El Cairo, 25-26 January 2018

The Future and New Concepts in Intraocular Lenses for Presbyopia

Prof. Rafael I. Barraquer
Barraquer Institute
Barcelona, SPAIN

Options for Presbyopia Correction

- Spectacles (bi-, prog-)
- Contact lenses (pr.)
- Scleral surgery
- Corneal surgery
- Phakic IOLs
- Lens surgery
  - IOLs (MuF, Accom.)
  - Lentotomy (Lfs)
- Drugs
- Exercise/Stimulation



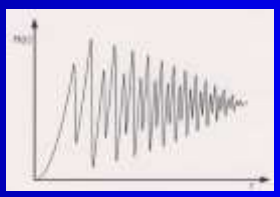



IOL options for Presbyopia

- **Multifocals:**
  - Refractives
    - Zonal (concentric)
    - Sectorial (M Plus)
  - Diffractive
    - Bifocal
    - Trifocal
- **Advantages:**
  - Proven Eficacy/Safety (wide literature)
  - Complete addition for NearV (+MidV if trifocal)
  - No regression of effect



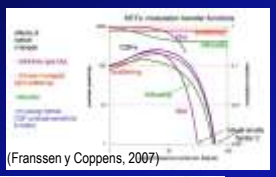


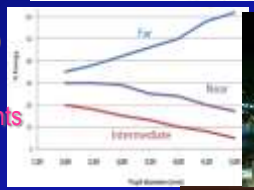




Multifocal IOL: Cons

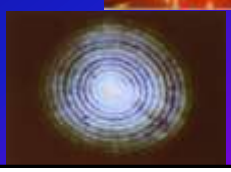
- Quality Loss (MTF, CSF slightly noticeable but measurable)
- Light intens. loss (diffractive 14% - 22%, little noticeable exc. in low light)
- Increased Straylight
- Pupil-dependant (+ refractive, apodized)
- Dysphotopsia (halos, glare, etc.)
- Damanding calculations ➔ enhancements for RRE
- Do not provide continuous focus at all distances
- More sensitive to additional causes of visual quality loss (alt. Tear F., PCO, mácula)

- Require learning / neuroadaptation
- Dependes on personality, expectations…


(Franssen y Coppens, 2007)

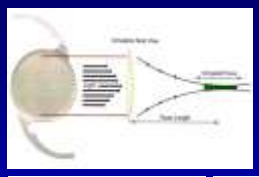
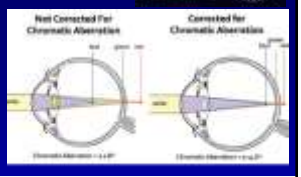


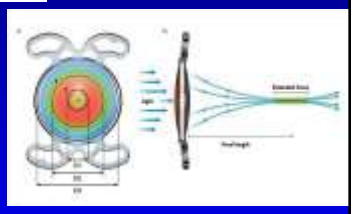




"Extended Range"

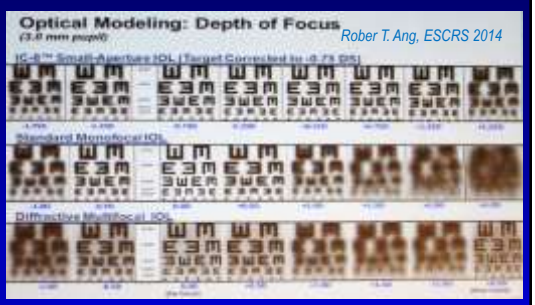
- Symfony (Tecnis)
  - "Echelette"
  - Incorporates correction of spherical aberration
- Mini Well (SIFI)
  - "Progressive"
  - "Continuous focus" in place of multiple focus points
- IC-8 (Acufocus)
  - Increases Depth of Focus by 1,5 D
  - Dominant eye: Monofocal IOL
  - Nondominant eye: IC-8 (-0,75D target refraction)

