Surgical Correction of Presbyopia

- Area of intense research and development
- Ideal solution to prevent or reverse hardening of crystalline lens

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Refractive Surgery

- Significant advances in treatment of myopia, hyperopia, and astigmatism
- Presbyopia is final frontier in refractive surgery

Aristotle - First Reference to Presbyopia

- 384 to 322 BC
- Presbytes: individuals suffering from difficulty with reading
- Modern term of presbyopia derived

Aristotle

- Presbyopic Romans would call on slaves to read documents

Roman Era
Benjamin Franklin

- 1760 invention of bifocal glasses
- Bifocal adoption may be difficult
- Patient's must rotate eyes downward instead of rotating the head

Correction of Presbyopia

- Natural Vision Therapy is a proven, non-intrusive, and holistic natural vision correction method to improve nearsightedness (myopia), astigmatism, farsightedness (hyperopia), and presbyopia (age-related) without the use of glasses, lenses, surgery, or medical aids. The therapy re-educates the eyes and mind about the principles and habits of seeing clearly and naturally.
**Correction of Presbyopia**

- All these nonsurgical options have not been proven to have a permanent effect on presbyopia.
Amplitude of Accommodation

- Gradual reduction from early teenage years and ends in 6th decade of life
- Reading glasses required near-point has receded to an inconvenient distance

Helmholtz

- Modern physiological studies confirm Helmholtz's theory
- Progressive hardening of crystalline lens is the main cause of loss of accommodation

Helmholtz Theory

- Ciliary muscle contraction releases tension on zonules, leading to a relaxation and rounding of the lens, so increasing its power

Helmholtz Theory

- Confirmed with A scan technology
- Anterior chamber depth is decreased with accommodation

Etiology of Presbyopia

- Increased rigidity & size of lens
- Change in vitreous support
- Loss of capsular elasticity
- Loss of choroidal elasticity

Changes in geometry of zonular attachment
Reduced gap between lens equator and ciliary ring
Loss of ciliary muscle power
Surgical Correction of Presbyopia

Procedures

- Sclera
- Cornea
- Lens

Scleral Procedures

- Theory: Growth of crystalline lens without growth of other structures is a factor in presbyopia
- Procedures attempt to expand distance between lens equator and ciliary muscle thereby increasing zonular tension

Scleral Procedures

- Scleral expansion bands in four quadrants
- Outcomes with scleral expansion bands have neither been long lasting nor predictable

Scleral Procedures

- Laser ACE procedure
- Erbium YAG laser
- Ablate at 90% depth of sclera
- Collagen filler is applied to the incisions to prevent fibrosis and maintain the incisions
Scleral Procedures
- Erbium laser procedure
- 135 eyes at 18 months with 1.25 to 1.5 D of accommodation (Hipsley 2011)
- Clinical trial to corroborate these early results
- May be useful technique for early presbyopia

PresbyLASIK
- Excimer laser to create multifocality
- Peripheral PresbyLASIK
- Central PresbyLASIK
- Procedures increase higher-order aberrations and increase the depth of focus

Peripheral PresbyLASIK
- Centre of cornea for distance and periphery for near
- Pupil size influences outcome
- Pupil dilates, more area covered for near correction, distance may be compromised
- Pupil becomes miotic, near-vision is reduced

Central PresbyLASIK
- Creation of central steep area for near vision
- Ablation profile is dependant on pupil size
- Small pupil near vision is enhanced
- Less tissue needs to be removed with this technique

PresbyLASIK Outcomes
- Outcomes with Peripheral PresbyLASIK and Central PresbyLASIK: high percentage of 20/25 distance and J2
- Further studies necessary to determine long-term success and quality of vision under low light and low-contrast conditions

Corneal Inlays
- Challenges over the years
- Early inlays associated with corneal opacification, vascularization, keratolysis, and decentration
- Must be thin, small diameter, allow adequate nutritional and fluid permeability, and inserted deep in cornea
Corneal Inlays

Critical Not to Disturb the Normal Nutritional Supply to Epithelium and Stroma

Corneal Inlays

- Most inlays the goal is minimal or no corneal surface changes
- Surface changes will result in a poor outcome like the Princess and the Pea

Corneal Inlays

- Long-term success dependant on biocompatibility, excellent refractive outcomes, and quality of vision

Pocket Procedure

1. KAMRA Inlay
2. Raindrop Inlay
3. FlexiVue Microlens
4. ICOLENS Inlay

Approved in Canada
Special Access
Investigational
KAMRA Inlay

- Small aperture corneal inlay
- Enhances depth of focus
- Inserted in the cornea
- Can be performed at the same time as LASIK or in a corneal pocket
- Polyvinylidene fluoride

