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Advances in Presbyopia Correction

Professor James Wolffsohn
BSc MBA PhD FBCLA

Disclosures

Abbott Medical Optics
Johnson & Johnson Vision Care
Alcon
Rayner
EPSRC Engineering and Physical Sciences Research Council
Seventh Framework Programme
Marie Curie Actions
Valeant Pharmaceuticals North America LLC
Bausch + Lomb
Euclid
Thea Pharmaceuticals
Innovate UK Technology Strategy Board
Aston eyetech
wellcome trust
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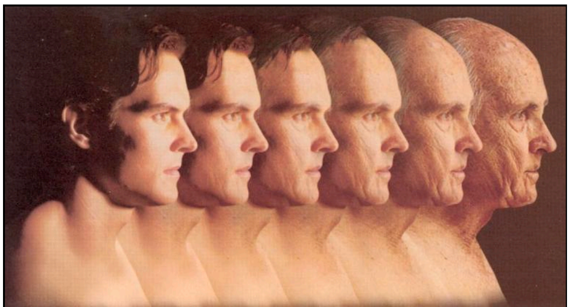

Vested Interest

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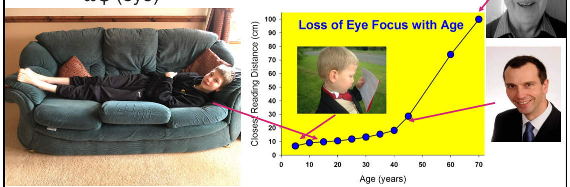
presbyopia comes from the Greek words *presbys* (πρέσβυς), meaning "elderly", and ωψ (eye)



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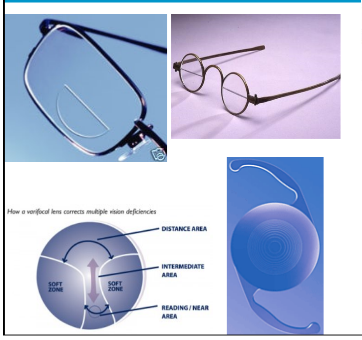
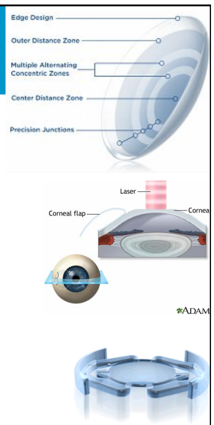
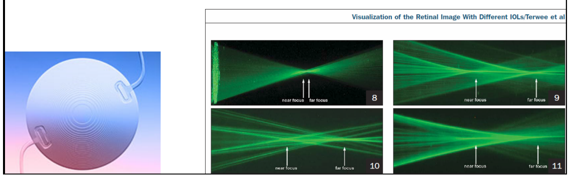
Options for correcting Presbyopia





Principals

- Eye moves
- Splitting light
- Ciliary muscle driven



Do they Work?

- Clear vision at all required distances
- Subjective
  - No need for additional correction
  - Satisfaction
- Minimal undesired visual effects
  - Loss of contrast sensitivity
  - Dysphotopsia
- Restoration of function
  - Lens movement / curvature imaging
  - Measurement of eye focus

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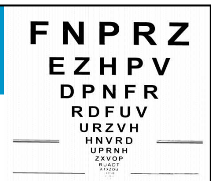
Clear Vision



- Visions
  - Distance
  - Intermediate??
  - Near??
- Lighting dependence?

ARTICLE

Comparison of near visual acuity and reading metrics in presbyopia correction

Navneet Gupta, PhD, James S.W. Wolffsohn, PhD, Shehzad A. Naroo, PhD

PURPOSE: To provide a consistent standard for the evaluation of different types of presbyopic correction.

SETTING: Eye Clinic, School of Life and Health Sciences, Aston University, Birmingham, United Kingdom.

METHODS: Presbyopic corrections examined were accommodating intraocular lenses (IOLs), simultaneous multifocal and monovision contact lenses, and varifocal spectacles. Binocular near visual acuity measured with different optotypes (uppercase letters, lowercase letters, and words) and

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Invest Ophthalmol Vis Sci 2007;48: E-Abstract 3563.
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3563—B1026

Can Jaeger Numbers Be Standardized

A. Colenbrander[1] and P. Runge[2]

[1]Smith-Kettlewell Eye Res Inst, Novato, California
[2]Ophthalmology, University of South Florida, Sarasota, Florida

Actual size	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	J13	J14	J15	J16	Actual size
5 M																2	5 M
4 M														1	1	2	4 M
3.2 M							1					1		2	* *	*5*	3.2 M
2.5 M						1				2		2	1	*4*			2.5 M
2 M				1	1		2	1		1	1	7	* *				2 M
1.6 M					2	4	2	1	1	3	* *	*1*					1.6 M
1.25 M			2	3	4	1	2	4	* *	*4*							1.25 M
1 M		4	5	3	1	*7*	*6*	*4*									1 M
0.8 M	3	4	3	7	*4*	3											0.8 M
0.63 M	5	2	*8*	*2*	1												0.63 M
0.5 M	5	*9*	2														0.5 M
0.4 M	*4*																0.4 M
Range	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	J13	J14	J15	J16	Range
lines	4	4	5	6	6	6	6	4	2	4	2	4	2	3	2	3	lines
ratio	2x	2x	2.5x	3x	3x	3x	3x	2x	1.25x	2x	1.25x	2x	1.25x	1.5x	1.25x	1.5x	ratio

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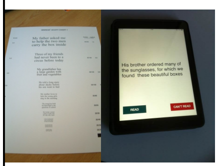
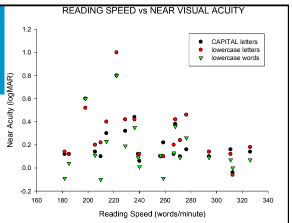
Functional Vision Reading Chart





Clinical science

Mobile app reading speed test

Alec Kingsnorth, James S Wolffsohn

- Reading Speed
  - NVA not well correlated to critical print size reading speed (r=-0.16 to –0.33, p>0.05)

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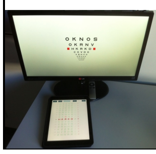
Defocus curves

- Measures pseudoaccommodative function
- +1.50 D to –5.00 D in 0.50 D steps
- Randomised letters and lenses



ARTICLE

Optimizing measurement of subjective amplitude of accommodation with defocus curves

