Monroe J. Hirsch Research Symposium: Mechanisms of Presbyopia Correction - Beyond Benjamin Franklin

Title: Extralenticular Aspects of Accommodation and Presbyopia

Paul Kaufman, MD

We seek to better understand human accommodative amplitude and accommodative loss (presbyopia), the most common ocular affliction. Recent research in rhesus monkeys has identified extralenticular-zonular structures and vitreous movements that are linked to accommodation. Age-related immobility of the ciliary muscle due to posterior restriction may limit accommodation and physically stress the optic nerve head as we age. Eliminating such restrictions may restore mobility of the muscle, facilitate the function of accommodating intraocular lenses (AIOLs), and mitigate accommodative stress to the optic nerve region. Identification and study of all the intraocular structures associated with accommodation will increase understanding of how the eye accommodates earlier in life, and change how we understand and treat presbyopia and perhaps glaucoma.

Outline

Significance:

The Mechanism of Accommodation - As we previously knew it:

-Helmholtz
-Schachar
-Coleman

Innovation

A challenge to uncovering all of the relevant accommodative structures and their movements has been that many of these structures are optically inaccessible (posterior
zonules and ora serrata) and essentially clear (i.e., vitreous membranes). The challenge has been met by:

**Model**

- Human vs Monkey
- Imaging Techniques
  - Scheimpflug
  - Ultrasound
  - Goniovideography
- Surgical Procedures
- Contrast Agents

**The accommodative structures and what happens during accommodation and aging:**

- Lens
- Ciliary muscle
- Zonula
- PVZ INS-LE Strand (attached anteriorly to the posterior lens equator and posteriorly to the vitreous zonule insertion zone)
- Vitreous
- Choroid elastic network
- Optic nerve
- Fluid flow/displacement

**Accommodating Intraocular Lenses (AIOLs)**

Must they be “better” than Mother Nature’s crystalline lens?

**Glaucoma Pathophysiology and Therapy**

Implications
Susana Marcos, PhD

Imaging technologies to inspire, design, and evaluate presbyopic corrections

Presbyopia affects 100% of the population after the age of 45, yet there are not fully satisfactory corrections for presbyopia. Mimicking the physiological process of the young accommodating lens, and understanding the limits imposed by optics and neural processes in multifocal corrections are key to assess state-of-the-art presbyopic corrections and provide improved solutions. Quantitative anterior segment imaging has allowed three-dimensional, high resolution, high-speed assessment of the optical and structural properties of the accommodating and aging crystalline lens. On the other hand, adaptive optics techniques allow simulation of new corrections while manipulating the ocular optics, before corrections are prescribed or even manufactured. This talk will discuss advances in multifocal and accommodating intraocular lenses, based on sound understanding provided by these new technologies.

Imaging technologies to inspire, design, and evaluate presbyopic corrections
Susana Marcos, PhD

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Outline

Multifocal and Accommodating IOLs are increasingly used corrections for presbyopia. The current talk will discuss how imaging technologies allow us to quantify physical and neuronal processes in accommodation and perception, which will serve as inspiration for new designs

- New imaging technologies
  - Anterior segment optical coherence tomography provided with analysis and distortion correction tools provides quantitative geometrical and structural properties of the cornea and lens
  - Adaptive Optics allows testing visual performance and the effects of neural adaptation under manipulated optics
  - Simultaneous Vision simulators allow testing vision under simulated bifocal optics

- Crystalline lens optical properties
  - OCT technology has allowed measurement of crystalline lens topography in vivo, as well as the Gradient Index distribution of the crystalline lens in vitro
- Lens geometry and GRIN change with accommodation and aging, both contributing to the change of optical aberrations

- Visual Perception and Neural adaptation to manipulated optics
  - Manipulating aberrations has an impact on visual acuity
  - Short-term adaptation occurs to changes in optical quality
  - The eye is adapted to the amount and orientation of optical aberrations

- Assessing Accommodating Intraocular Lens Performance
  - Quantitative 3-D full biometry in eyes implanted with accommodating IOLs allows understanding performance of these lenses
  - Relating geometry (from OCT) and aberrometry (using wavefront sensing) allows linking structural and optical changes

- Visual Perception and Adaptation to Simultaneous Vision
  - Visual performance and perception varies across bifocal and multifocal lens designs (addition and near/far pupillary pattern distribution).
  - Adaptation to simultaneous vision occurs in similar ways to other forms of blur adaptation

- New Multifocal lens designs
  - Based on knowledge gathered from optical simulations, and optical and psychophysical methods

- New Accommodative lens designs
  - Based on sound understanding of human crystalline lens accommodation

Stephen D. McLeod, MD

**Strategies for Surgical Management of Presbyopia**

Numerous clinically practical strategies exist for producing functional vision at distance and near following the onset of presbyopia. These strategies can be divided by optical principle engaged (dynamic accommodative change in conjugation power of the eye vs. enhanced depth of focus vs. multifocality vs. monovision), target structure (cornea vs. crystalline lens), and surgical procedure (structural modification vs. implant). This talk will discuss the advantages and limitations of these approaches in the context of available technology.

Stephen D. McLeod, MD

Outline
The goal in managing presbyopia is to establish functional vision for distance, intermediate and near tasks. Strategies to achieve this are not necessarily restricted to restoration of accommodative function.

These strategies include:
- Restoration of accommodative function through dynamic changes in the conjugation power of the eye
- Enhanced depth of focus
- Multifocality
- Monovision

The obvious target tissues for manipulation are the cornea and the crystalline lens, and they can be modified through manipulation of tissue shape and biomechanics, or by implantation of optical and accommodative devices.

**Cornea**
- As a static structure, interventions include multifocality, monovision and enhanced depth of focus through establishment of pinhole optics
- This can be achieved through laser reshaping of the corneal contour, or through implantation of devices that change shape or create a central pinhole

**Intraocular Surgery: modification of lens biomechanics**
- If presbyopia due to increase in lens diameter: scleral relaxation?
- Attempts made to reduce crystalline lens stiffness by femtosecond laser cleavage of lens fibres

**Intraocular Surgery: implantable accommodative lenses**
- Change in lens position
  - Limited excursion of optic
  - Single optic vs. dual optic
- Change in lens curvature
  - As measured by change in anterior chamber depth, more effective than lens position change
- Change in refractive index or optic power

Limitations to range and accuracy of baseline refractive target. Advances dependent upon available technology in materials, mechanoelectrical circuits, fluidics and