KAMRA Inlay Design

- 8,400 Laser Etched Micro Perforations
- Pores are 5 to 11 microns diameter
- Pseudo random hole pattern
- 3.8 mm
- 5 microns thick

Disposable Cameras - Small Aperture

KAMRA Inlay

- Nondominant eye
- 32 eyes followed 4 years
- 97% J2 or better
- Average preop J6
- Distance acuity 20/20 -
- No biocompatibility concerns


KAMRA Inlay

- "Reading on the go", Arthur Cummings from Dublin, Ireland
- May not allow satisfactory prolonged reading
- Severe glare at night (15%)
- Ongoing research to improve results

KAMRA Inlay

- May take months to achieve best uncorrected acuity
- Refractive error may shift in 6 to 12 months postop
- Steroid drops may be required in 6 to 12 months to control refractive shift
- Patients may have glare at night
Raindrop Inlay

- 2 mm, 25 micron thickness
- Clear hydrogel plastic
- Refractive index similar to cornea
- Pupil constriction causes pseudoaccommodation
- Inlay induces central steepening

Raindrop Inlay

- Design allows reading vision in dim light

Corneal map of Raindrop patient illustrating prolate shape

FlexiVue Inlay

- Hydrophilic acrylic hydrogel
- No refractive power centrally
- 3.2 mm, peripheral thickness of 15 microns
- Refractive index altered in periphery creating +1.5 to +3.5 D power
- Corneal pocket of 280 to 300 microns

FlexiVue Inlay

- 45 patients (average age 52 years)
- 1 year, 93% J2 or better
- Pallikaris 2012 Journal of Refractive Surgery
ICOLENS™ Inlay

- Newest inlay in development
- Multifocal design
- 3 mm diameter
- Edge thickness of 15 microns
- Hydrophilic acrylic hydrogel

ICOLENS™

- Neutral central zone for distance vision and a peripheral optical zone for near of 3 diopters

ICOLENS™ Inlay

- 52 patients followed for 6 months
- 60% gained 2 or more lines of near vision
- 34% gained 3 or more lines of near vision
- No corneal complications

Corneal Inlays for Presbyopia

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<th>Procedure</th>
<th>KAMRA</th>
<th>Raindrop</th>
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<tr>
<td>Principle of action</td>
<td>Increases depth of focus</td>
<td>Steepens anterior corneal curvature</td>
<td>Refractive index</td>
<td>Multifocal effect</td>
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<td>Stromal depth</td>
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<td>Transparency</td>
<td>No</td>
<td>Yes</td>
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</tr>
</tbody>
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Intrastromal Femtosecond Laser for Presbyopia

- Dr. Luis Ruiz from South America developed a technique of flapless intrastromal treatment
- Minimal glare and halos

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

Near UCVA

- Preop J8
- Postop 97% J2 or Better

Goker S, AAO Subspecialty Day, Chicago Oct 2010
**Intrastromal Femtosecond Laser for Presbyopia**

- 12 months, 7.1% lost two or more lines of best corrected distance visual acuity, 11.5% lost two or more lines of best corrected near visual acuity, and 19.6% were not satisfied
- Side-effects may not be reversible
- Long-term concern of biomechanical problem with ectasia

**Classic Monovision**

- Corneal refractive surgery (LASIK or PRK)
- Lens exchange with a monofocal implant

**Classic Monovision**

- Established procedure
- Loss of fusion due to anisometropia
- Reduced binocular contrast sensitivity
- Reduced stereoacuity
- Limitations can be avoided by limiting anisometropia to 1.25 or 1.50 D

**Mini-Monovision – Laser Blended Vision**

- Elements of monovision + increasing the depth of field
- Micro-monovision performed monocularly

**Mini-Monovision – Laser Blended Vision**

- Excimer laser to increase spherical aberration which increases depth of field
- Induction of spherical aberration within a certain range to mitigate adversely affecting contrast sensitivity and quality of vision
Custom LASIK vs Laser Blended
Wavefront or TG-linked LASIK – Aberrations Decreased
Laser Blended Vision – Aberrations Increased

Laser Blended Vision - Aberrations Increased

Lens Based Procedures
- Multifocal IOLs
- Accommodating IOLs
- Lens Refilling Procedures
- Femtosecond Crystalline Lens Procedures

Multifocal IOLs
Advantages
- Spectacle independence
- Good near and distance
- Depth of field
- Neuro-adaptation the symptoms of glare and halos tend to improve

Disadvantages
- Potentially limited intermediate vision
- Reduced contract sensitivity
- Pupil size and centration dependent
- Glare and halos

Multifocal IOLs
Contraindications
- Epithelial basement membrane dystrophy
- Irregular astigmatism eg keratoconus, corneal scars
- Macular disease (AMD, ERM, macular hole, etc)
- Type A personality

