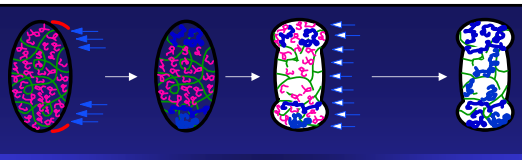

" New IOL Materials: Manufacturing and More"

Liliana Werner, MD, PhD

Berlin Eye Research Institute (BERI)
Berlin, Germany

John A. Moran Eye Center
University of Utah
Salt Lake City, UT, USA

Light Adjustable Lens (LAL)

- ***Incorrect lens power:* one of the most common reasons for explanting IOLs**
- Mamalis N. Spencer TS. Complications of foldable intraocular lenses requiring explantation or secondary intervention – 2000 survey update. *J Cataract Refract Surg* 2001; 27:1310-1317.
- Mamalis N. Complications of foldable intraocular lenses requiring explantation or secondary intervention – 2001 survey update. *J Cataract Refract Surg* 2002; 28:2193-2201.

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Incorrect Lens Power

- **IOL explant/exchange**
- **Piggyback pseudophakic IOL**
- **Piggyback phakic IOL**
- **Corneal refractive procedures: LASIK, corneal incisions, corneal thermal keratoplasty, intrastromal corneal ring segments…**
- **For refractive lens exchange: "Bioptics" procedure**

-Zaldivar R, Oscherow S, Piezzi V. Bioptics in phakic and pseudophakic intraocular lens with the Nidek EX-5000 excimer laser. *J Refract Surg* 2002;18:S336-S339.

-Nichamin LD. Expanding the role of Bioptics to the pseudophakic patient. In: Buratto L, Werner L, Zanini M, Apple DJ, eds. Phacoemulsification: Principles and Techniques. Thorofare, NJ: Slack Inc.; 2002:531-532.

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Light Adjustable Lens (LAL)

- Calhoun Vision: three-piece silicone lens with photosensitive silicone subunits that move within the lens under a low intensity near-UV light
- Non-invasive postoperative adjustment of the lens power
- 6.0 mm optic; 13.0 mm diameter
- Optic refractive index: 1.43
- Square optic edges (PCO prevention)
- Modified C, PMMA haptics
- Optic-haptic angulation of 10°

BERI

Light Adjustable Lens (LAL)

-Schwartz DM. Light adjustable lens. *Trans Am Opthalmol Soc* 2003; 101:417-436.

-Werner L, Mamalis N, Apple DJ. Biomaterials for wavefront customization. *In:* Krueger RR, Applegate RA, MacRae SM, eds. Wavefront Customized Visual Correction. Thorofare, NJ: Slack Inc., 2004:271-278.

-Werner L, Mamalis N. Wavefront corrections of intraocular lenses. *Ophthalmol Clin N Am* 2004;17 (2):233-245.

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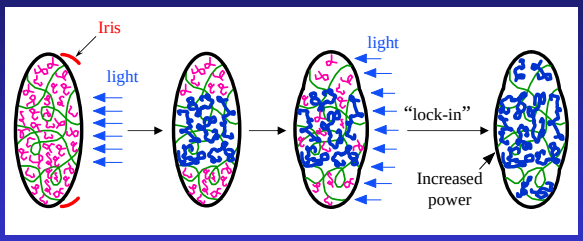
Light Adjustable Lens (LAL)

LAL Material Formulation

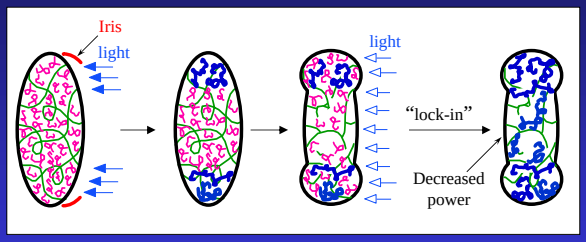
- Silicone matrix polymer
- Macromer
- Photoinitiator
- Ultraviolet light absorber

Adding Power to the LAL



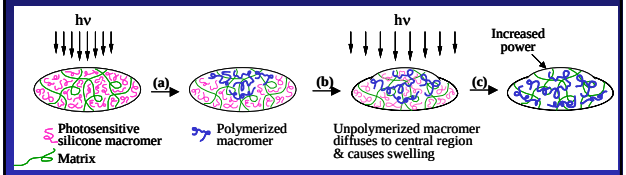
=> change in radii of curvature => change in power
(*total time for macromer diffusion: 12-18 hours*)

Subtracting Power from the LAL



=> change in radii of curvature => change in power

LAL: Mechanism for dioptric change (hyperopic)