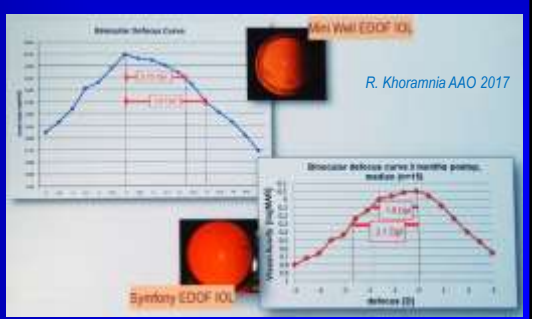



"Extended Range" IOLs

- **PROS**
  - Avoid some problems of multifocal IOL
  - No loss of distance visual quality
  - Cromatic aberration correction (Sy)
  - Progresive focus (MW)
  - Less / No halos
- **CONS**
  - Insufficient UC Near Vision
  - Monovision scheme (IC-8)
  - *How to select "Premium IOL" patients which will require glasses for near vision?*



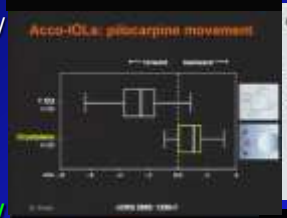


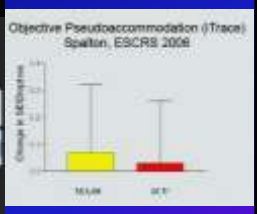
"Accommodative" IOL

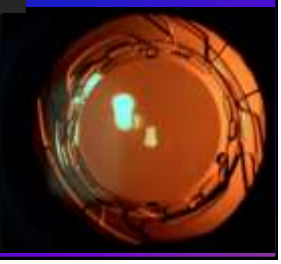
- *Those that experience active changes in their power or effective focus* (by position, moving parts, flexion or other deformation, etc.), **NOT EXCLUDING additional pseudoaccommodative phenomena.**
- **TYPES:**
  - Flexible (by ciliary action vs. "vitreous pressure" ?)
    - **Axial movement** (1 or 2 optics: Hara 1990, Crystalens, CU-1, Synchrony, etc.)
    - **Elastic deformation** by direct ciliary **compression** (NuLens)
    - **Hydraulic deformation** by idem (Sergienko 1993, FluidVision)
    - **Capsular bag refilling** with elastic gel by ciliary ***decompression*** (Phaco-Ersatz)
  - Lateral movement (by ciliary action)
    - Alvarez 2-optics (Akkolens Lumina)
    - Gaussian 6-optics (Shen & O'Day ARVO 2002)
  - Electro-óptic
    - MSAA: Mechanotronic System of Artificial Accommodación (KIT-Rostock)

Axial Movement IOLs

- 1 optic: Crystalens AT-45, Humanoptics 1CU, ActaLens
  - Insufficient movement or real effectivity (several studies)
  - Other mechanisms: Astigmatism by folding of the optic ?
  - Problems due to capsular retraction
- 2 optics: Hara (1990), Synchrony (Visiogen)
  - Improved efectivity
  - Loses effect with time (capsular fibrosis)



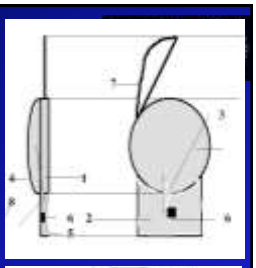
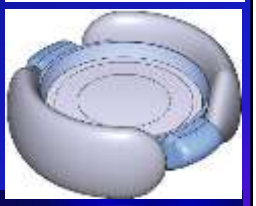
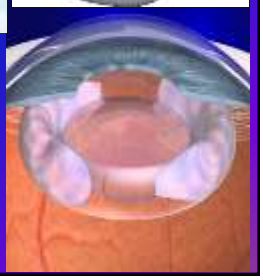
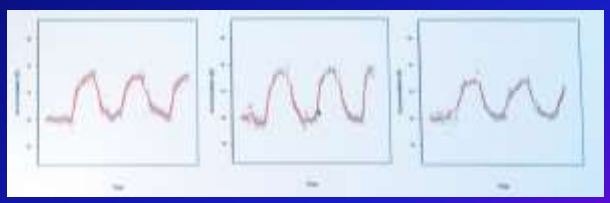




Hydraulic Deformation

- *FluidVision IOL*
  - Concept by N. Sergienko (1993)
  - Hollow optic & haptics, filled with silicon fluid. 3.5 mm incision.
  - Ciliary muscle compression pushes fluid into optics ➔ power increase (accommodation).
  - Ciliary muscle relaxation causes deaccommodation.
  - Clin. Study (2nd Gen): 3.5 – 4.0 D accom. (D. Koch, AAO 2017).