Navneet Gupta, James S.W. Wolffsohn, PhD, Shehzad A. Naroo, PhD

Available online at www.sciencedirect.com
ScienceDirect
ELSEVIER
Contact Lens & Anterior Eye 30 (2007) 119–124
contactlens & ANTERIOR EYE
www.elsevier.com/locate/clae

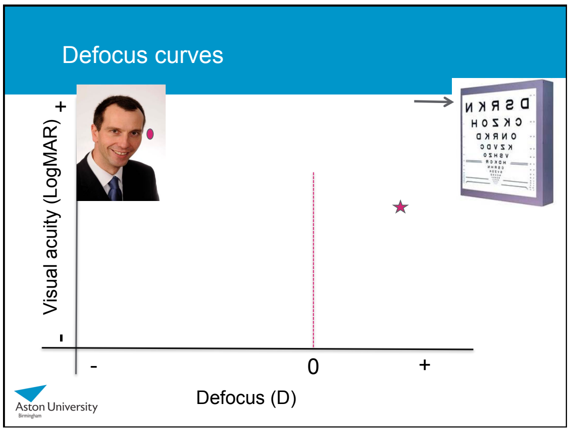
Is randomisation necessary for measuring defocus curves in pre-presbyopes?

Navneet Gupta, Shehzad A. Naroo*, James S. Wolffsohn

Ophthalmic Research Group, School of Life and Health Sciences, Aston University, Birmingham B4 7ET, UK

Abstract

Purpose: Defocus curves are used to evaluate the subjective range of clear vision of presbyopic corrections such as in eyes implanted with accommodating intraocular lenses (IOLs). This study determines whether letter sequences and/or lens presentation order ought to be randomised when measuring defocus curves.
Methods: Defocus curves (range +2.00DS to −2.00DS) were measured on 18 pre-presbyopic subjects (mean age 24.1 ± 4.2 years) for six combinations of sequential or randomised positive or negative lens progression and non-randomised or randomised letter sequences.


Defocus curves
Visual acuity (LogMAR)
+
-
0
Defocus (D)
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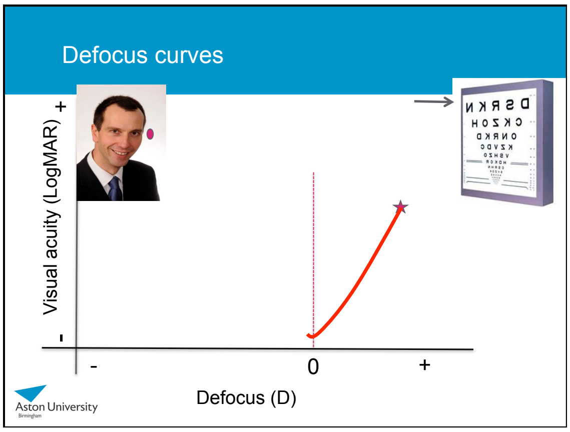
Defocus curves
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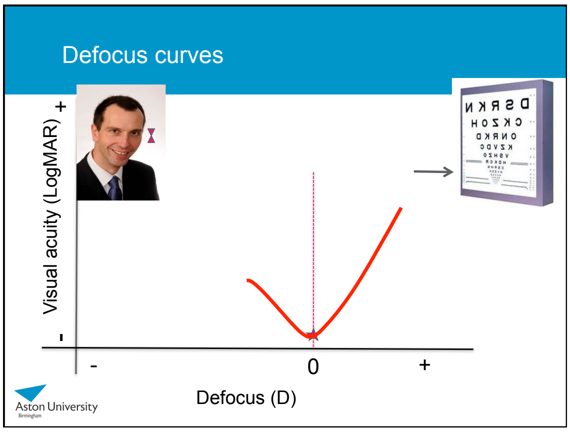
Aston University


Defocus curves
Visual acuity (LogMAR)
+
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0
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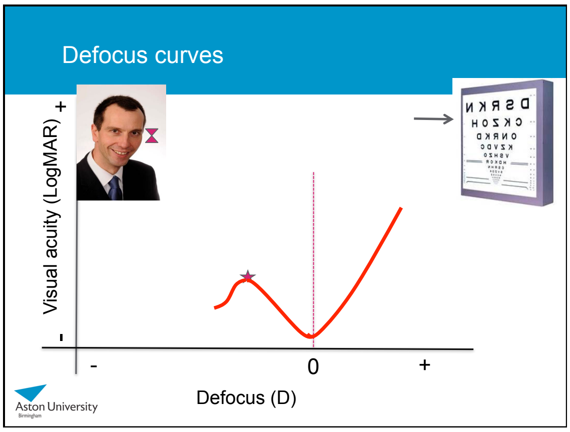
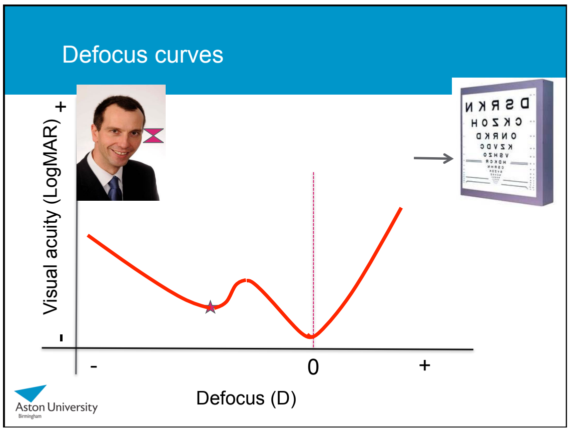
Aston University


Defocus curves
Visual acuity (LogMAR)
+
-
0
Defocus (D)
Aston University


Defocus curves
Visual acuity (LogMAR)
+
-
0
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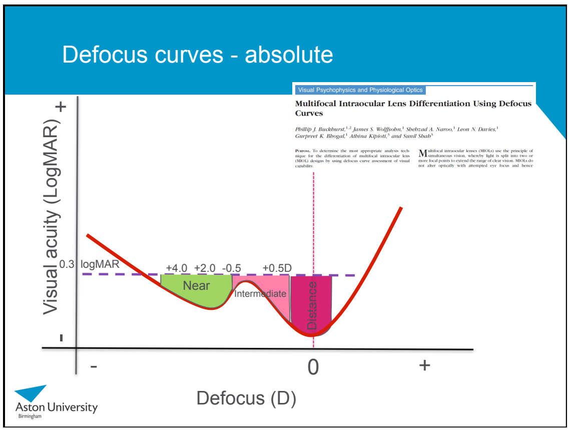
Aston University