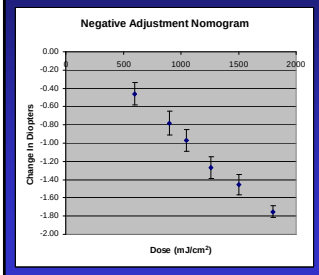


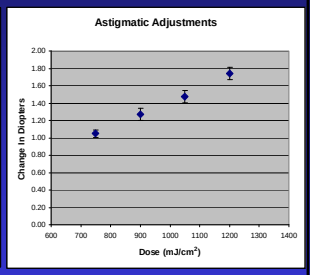
Treatment (2-4 weeks after implantation)

"Lock-in"

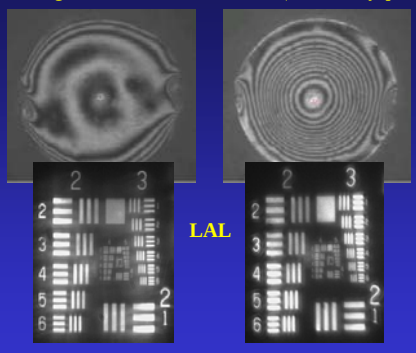
-Myopic treatment: irradiation of the lens edges
-Astigmatic treatment: band-shaped pattern
-Higher order aberrations: new digital delivery system (Carl Zeiss Meditec)
-Use of sunglasses with UV absorbers in outside activities before treatment and "lock-in"

Light Adjustable Lens (LAL): Laboratory Results



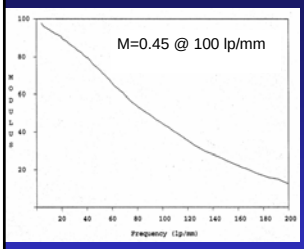


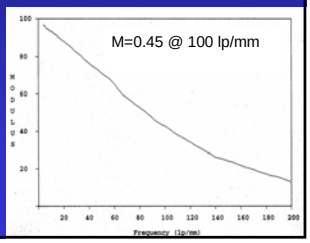
•Interference fringes before and after treatment (-1.5 D of myopic correction)



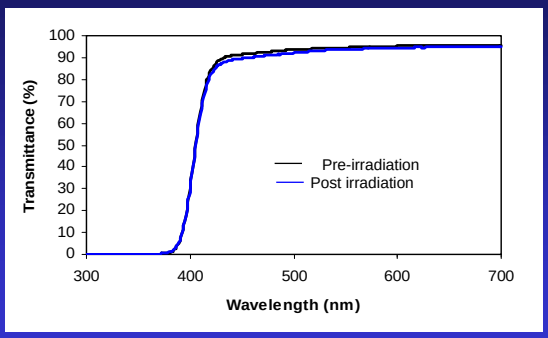
•Resolution efficiency before and after treatment: not compromised

•Modulation Transfer Function curves before and after treatment





•Light transmittance curves before and after treatment



Light Adjustable Lens (LAL)

- Light application (365 nm) device: similar to slit lamp coupled with computer
- Irradiation system: mercury arc lamp
- Pupil dilation, topical anesthesia, 0.835X contact lens with hydroxypropylmethylcellulose
- Reticule target (6.0 mm diameter) aligned with the edge of the optic (focus at the optic-haptic junctions)
- Enter base power and correction needed
- -2.0 D for a +20.0 D LAL: 10 mw/cm^2 for 120 seconds
- "Lock-in": higher intensity

Light Delivery Device

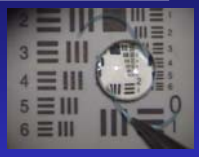
Digital Light Delivery System

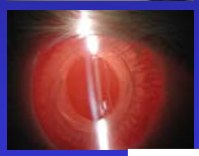
Designed and Manufactured By Carl Zeiss Meditec AG

- Modified slit-lamp device
- Digital chip with 1.3 million microscopic mirrors
- Worldwide installation and service by Zeiss
- System and software sold by Calhoun

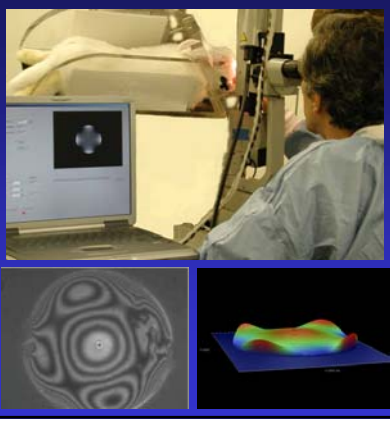
Light Adjustable Lens (LAL): *Animal Studies*