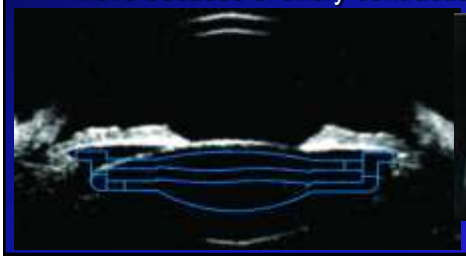
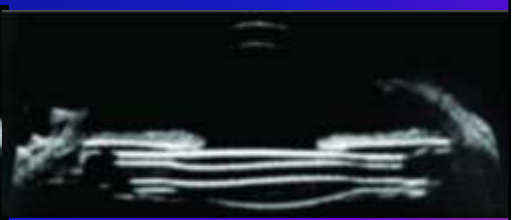


Lateral Movement IOL

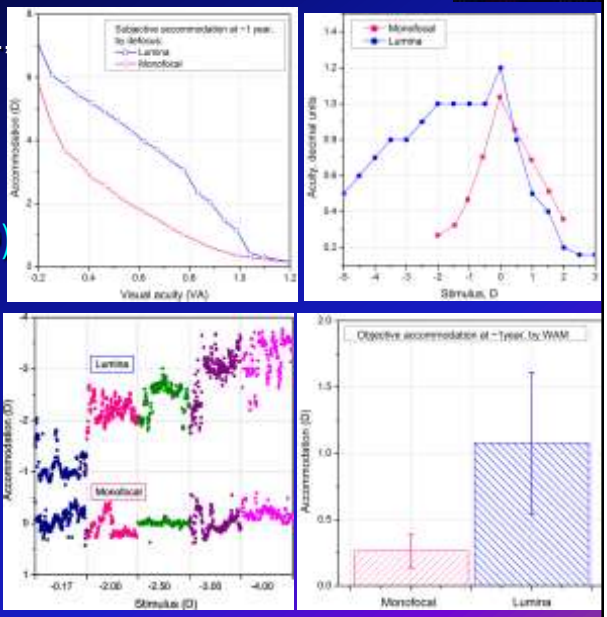
- *Akkolens Lumina*
  - 2 parallel optics with “S” faces “S”
  - Luis W.Álvarez principle (US Patent 3305294, 1967) Physics Nobel Prize 1968
  - Power changes with relative position of the optics
  - Current design: M. Rombach
  - Sulcus implantation, foldable 2.8mm.
  - Move because of ciliary contraction



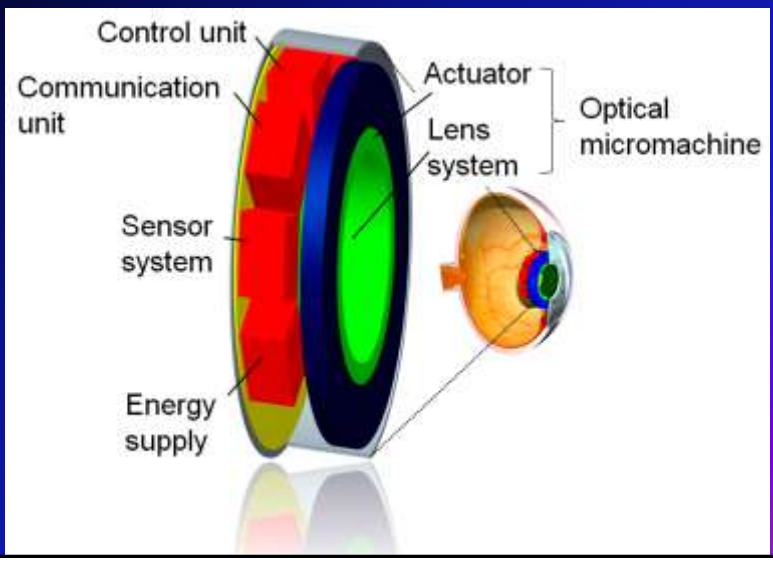
Lumina Pilot Study (Sofia, Bulgaria)