Defocus curves - absolute
Visual Psychophysics and Physiological Optics
Multifocal Intraocular Lens Differentiation Using Defocus Curves
Visual acuity (LogMAR)
0.3 logMAR
+4.0 +2.0 -0.5 +0.5D
Near
Intermediate
Distance
0
Defocus (D)
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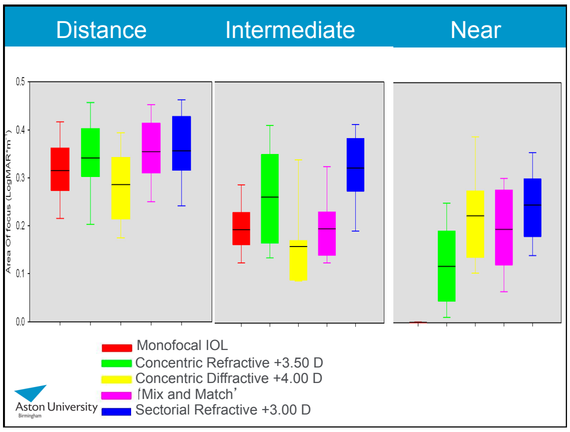
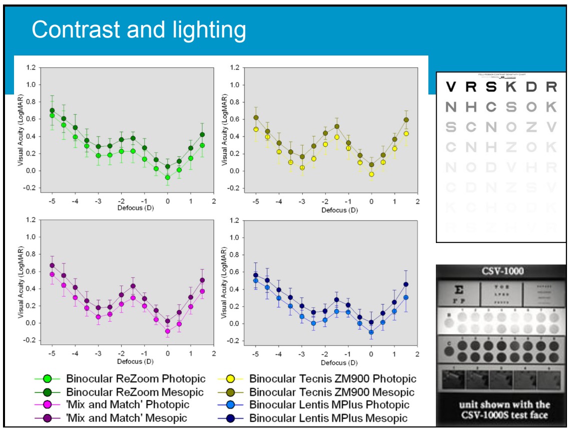
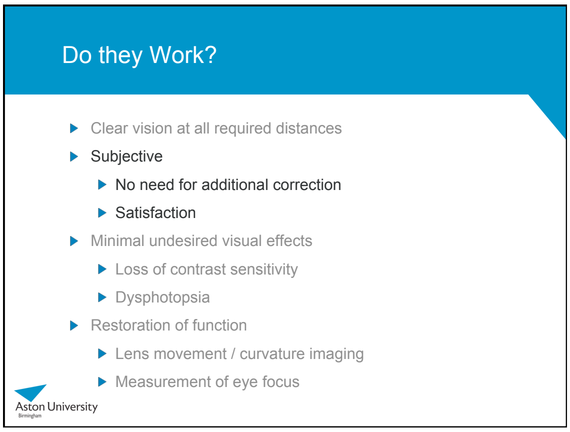






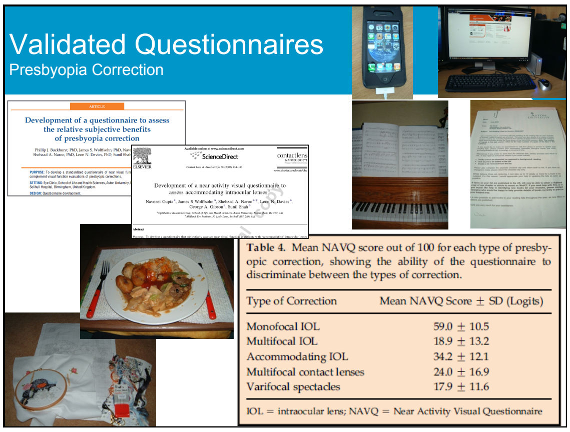
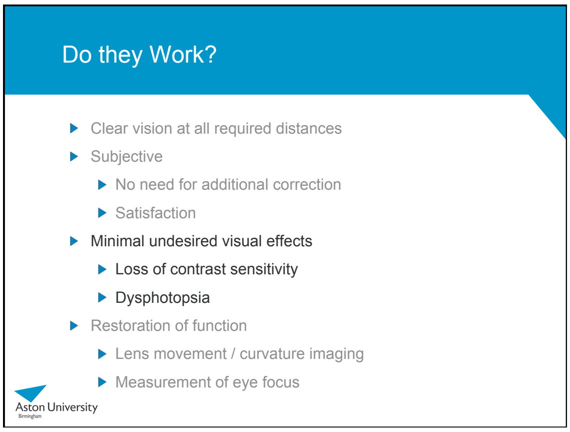
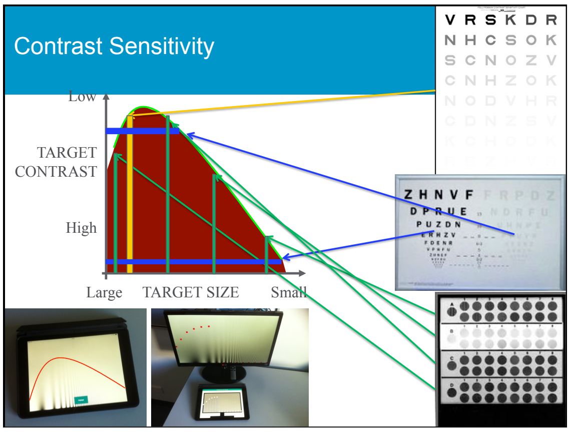


Table 4. Mean NAVQ score out of 100 for each type of presbyopic correction, showing the ability of the questionnaire to discriminate between the types of correction.

Type of Correction	Mean NAVQ Score ± SD (Logits)
Monofocal IOL	59.0 ± 10.5
Multifocal IOL	18.9 ± 13.2
Accommodating IOL	34.2 ± 12.1
Multifocal contact lenses	24.0 ± 16.9
Varifocal spectacles	17.9 ± 11.6

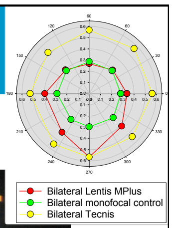
IOL = intraocular lens; NAVQ = Near Activity Visual Questionnaire

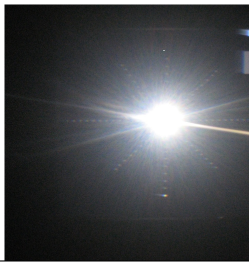




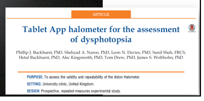
Glare testing

- Moving letter
- Measures size of glare area in degrees





Recent ghosting questionnaire (Kollbaum et al., 2012)