- *In vivo*, rabbit studies:
  -Histopathological studies: biocompatibility
  -Optical bench testing: reproducibility
- *In vitro* studies: no cytotoxicity after Nd:YAG laser

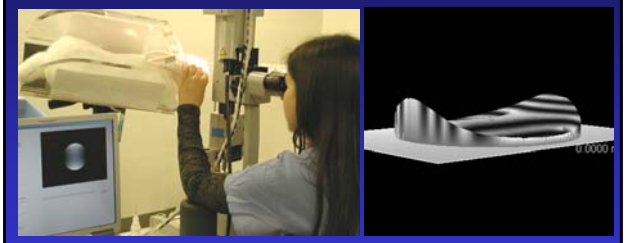




LAL digital light delivery device: *Tetrafoil pattern*



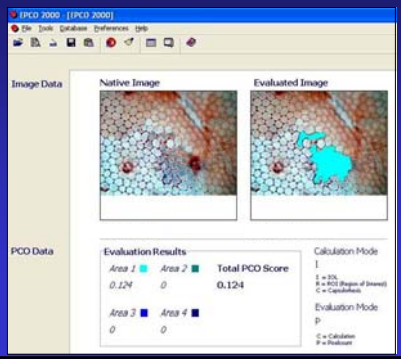
LAL digital light delivery device: *Astigmatic pattern*



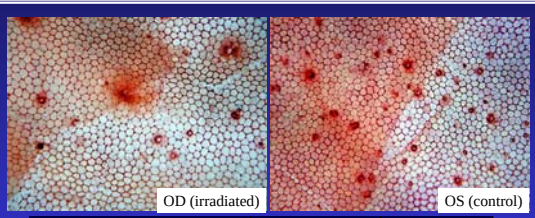
Werner L, et al. Corneal endothelial safety with the irradiation system for the light adjustable lens. *J Cataract Refract Surg* 2007 (in press)

- 12 cats (similarity with the human cornea)
- **"Lock-in" treatment:** near UV (365 nm), 250 mW/cm^2, central 6.0 mm of right cornea, 120 seconds
- Sacrifice (3 cats) 1 day, 1 week, 1 and 3 months

- Vital staining of cornea: Trypan blue/Alizarin red
- Quantification of cell damage/loss with digital system (EPCO, originally develop for PCO quantification; Tetz MR, et al. Photographic image analysis system of posterior capsule opacification. *J Cataract Refract Surg* 1997; 23:1515-1520)



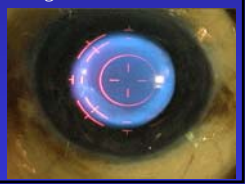
Werner L, et al. Corneal endothelial safety with the irradiation system for the light adjustable lens. *J Cataract Refract Surg* 2007 (in press)



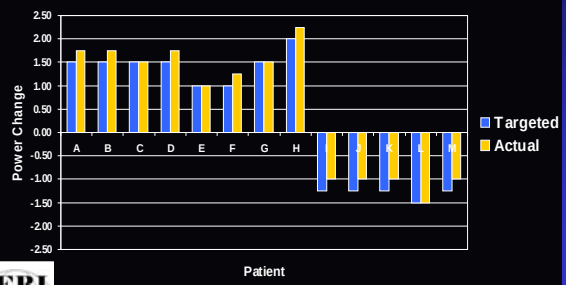
Sacrifice	Cell Damage (OD)	Cell Damage (OS)	*P Value*
Day 1	*0.215 +/- 0.079*	*0.224 +/- 0.387*	*0.483 (NS)*
Day 7	-	-	-
Day 30	*0.042 +/- 0.072*	*0.074 +/- 0.065*	*0.281 (NS)*
Day 90	-	-	-
Day 1-90	**0.064 +/- 0.103**	**0.074 +/- 0.193**	***0.401 (NS)***

Light Adjustable Lens (LAL)

- Initial clinical application: pseudophakic lens for cataract surgery
- Technology can be applied to accommodating, phakic lenses…
- Use in conjunction with wavefront sensing: full customization
- ***Initial clinical trials:*** 2004
- Availability: 2006 in Europe (?)
- Availability: 2008 in the US (?)