- Prelim. results J. Alió et al. (EVER 2014)
- Accommodation:
  - Subjectiva 2.5 - 5 D
  - Objective >1 D (3.5D)
- AVd, AVn, CS - OK
- Safe (IOP, no inflam.)
- Good patient satisfaction
- 2018: Clinical Sutdy



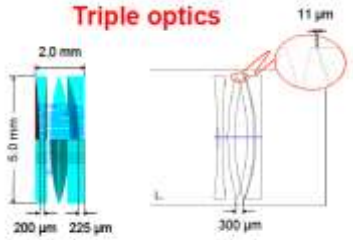
Mecanotronic System of Artificial Accommodation - SMAA

(Karlsruhe Institute of Technology / U. of Rostock)



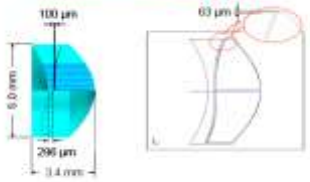
Different possible active optical elements

Triple optics



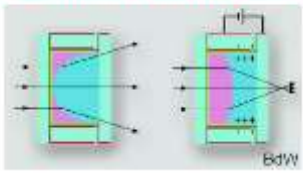
Axial translation of lens

Alvarez-Humphrey-lens

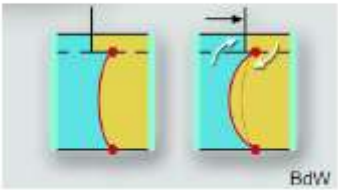


Lateral translation of asherical optical elements

Electrowetting lens



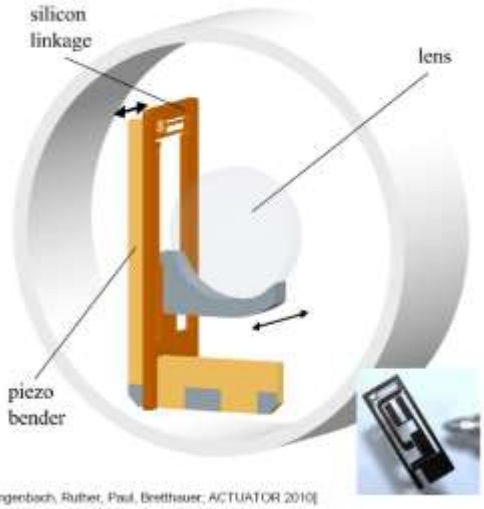
Fluid lens



Piezoelectric Actuator System

(for a triple optic)

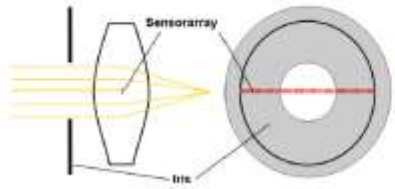
- **Piezoelectric bending actuator**
  - high dynamics
  - energy efficient
  - high durability
  - industrially proven
- **Elastic linkage**
  - lens suspension
  - displacement amplification
- **Functional model scaled 1.5:1:**
  - 4.6 dpt refractive power range = 3 dpt + postoperative refractive compensation
  - Safe failure mode: optically equivalent to conventional IOL
  - friction-free, wear-free



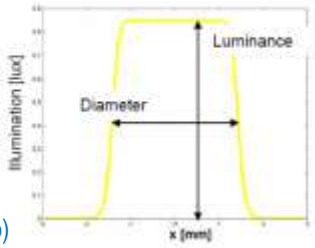
[Martin, Gengenbach, Ruther, Paul, Breithauer; ACTUATOR 2010]

Accommodation Sensors

- Pupil near reaction measurement



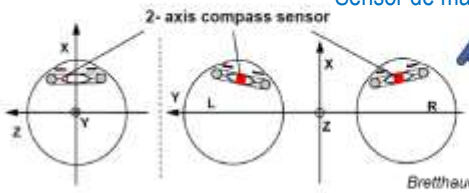
Patent granted



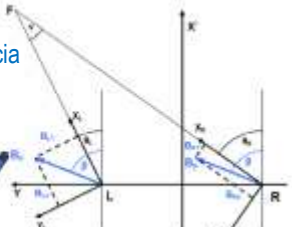
Sensor de tamaño pupilar y luminancia (0,5 mm ancho)