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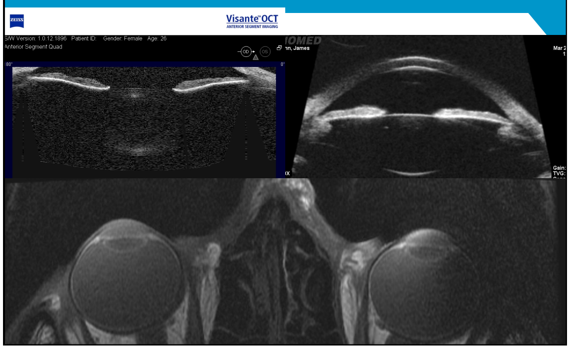
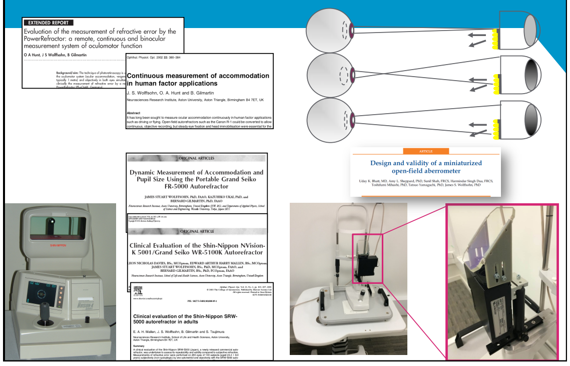
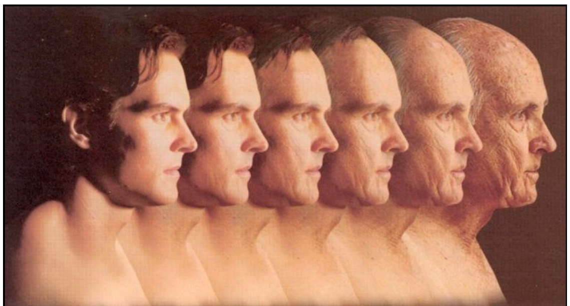
IOL Movement



Objective Accommodation





Spectacle Options

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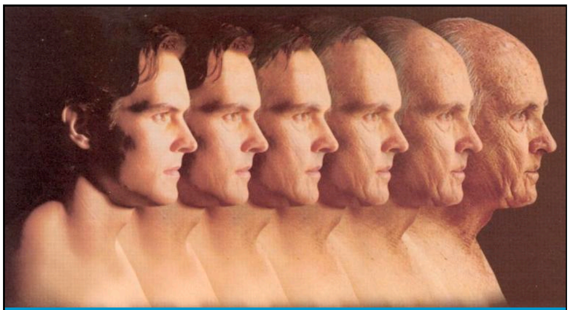
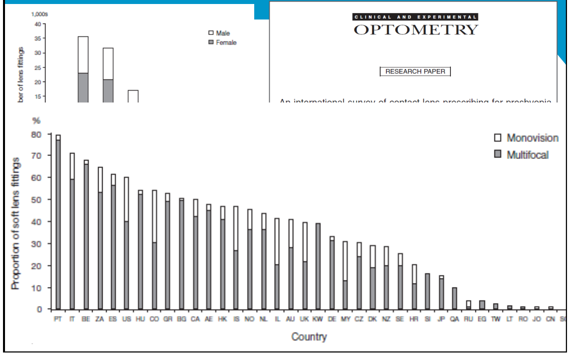
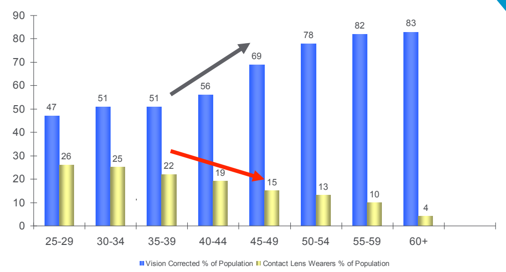


Contact Lens Options

Current Presbyopic Contact Lenses



Multifocal patient drop out rate



(Source: US Market Incidence Study 2007)

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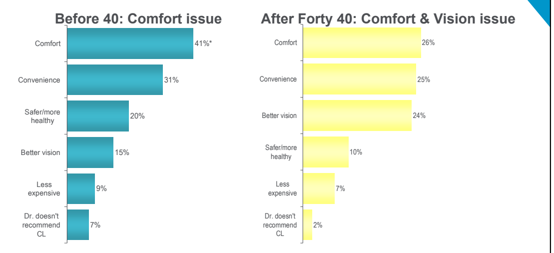
Why patients drop out after forty?

One Main Reason Stopped Wearing CL
(Base = Total CL Dropouts)
(n=13637)



2008 – Ciba Vision Data on files

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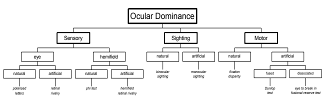
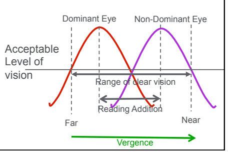
Monovision – splitting light between eyes

- Evans et al OPO 2007: CLs 59-67%
- Reilly et al Cornea 2006: IOLs 72-97% with contact lens pre-testing
- Dependant on strong ocular dominance (Handa et al., 2004)
- Stereopsis significantly reduced >1.5D anisometropia (Hayashi et al., 2011)
- Cochrane review – multifocal IOLs improve near vision vs monovision, but variable point outweighs visual phenomena (Calladine et al., 2012)
- Modified monovision





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Contact Lenses

Daily disposables
Fortnight/monthly
Soft, RGP, scleral, hybrid
Multifocal torics

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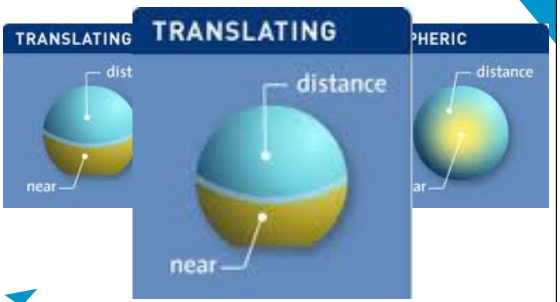
Contact Lenses



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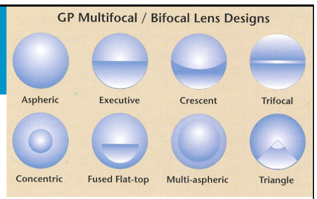
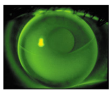
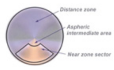
Alternating Images





Translating bifocal CL

- near vision zone in lower half of CL or outer concentric ring
- lenses translate upward and outward as eyes look down and converges – due to upper lid traction on top edge of lens.
- if pupil doesn't fully translate ⇒ distortion