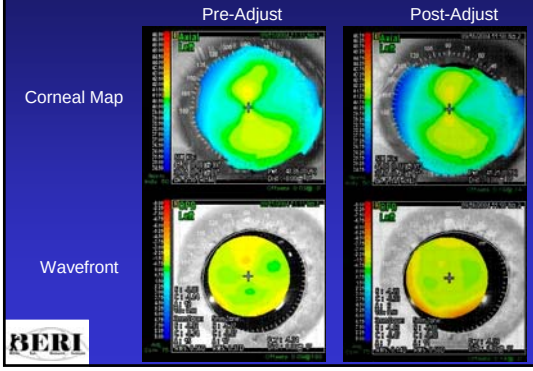
Initial Clinical Results - 13 Patients with Spherical Correction - All within 0.25 D of intended outcome (Dr. Chayet, Mexico)



Initial Clinical Results - Astigmatic Correction (Dr. Chayet, Mexico)

	Pre-Adjust	2 Month Post-Adjust
UCVA	**20/30-**	**20/20-**
BCVA	20/20	20/20
MR	**0.0-1.25 X 10**	**0.0-0.50 X 10**

Light Adjustable Lens (LAL): *Astigmatism Correction*



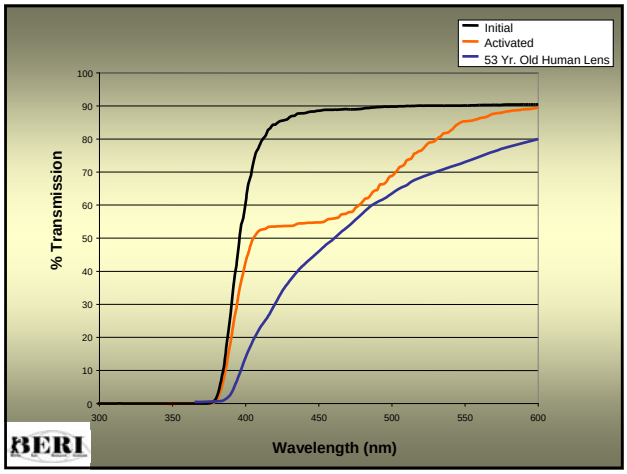
Yellow Intraocular Lenses

- **The natural human crystalline lens yellows with age**
- **Progressive increase in absorbance within the blue range of the visible spectrum**
- **Blue-light was shown to have significant retinal phototoxicity**
- ***Blue-light absorbing (yellow) IOLs:* Reduction of the risk for macular degeneration (indirect evidence)**

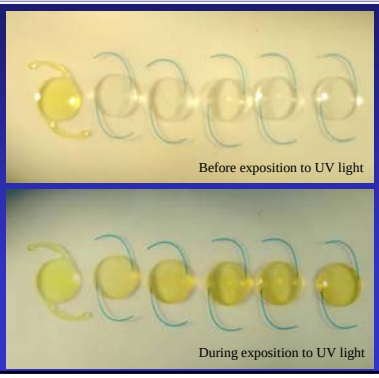
SmartYellow™ Lens

- Proprietary hydrophobic acrylic material (Photochromic Matrix), Medennium Inc.
- Three-piece lens, blue-colored PVDF haptics*
- UV-near blue absorption curve similar to the AcrySof® Natural lens when exposed to UV light
- Standard UV absorbing IOL in an indoor environment

*Werner L, Mamalis N, Romaniv N, et al. New photochromic foldable intraocular lens: Preliminary study on feasibility and biocompatibility. *J Cataract Refract Surg* 2006; 32:1214-1221.

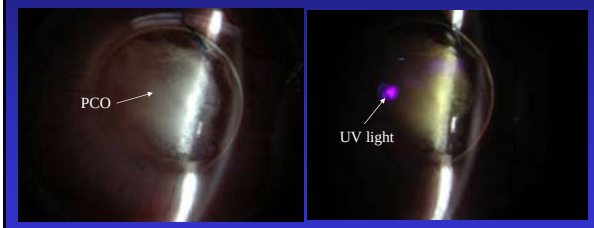


SmartYellow™ Lens: *In vitro study*

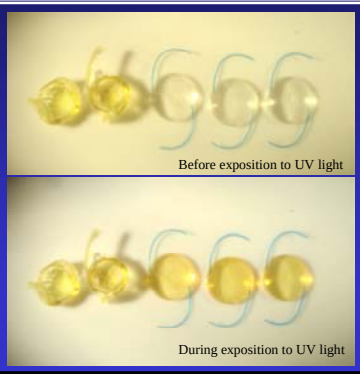


SmartYellow™ Lens: *In vivo study*

Rabbit eyes (6-month study)



SmartYellow™ Lens: *After rabbit sacrifice and IOL explantation*



SmartYellow™ Lens

Photochromic changes:

- Reversible
- Reproducible
- Stable over time
- Biocompatible in rabbits

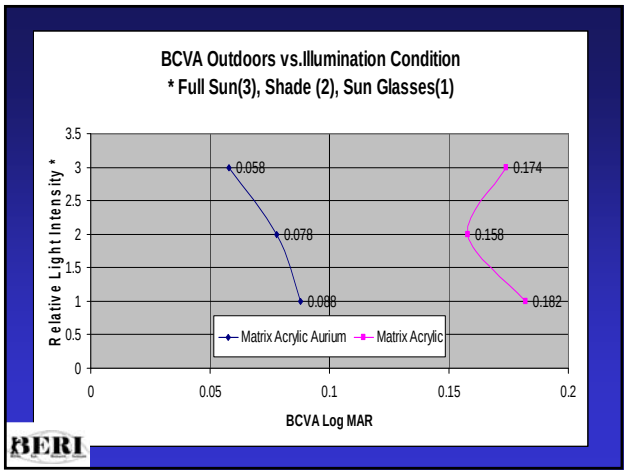
This innovative concept of a photochromic IOL deserves further investigation, including evaluation of the lens when exposed to natural sunlight and to white light sources…

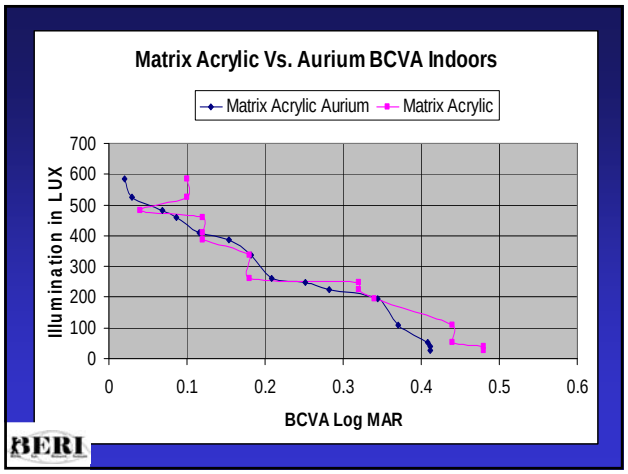
Clinical Study

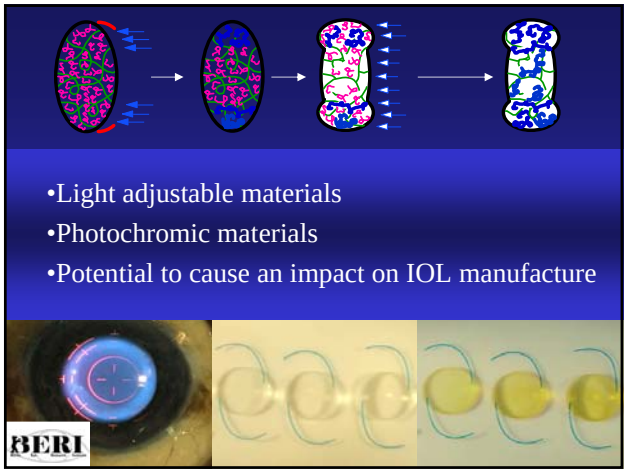
- Dr. Guillermo Avalos, Mexico
- SmartYellow™ Lens = Photochromic Matrix Acrylic Aurium®
- 10 subjects; 10 eyes implanted with Aurium® and 10 eyes implanted with Matrix Acrylic
- Examination at 1, 3, 14, and 30 days postoperatively
- BCVA at 30 days outdoors and indoors

Clinical Study

- Aurium® provides blue light protection outdoors and equal or better visual acuity under UV light
- Aurium® performs similarly to regular Matrix indoors
- Subjective evaluation indicates that subjects prefer the Aurium®


BCVA Outdoors vs.Illumination Condition
* Full Sun(3), Shade (2), Sun Glasses(1)
Relative Light Intensity *
3.5
3
2.5
2
1.5
1
0.5
0
0.058
0.078
0.088
0.174
0.158
0.182
Matrix Acrylic Aurium
Matrix Acrylic
0
0.05
0.1
0.15
0.2
BCVA Log MAR
BERI


Matrix Acrylic Vs. Aurium BCVA Indoors
Matrix Acrylic Aurium
Matrix Acrylic
Illumination in LUX
700
600
500
400
300
200
100
0
0
0.1
0.2
0.3
0.4
0.5
0.6
BCVA Log MAR
BERI


•Light adjustable materials
•Photochromic materials
•Potential to cause an impact on IOL manufacture
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MORAN
EYE CENTER
Liliana Werner, MD, PhD
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Salt Lake City, UT, USA