- Vergence angle measurement

Sensor de magnetoresistencia

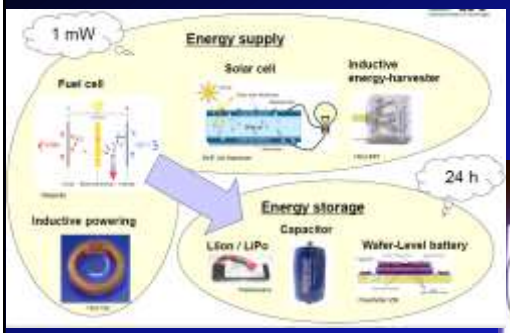


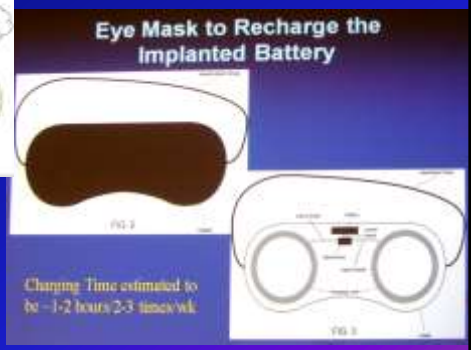
Patent granted



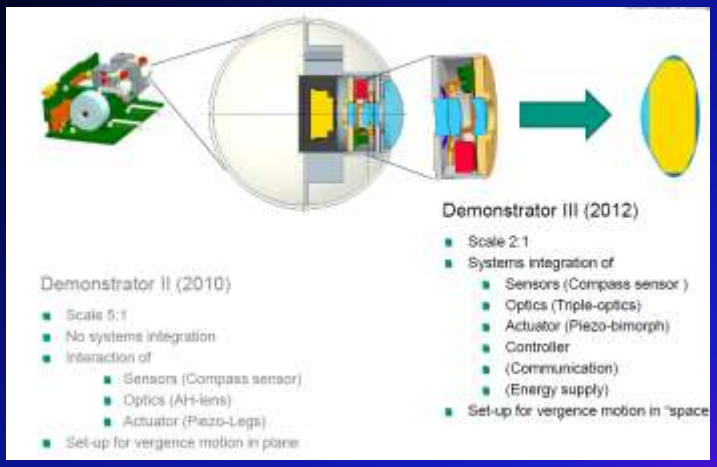
Bretthauer G et al. Klin Monatsbl Augenheilkd 2010; 227: 935–939

Energy Supply (Induction rechargeable batteries)





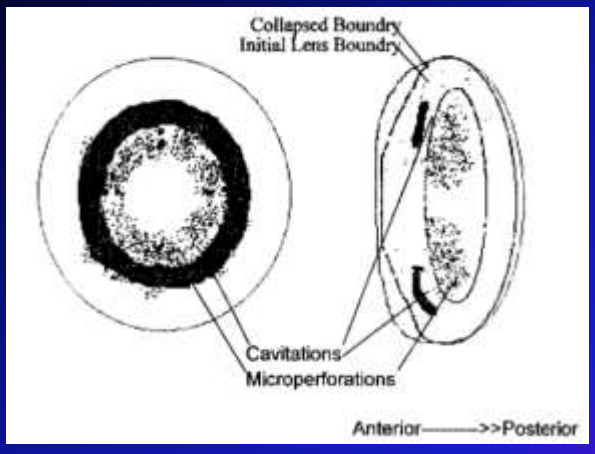
SMAA: Integratión



Technically feasible
Economically viable ??