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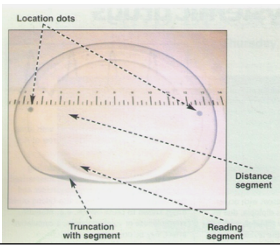
Alternating Images

Translating Soft bifocal CL

Don Ezekiel May 17th 2002

- TD horiz 14.5/15.0mm; vert 13.9/13.4/12.9 /12.4/11.9/11.4mm



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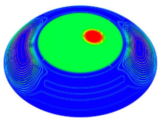
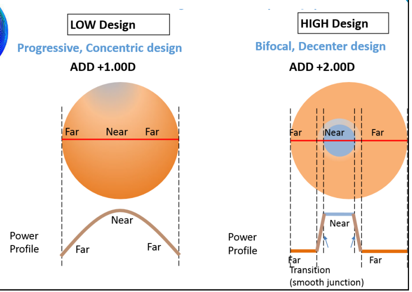
New asymmetric design





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Contact Lenses

RGP or Soft

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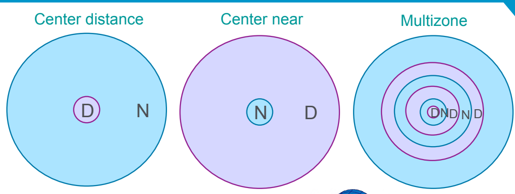
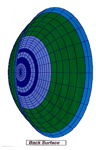
Concentric Designs



Zone size important
Usually CD

Pupil Intelligent Concept



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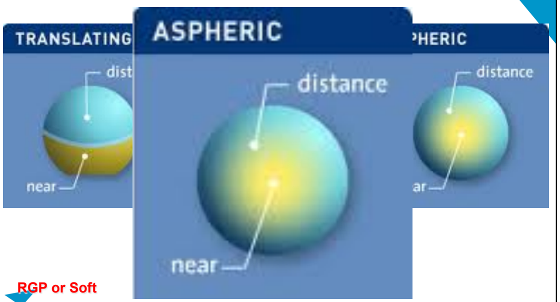
Contact Lenses



RGP or Soft

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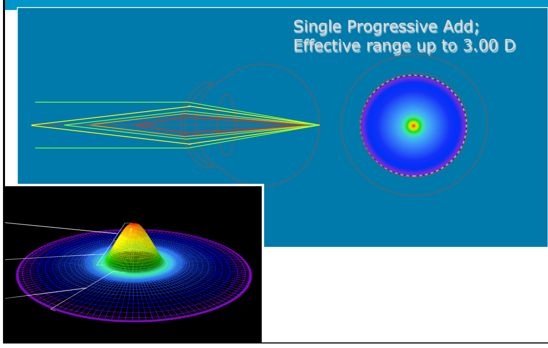
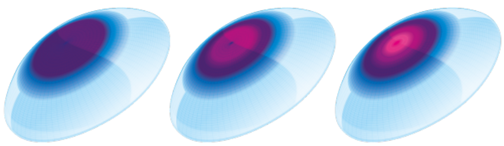
Aspheric design



Design varies with near addition



- Low Add (up to +1.25)
- Med Add (+1.50 to +2.00)
- High Add (≥ +2.25)

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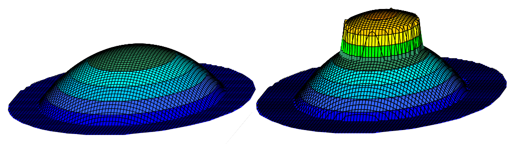
Power Profiles: *Low vs. High*

Low ADD

High ADD



Power gradually becomes more plus (+) towards lens center

Power becomes more positive towards lens center, plus a distinct central zone of greater plus (+) power

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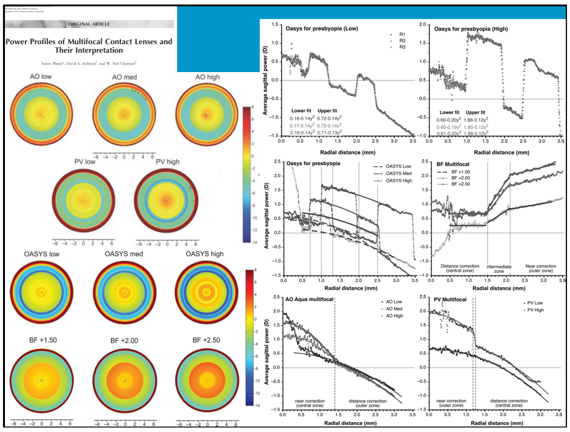
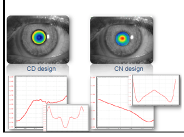
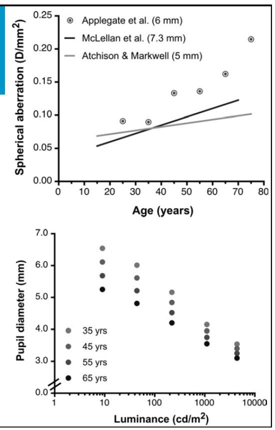


Other Considerations

- Centration
- Pupil Size
- Aging ocular optics
- Ocular comfort
- Ocular physiology