Multifocal IOLs
- Multiple focal points, which create multiple images at different focal lengths
- Patients tend to perceive only the focused image of interest
- Multifocal IOL’s divided into refractive and defractive lenses
Multifocal IOLs

- High hyperopes might face difficulties due to a large positive angle kappa that can result in multifocal intolerance
- Neuro-adaptation may take six months or longer

Apodized Defractive IOL

- Gradual reduction in defractive step heights from the centre to the periphery
- Restor IOL

Apodized Defractive IOL

- As pupil size increases, more defractive zones with smaller step heights are exposed and direct a larger portion of light rays to the distant focal points
- In theory, this design allows enhanced distance vision in low light situations, such as driving at night

Apodized Defractive IOL

- Restor implant has an apodized defractive optic zone centrally and a refractive peripheral zone
- +3 D & +2.50 D
- +2.5 distributes more light for distance vision, fewer diffractive zones, a larger central refractive zone

Nonapodized Defractive IOLs

- Designed with defractive steps that have a uniform height from the periphery to the center
- Results in an equal amount of light to near and distance foci for all pupil diameter
- Tecnis multifocal IOL
Nonapodized Defractive IOLs

Diffractive Multifocal IOL
- Primary Loss of light = 18%
- Due to physical diffraction

Rotationally Asymmetric IOL’s
- New category of IOL’s, which utilize rotational asymmetry
- Mplus now approved in Canada
- Independent of pupil size
- Able to read in dim light
- Minimal glare/halos

Mplus Advantages
- Reduced glare and halos
- Improved contrast sensitivity
- High patient satisfaction
- Minimum chair time postop
- Excellent range of distance, intermediate, and near vision

Contrast Sensitivity
- Normal 50-75 yrs
- Mplus
- Restor +3 D
Accommodative IOLs

- Single optic: designed to alter the focal length of the IOL-eye optical system, based on anterior movement of the lens and changes in lens architecture.
- Dual-optic: designed based on the concept of not only axial movement, but on changing the power of the implant, which changes in position.

Single-Optic (Crystalens)

- Flexible hinges to facilitate anterior movement of the lens.
- 1 D of accommodation reported.
- Typically this is insufficient for satisfactory near vision.
- Most surgeons aim for slight monovision (<0.75) in one eye to allow satisfactory reading.
- Mechanism of action remains controversial.

Dual-Optic IOL (Synchrony)

- Utilizes 2 IOLs.
- Higher power anterior IOL eg +32.0 D.
- Negative power posterior IOL.
- Accommodative range +3.22 D.
- 3.7 mm incision.
- Investigational.

Research Stage of Accommodating IOLs

- FineVision IOL
- AutoFocal IOL
**FineVision IOL**
- Implant has soft haptics filled with silicone oil
- Accommodative effort fluid is forced to move centrally which changes the shape of the anterior optic
- Early studies suggest that the lens can provide at least 5 D of accommodation

**AutoFocal IOL**
- Potential to provide full range of vision
- Microscopic battery inside IOL, stimulates the optic to change shape when it senses accommodation
- Optic is comprised of liquid crystal that can alter its molecular configuration to change the optical power

**AutoFocus IOL**
- IOL has sensors that detect small changes in pupil size
- Smaller pupil, electromechanical impulses to the liquid crystals to induce a refractive change to provide reading

**AutoFocal IOL**
- Technology builds upon an existing patent from PixelOptics (Roanoke, Va.), which created the world's first electronically focusing prescription eyewear
AutoFocus IOL

- Microscopic rechargeable lithium-ion battery
- Similar batteries used in cochlear implants, but these batteries are the smallest known to man
- Battery estimated to have a 50-year life-cycle, but requires recharging every 3-4 days
- Developing a system of recharging the IOL during sleep, building a system into a pillow or an eye mask

AutoFocal

- Implant does not rely on the muscles in the eye functioning and capsular bag contraction to be effective
- Technology is in early development and will be undergoing an animal study in the near future
- Potential to provide the full range of vision

Capsular Filling

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

Capsular Bag Refilling

- Unsatisfactory results to date

Femtosecond Laser to Crystalline Lens to Restore Accommodation

- 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
- Cut some crystalline lens fibers to enhance flexibility and restore accommodation

Femtosecond Laser to Crystalline Lens
- Lens clarity returns in 60 minutes
- Limited effect

Scleral
- Scleral inserts
- Laser ablation

Corneal
- Mono LASIK
- PresbyLASIK
- Laser Blended
- Corneal Inlays
- Femto Stroma

Lens
- Mono IOL
- Multifocal IOLs
- Accom. IOLs
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- Femto Lens

Surgical Correction of Presbyopia
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- Corneal
- Lens

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Summary

- Ideal solution to prevent or reverse hardening of crystalline lens

Thank You