Lentotomy: History (YAG laser)

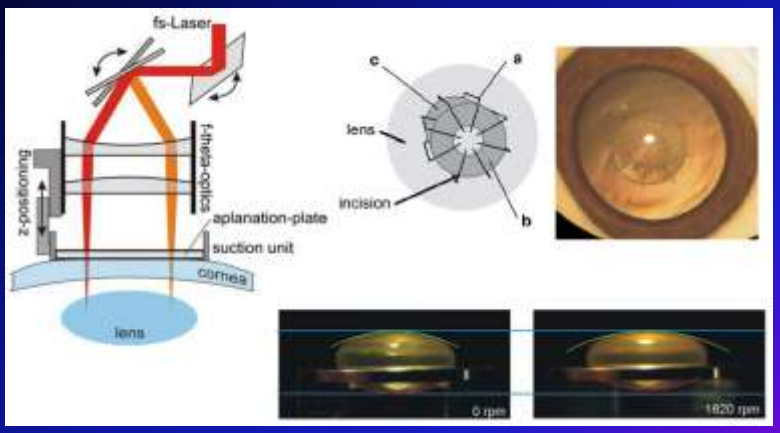
1st ideas from (at least) 1990-2000 decade



Myers, R.I. and Krueger, R.R.
Novel approaches to correction of presbyopia with laser modification of the crystalline lens. Journal of Refractive Surgery, 1998

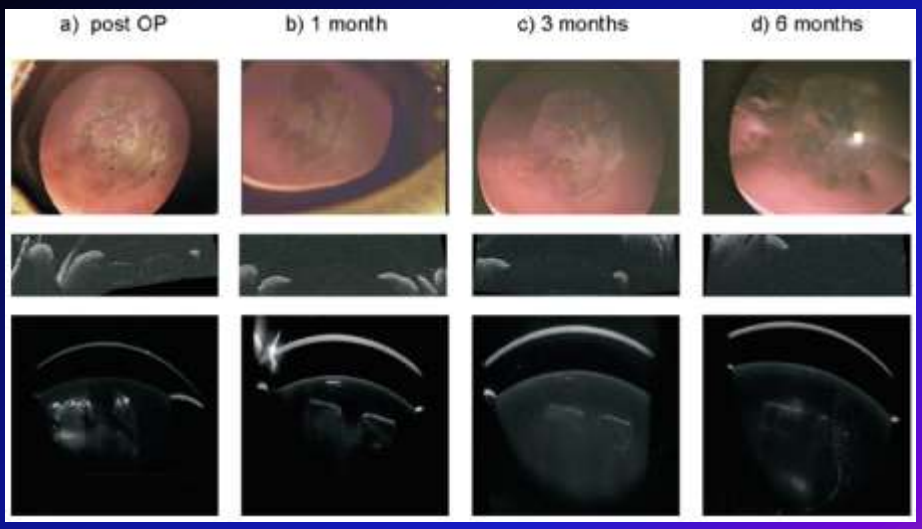
FsL-Lentotomy (Lubatschowsky et al., 2010)

To create “sliding planes” in the lens nucleus: radial & cylindric:
Increase in flexibility measured **by centrifugation**



H. Lubatschowski et al. Femtosecond lentotomy: generating gliding planes inside the crystalline lens to regain accommodation ability, J Biophotonics 3, 265-268 (2010).

No progression of opacities (rabitt)



H. Lubatschowski et al. Femtosecond lentotomy: generating gliding planes inside the crystalline lens to regain accommodation ability, J Biophotonics 3, 265-268 (2010).

FsL-Lentotomy for Presbyopia

1st trials in humans (Mexico & Philippines, LenSAR 2010)

50% improve Subjective accomodation (push down)
33% improve Objective accommodation (Grand Seiko autoRefr.)
40% improve Distance-corrected Near VA (DCNVA)

S. Shah AAO 2017

FsL-Lentotomy: New Patterns

Central Zone of 2 mm

Annular Patterns (in study)

Improve Near UCVA **94.7%** - LogMAR =0.51 ➔ 0.14
Improve DCNVA **88.2%** - LogMAR improvement 0.234
Improve Defocus Range > 20/40 **84.2%**

S. Shah AAO 2017

Summary

- ➔ We still need to improve the basic knowledge on accommodation mechanism and its loss with age.
- Currently preferable options (efficacy & safety):
  - > 53-55 y. or high ametropia: Multifocal IOL (bi- tri-)
  - < 53-55 a. and low ametropia: Advanced Monovision (hyperprolate LASIK)
  - Extended range IOLs: some obbjective advantages, ***niche?***
- **Future:**
  - New accommodative IOLs: + effective (clinical studies)
  - *Femtolaser Lentotomy* ➔ some promising results
- Many ideas (including non-surgical) but…

Thank You