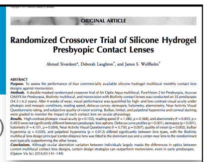




Previous Studies

Study	Nº	Age	Design	Lenses	Measurements
Sha et al OVS 2019	72	40-73	1wk Crossover	Acuvue Moist MF, BioTrue 1day, Dailies AquaComfort+	VA+low contrast, NVA, stereopsis, Qs
Novillo-Diaz et al CLAE 2018	150	40-62	3 months n=50x3	Spherical centre near, centre distance or aspheric centre near	Drop-out rate
Bakaraju et al J Optom 2018	43	42-63	1wk Crossover	Air Optix Aqua, Acuvue OASYS + extended DoF prototypes	VA, NVA, CSF, stereopsis, Qs
Sivardeen et al OVS 2016	50	42-65	1mth Crossover	Air Optix Aqua, PureVision 2, Acuvue OASYS, Biofinity MFs & monovision	VA, NVA, CSF, defocus, aberrometry, stereopsis, reading speed, Qs, halometry
Woods et al OVS 2015	49	43-66	2wk Crossover	Air Optix Aqua vs monovision	VA, IVA, NVA, stereopsis, Qs
Garcia-Lazaro et al CXO 2013	22	50-64	Contralateral	PureVision MF vs Pinhole	VA, NVA, CSF, photopic/mesopic, defocus, stereopsis
Plainis et al OPO 2012	12	22-29	No adaptation Crossover	Air Optix Aqua MF low, medium, high add	VA, defocus, artificial pupil, aberrometry
Madrid-Costa et al OPO 2012	20	45-65	1mth Crossover	PureVision MF low vs Acuvue Oasys	VA, NVA, CSF, photopic/mesopic, defocus
Madrid-Costa et al OVS 2012	20	45-65	1mth Crossover	Proclear MF toric vs Proclear toric with reading spex	VA, NVA, CSF ±glare, photopic/ mesopic, defocus, stereopsis
Llorente-Guillemot et al CXO12	20	41-60	1mth Crossover	PureVision MF high vs spex	VA, CSF ±glare, photopic/ mesopic
Ferrer-Blasco et al CXO 2011	25	50-60	1mth Crossover	Proclear MF vs dist CL + spex	VA, NVA, stereopsis
Ferrer-Blasco et al OVS 2010	20	50-60	1mth Crossover	Proclear MF vs dist CL + spex	VA, NVA, stereopsis
Sun Chu et al IOVS 2010	11	45-64	No adaptation Crossover	PALs, BF spex, MF CLs	Driving metrics
Sun Chu et al OVS 2009	20	47-67	No adaptation Crossover	PALs, BF spex, MF CLs	Driving Metrics
Woods et al., Eye CL 2009	25	38-50	1wk Crossover	Focus MF, Monovision, Habitual, Dist CLs	VA, CSF, stereopsis, reading speed, Qs
Chu Sun et al., Eye CL 2009	255	?	Survey	Habitual	Survey
Papas et al., Eye CL 2009	88	40-60	4day Crossover	Acuvue BF, Focus MF, Proclear MF, Soflens MF	VA, IVA, NVA, photopic/mesopic, steropsis, reading speed, Qs
Gupta et al., OVS 2009	20	49-67	1mth Crossover	PureVision MF vs Monovision	VA, IVA, NVA, CSF, reading speed, defocus, stereopsis, Qs
Freeman & Charman CLAE 2007	8	63±4	1hr	Diffractive bifocal vs monovision	VA, NVA, CSF, stereopsis
Ueda & Inagaki, Eye CL 2007	16	?	30minCrossover	GP BF vs soft BF	VA, NVA, photopic/mesopic, Qs
Rajagopalan et al., J Mod Opt 2007	26	42-65	N=8 adapted	GP monovision, Acuvue BF, GP MF, varifocals	CSF
Rajagopala net al., OVS 2006	32	42-65	N=8 adapted	GP monovision, Acuvue BF, GP MF, varifocals	CSF±glare, near task performance
Richdale et al., OVS 2006	38	41-64	N=19 1mth	Soflens MF vs Monovision	VA, NVA, CSF, stereopsis
Ardaya et al., Optometry 2004	20	≤45yr	Non-dispense	Acuvue BF +1 +1.5 +2.0 +2.5	VA, CSF

METHOD



- N=35 (54.3 ± 6.2 years, range 42-65)
- SiHy monthly
  - Biofinity multifocal (centre-distance / centre-near)
  - Acuvue OASYS for Presbyopia (concentric aspheric distance and near zones)
  - Air Optix Aqua (centre-near aspheric)
  - PureVision 2 for Presbyopia (centre-near aspheric)
  - Monovision with Biofinity single vision
- Fitted according to manufacturer's guidelines.
- Near add power based on near spectacle add.

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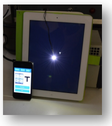
Tests - *binocular*

- Aberrometry (KR-1W Wavefront Analyzer, Topcon).
- VA - high (95%) and low (12.5%) contrast (David Thomson Chart 2000) at 6 m under both photopic (85 cd/m^2) and mesopic (5 cd/m^2).
- Reading speed/CPS (Aston CS mobile app).
- Subjective evaluation (NAVQ / iPhone image clarity).
- Binocular defocus range +1.50DS to -5.00DS in 0.50DS steps with randomised letter sequences and lens presentation.
- Stereoacuity at 40 cm (TNO random dot stereogram test).
- Halometry (Aston Halometer).
- Slit lamp Efron grading bulbar, limbal & palpebral hyperaemia and corneal staining.



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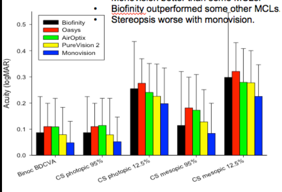
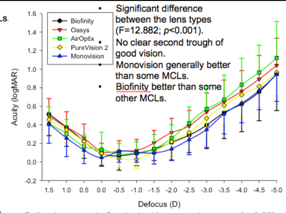
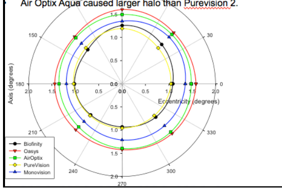
- Monovision better than some MCLs.
- Biofinity outperformed some other MCLs.
- Stereopsis worse with monovision.



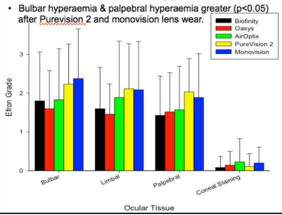
- Significant difference between the lens types (F=12.882; *p*<0.001).
- No clear second trough of good vision.
- Monovision generally better than some MCLs.
- Biofinity better than some other MCLs.



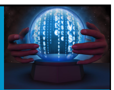
- Halo differed between lens types (F=4.101, p=0.004) & tested meridians (F=14.984, p<0.001).
- Air Optix Aqua caused larger halo than Purevision 2.



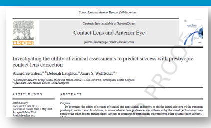
- Bulbar hyperaemia & palpebral hyperaemia greater (p<0.05) after Purevision 2 and monovision lens wear.



