- Limited number of aspheric IOLs

Multifocal or Toric Sulcus IOLs
- Piggy-back IOLs
- Pseudophakic eyes
- Enhance distance, intermediate, and/or near vision
- Available from Rayner
- 6.5 mm optic
- Allows all surgeons to become refractive surgeons

Posterior Capsular Opacification
- Most common postop complication
- YAG laser capsulotomy: IOP rise, IOL cracks, IOL dislocation, CME, RD, floaters
- High cost factor in every health-care system

Prevention
- Sharp-edged optic
- Capsulorhexis covers the optic
- Modification of IOL surface
- Intraocular medications: eg dyclofenac sodium

Correction of Presbyopia

- Holy grail in ophthalmology
- Today multifocal or accom. IOLs, or monovision are techniques of choice
- Will there be other options?

Presbyopic Options in the Future

Can We Fill the Capsular Bag to Restore Accommodation?

- Potential to fill the capsular bag with a soft material to allow ciliary muscle to function
- Obstacle of capsular opacification

Multifocal Phakic IOL

- Phakic IOLs can potentially be multifocal
- Reversible procedure
- Correct any refractive error & presbyopia
- IOLs can be used in phakic +/- pseudophakic eyes

Synchrony IOL (Dual Optic)

- One-piece silicone
- +32 D anterior optic and a minus-powered posterior optic that varies based on the biometry of the patient
- The lenses joined by a unique spring system

Synchrony IOL (Dual Optic)

- Distance focus the two lenses are close together
- Accommodation (ciliary body contracts) the anterior lens moves forward, changing the focus to intermediate or near vision
Synchrony IOL (Dual Optic)
- No interlenticular opacification in over 200 patients with up to 3 years of F-U
- 85% of patients spectacle-free for computers or newspaper

NuLens
- Sulcus fixated lens composed of a flexible silicone gel between 2 rigid plates with an opening on the front plate
- NuLens can achieve 30-50 D of accommodation

NuLens
- Ciliary muscle contraction and increased vitreous pressure
- Plates compress and the polymer bulges through the anterior aperture
- Increased curvature

Femtosecond Laser Treatment for Presbyopia
- Dr. Luis Ruiz from South America developed a new technique of flapless intrastromal treatment
- Minimal glare and halos that resolves

12.4 M (3 - 26 M)
N = 220 eyes

<table>
<thead>
<tr>
<th>Near UCVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preop J8</td>
</tr>
<tr>
<td>Postop 97% J2 or Better</td>
</tr>
</tbody>
</table>

Femtosecond Laser Treatment for Presbyopia
- Photodisruption of areas of the lens to improve flexibility & restore accommodation
- Cadaver eyes the mean changes in lens power over central 3 mm was 5.8 D +/- 2.8 D (range 2.22 to 8.57 D)

Femtosecond Laser to Crystalline Lens to Restore Accommodation

Goker S, AAO Subspecialty Day, Chicago Oct 2010

Corneal Inlay - Kamra (AcuFocus)

- Diameter 3.8 mm
- Central aperture 1.6 mm
- 5 μm thickness; 8,400 holes
- Polyvinylidene fluoride
- Inserted in a corneal pocket made with Femtosecond laser
- Reversible
- Used in phakic, pseudophakic, and post-LASIK eyes

Corneal Inlay - AcuFocus

- Increases depth of field
- Nondominant eye
- 32 eyes followed 2 years
- 97% J3 or better
- Average preop J6
- No biocompatibility concerns


Corneal Inlay - Kamra (AcuFocus)

- Inlay can also be used at the time of LASIK
- Simultaneously correct refractive error and presbyopia
- Potential to be a safe, stable, and effective treatment for presbyopia

Laser Vision Correction in Future
Laser Vision Correction

20 years of follow-up (1991-2011)

Advances in Excimer Laser

- Speed (Hz rate)
- Smoother ablation
- Accurate Trackers
- Aspheric Curves
- Wavefront Guided
- Topoguided

Advances in Flap Creation

- Femtosecond laser
- Predictable thickness
- Customize diameter, location, hinge width, & edge profile
- Fewer induced higher-order aberrations
- Safer

Oblate Ablation & Small Optical Zones

- Oblique ablation & small optical zones

Real Time Feedback of Tissue Removal

- Today 95% of eyes are 20/20 or better
- Many factors why all eyes not 20/20
- Corneas may be dryer or wetter which affects tissue removal (microns per pulse)
- Real time feedback using a 3D anterior segment OCT to measure ablation depth will allow adjustment of laser pulses to optimize outcomes

LASIK Without an Excimer Laser

Femtosecond Lenticular Extraction

- Typical LASIK procedure involves a flap, flap lift, and excimer ablation
- A lenticule is cut in the stroma and then pulled out through a small pocket
- May allow for more predictable outcomes, enhance comfort, and reduce flap related complications
**Femtosecond Lenticular Extraction**

- 150 eyes
- 500 KHz femto laser
- Mean SE: $-4.75 \pm 2.64$ D
- 6 M 97% 20/20
- Loss of BCSVA of 2 lines in 2% of eyes

Shah R: AAO, Refractive Subspecialty Day, Oct 2010

**Femtosecond Lenticular Extraction**

- Currently a delay in achieving BCVA
- Unable to treat hyperopes
- May have less dry eye
- Potentially no flap related complications
- Need longterm studies to determine if superior to LASIK with a flap

**Ectasia is the Most Serious Complication of LASIK**

- High risk cases (high refractive errors or those with thin corneas) to perform corneal crosslinking (CXL)
- CXL improves the biomechanical strength of the cornea and may minimize risk of ectasia

**Reduce Risk of Corneal Ectasia**

- UV-A Light 370 nm
Microwave Technology

Keratoconus Pre-Microwave

Keratoconus Post-Microwave

Topographically-Guided PRK Combined with CXL

- Customize corneal shape
- PRK procedure
- Keratoconus/Ectasia/Scarred irregular corneas
- Enhance BCSVA or allow SCL wear

Topographically-Guided Ablation

- Developed by Theo Seiler from Germany
- Over 22,000 curvature points on the cornea
- Linked to the excimer laser
Topography Ablation Treatment

More tissue removed

Topolink Ablation
- Topography data transferred to laser
- Reduce irregular astigmatism
- Surface Ablation

Preop Postop 12 M

Difference
Map
5 D Steeper

Preop Postop 12 M

Difference
Map
2.5 D Steeper

Topographically-linked Ablations
- Promising treatment + CXL
- Reduce irregular astigmatism
- Allows improvement in BCSVA or SCL wear

Will We Be Able to Prevent Progressive Myopia?
- Encouraging results in rabbits of scleral crosslinking to enhance rigidity
- No histological evidence of retinal damage
- Potential to prevent progressive myopia
- Human trials to begin

Cataract & RLE in Future

Presbyopic Options in the Future

Laser Vision Correction in Future

The Future of Cataract & Refractive Surgery

OcularEmerg.com

- Website developed
- Book online
- Latest updates included
- New cases
- Lectures