RESULTS



- After trialling all the lenses
  - N=12 preferred Biofinity multifocal
  - N=10 preferred monovision
  - N=7 preferred Purevision 2 multifocal
- Lens preference not dependent on:
  - personality (F=1.182, *p*=0.323)
  - lifestyle (*p>0.05*)
  - ocular aberrations (p>0.05)
  - pupil size (p>0.05)



- No intersubject or intrasubject relationships emerged between lens preference and:
  - reading speed
  - NAVQ rating
  - halo size
  - aberrometry
  - ocular physiology (*p*>0.05)

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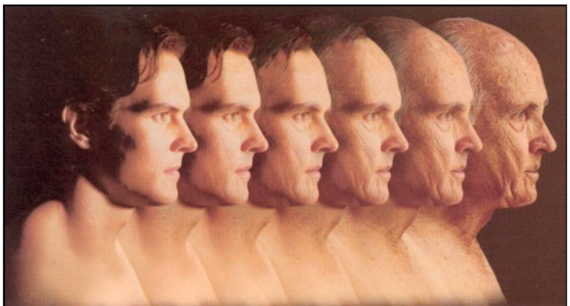
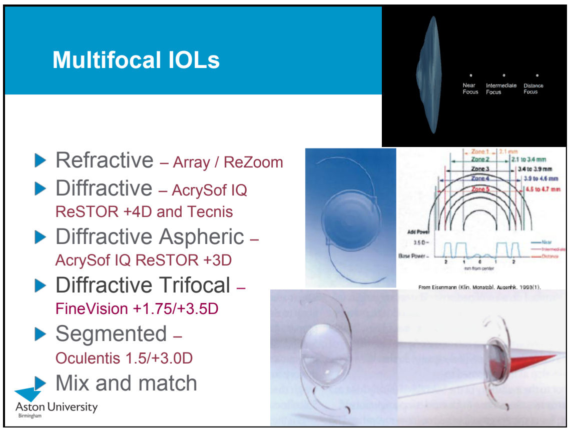


Surgical Correction of Presbyopia


The Intraocular Lens
2ND
1ST
67
Artificial lens implant surgery pioneered by Sir Harold Ridley, 1949


Multifocal IOLs
Refractive – Array / ReZoom
Diffractive – AcrySof IQ ReSTOR +4D and Tecnis
Diffractive Aspheric – AcrySof IQ ReSTOR +3D
Diffractive Trifocal – FineVision +1.75/+3.5D
Segmented – Oculentis 1.5/+3.0D
Mix and match
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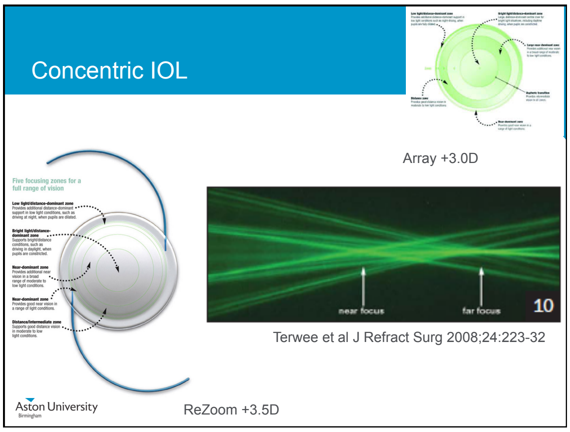
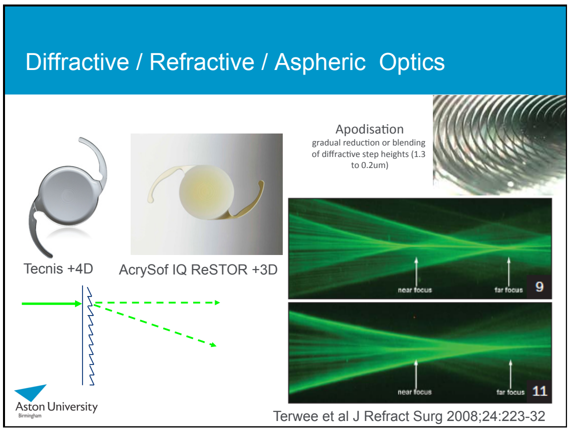
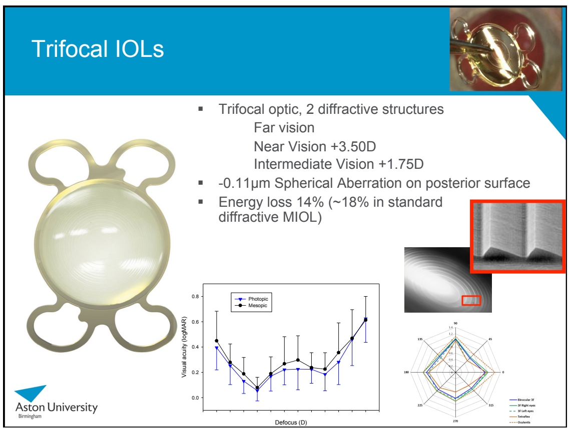

Concentric IOL
Array +3.0D
near focus
far focus
10
Terwee et al J Refract Surg 2008;24:223-32
Aston University
ReZoom +3.5D


Diffractive / Refractive / Aspheric Optics
Apodisation
gradual reduction or blending of diffractive step heights (1.3 to 0.2um)
Tecnis +4D
AcrySof IQ ReSTOR +3D
near focus
far focus
9
near focus
far focus
11
Aston University
Terwee et al J Refract Surg 2008;24:223-32


Trifocal IOLs
Trifocal optic, 2 diffractive structures
Far vision
Near Vision +3.50D
Intermediate Vision +1.75D
-0.11µm Spherical Aberration on posterior surface
Energy loss 14% (~18% in standard diffractive MIOL)
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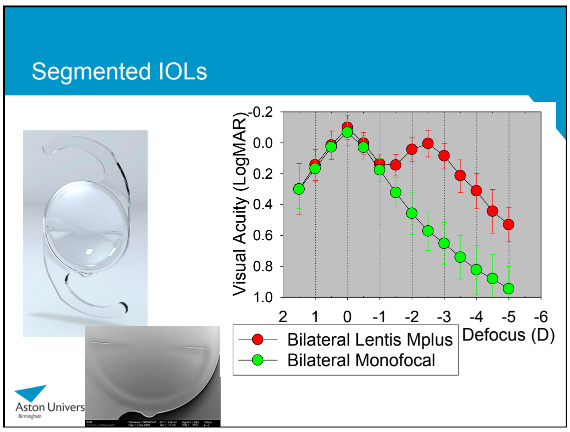
Segmented IOLs
Visual Acuity (LogMAR)
Defocus (D)
Bilateral Lentis Mplus
Bilateral Monofocal
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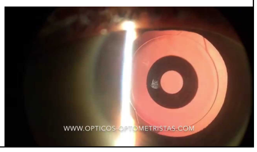
EDOF IOLs

- Diffractive
  - TECNIS® Symfony IOL (Abbott Medical Optics)
- Soft material
  - WIOL-CF (Medicem) polyfocal IOL.
- Small aperture
  - IC-8™ lens (AcuFocus, Inc.)



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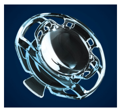
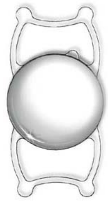
Accommodating IOLs

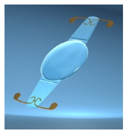
1CU - HumanOptics



Synchrony - AMO



Kellen TetraFlex
KH-3500 - Lenstec



Crystalens – B&L

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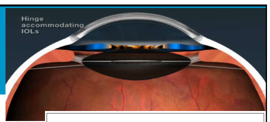
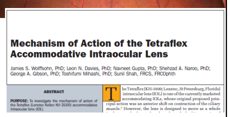
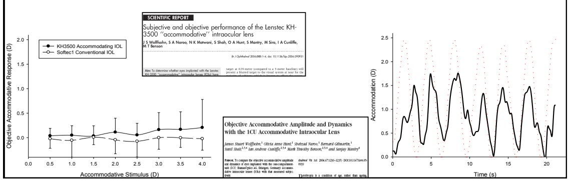
Single Optics



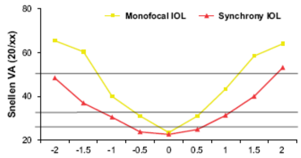
- Flexible Haptics
  - Generally forward movement on pharmacological stimulation
  - Patients happy, but limited objective accommodation, especially past 6 months
  - PCO rate high

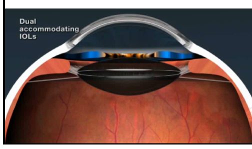




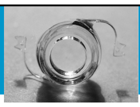
Dual Optic (Ossma et al 2007)

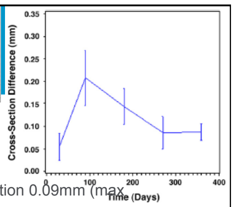
- Synchrony / Sarfarazi
  - +32D front optic / -ve back lens variable power
  - 24 eyes, 6 months, (11 eyes, 1 yr)
  - PCO 17%
  - 3.2D vs 1.7D →



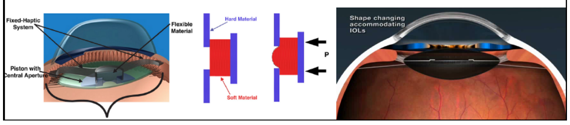


Shape Changing



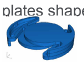


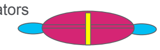
- NuLens (Alio et al., 2009)
  - 10 eyes, 12 months
  - PCO 60%
  - Movement on pharmacological stimulation 0.09mm (max 0.21mm @ 3 months) →10+D
  - **BUT** accommodation in reverse



Future Accommodating IOLs?

- Tek-Clear/C-Well
  - Mechanical shift
- Medennium Smart IOL – Nishi et al., 2009
  - Capsular bag refilling
- Alzarez – Simonov et al., 2006
  - 2 opposite rotating phase plates shaped as cubic polynomials
- LiquiLens
  - 2 immiscible fluids of different refractive index
- PowerVision / Atia Vision
  - Fluid actuators
- + + +





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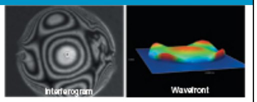
Light Adjustable Lens



- silicone matrix
- photoinitiator
- photosensitive macromer
- back UV absorbant layer

- Able to correct ±2DS, -1.75DC
- Typically 2 adjustments: partial polymerisation by UV 365nm
- Protective spectacles 10-14 days
- 2 additional photo-locking treatments

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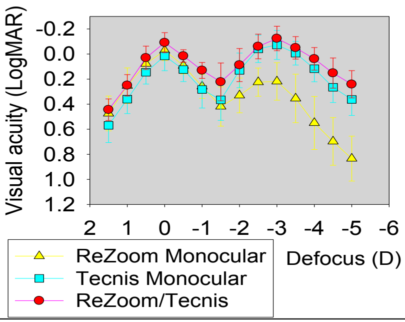
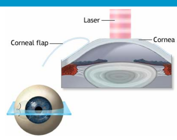
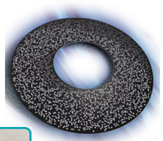
Mix and Match



Laser Refractive Surgery and Corneal Inlays



- Kamra ACI 7000 (AcuFocus & B&L)
  - DoF increasing 1.6mm aperture
  - 10 microns thick, thermoplastic polymer Kynar
  - LASIK bed



- PresbyLens (ReVision Optics)
  - 2mm

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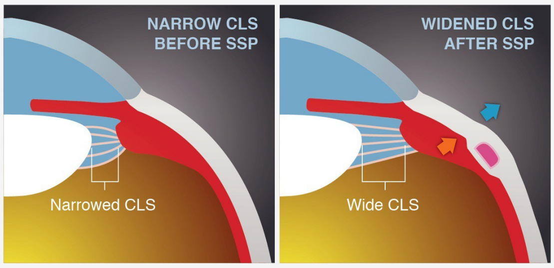
Scleral Expansion Surgery



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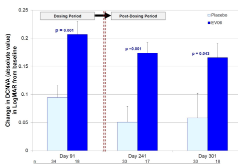
Other Options

Pharmaceuticals

- stimulating the contraction of the ciliary muscles in the presence of different miotics (Abdelkader, 2015; Abdelkader and Kaufman, 2016; Renna et al., 2016)
- nonsteroidal anti-inflammatory drugs (Benozzi et al., 2012)
- EV06 lipoic acid treatment - decrease in lens protein disulfides concurrent with increase in lens elasticity (Garner and Garner, 2016)
  - benefit maintained for 5-7 months after last 90 day 2x/day dose of EV06 (Stein et al., 2017)
- AGN-199201 ophthalmic solution (Oxymetazoline , a alpha adrenoceptor agonist) – up to 70% of patients ≥2 line improvement in UNVA



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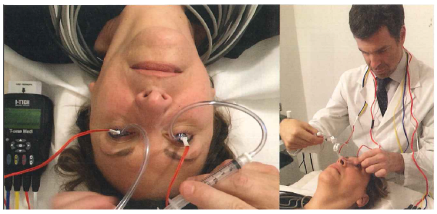
Electrostimulation



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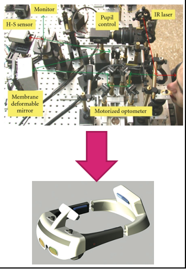
Optimising Prescribing

- Prepare early
  - Educate
  - Ocular surface health
- Process, not an event
- Consider mix and match strategy
- Enhancing near vision, so demonstrate first



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Advances in Presbyopia Correction

Professor James Wolffsohn
BSc MBA PhD FBCLA