Implant lenses after cataract surgery: new developments

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Moorfields Eye Hospital, London

No financial interest in any products mentioned!
Cataract
Incision
Capsulorhexis
Phacoemulsification
Intraocular lens (IOL)
New IOL Developments

- Toric IOL
- Aspheric IOL
- Multifocal IOL
- Accommodating IOLs
Aberrations of the eye

- Astigmatism
- Higher Order Aberrations: spherical aberration

<table>
<thead>
<tr>
<th>Common Names</th>
<th>Radial Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piston</td>
<td>0</td>
</tr>
<tr>
<td>Tip, Tilt (Prism)</td>
<td>1</td>
</tr>
<tr>
<td>Astigmatism (3, 5), Defocus (4)</td>
<td>2</td>
</tr>
<tr>
<td>Coma (7, 8) Trefoil (6, 9)</td>
<td>3</td>
</tr>
<tr>
<td>Spherical Aberration (12)</td>
<td>4</td>
</tr>
<tr>
<td>Secondary Coma (17, 18)</td>
<td>5</td>
</tr>
</tbody>
</table>
Causes

> 1.0 D Asti. - 20-32%
> 1.5 D - 15-20%
Astigmatism - Orientation
Toric IOL

Staar toric plate haptic IOL

– Rotationally instable – 20% of >25 degrees rotation
Toric IOL

Z-haptic (Dr. Schmidt)

- For high powered astigmatism
- Difficult to position
Toric IOL
Lens Recommendation

Surgeon & Patient Information
- Surgeon Name: Findl
- Patient Name: Test
- Additional Patient Information (I.D., Case, etc.): 001

Lens Details
- AcrySof® Toric IOL: SN60T5
- IOL Spherical Equivalent (SE): 20.0 D
- Axis of Placement: 90°
- Cylinder Power (IOI Plane): 3.00 D
- Cylinder Power (Corneal Plane): 2.06 D

Calculation Details
- Pre-Op Corneal Astigmatism: 2.00 D X 90°
- Surgically Induced Astigmatism: 0.50 D X 90°
- Crossed-Cylinder Result (corneal plane): 2.50 D X 90°
- Anticipated Residual Astigmatism: 0.44 D X 90°

Surgically Induced Astigmatism (SIA): 0.50 D
Incision Location (IL): 180°

Notes:
- Flat K: 42.000 @ 0° Sleep: K: 44.000 @ 90°
- P-IOL: 20.00 SE: A: 0.500 IL: 180° [V: 3.1.0]
- bfb718c055293f7a8c49a4952845c7c6 7/3/08 6:05:22
- Steep Axis
- Flat Axis
- Incision

New Calculation | Tutorial | Help | Privacy Policy & Legal Terms
Precision of alignment is key (Euler)

On meridian

1 deg off – 3% loss

10 deg off – about 1/3 loss = happy patient?

30 deg off – no correction + axis change = unhappy patient

> 30 deg off – worse off with toric = very unhappy
## Seated – Supine Cyclotorsion

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>n</th>
<th>mean °</th>
<th>&gt; 5°</th>
<th>max °</th>
<th>Excyclo.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chermyak</td>
<td>2004</td>
<td>51</td>
<td>2.0</td>
<td>14%</td>
<td>9.5</td>
<td>79%</td>
</tr>
<tr>
<td>Ciccio</td>
<td>2005</td>
<td>1019</td>
<td>4.1</td>
<td>-</td>
<td>17.5</td>
<td>46%</td>
</tr>
<tr>
<td>Hori-Komai</td>
<td>2007</td>
<td>192</td>
<td>2.3</td>
<td>-</td>
<td>7.3</td>
<td>-</td>
</tr>
<tr>
<td>Hyojin</td>
<td>2008</td>
<td>27</td>
<td>2.6</td>
<td>13</td>
<td>10</td>
<td>54%</td>
</tr>
</tbody>
</table>
Pre-Op Marking
Rotation

Boxplot:
Whiskers: minimum & maximum, box: middle 50%

n = 14
1st month

n = 33
6 months

n = 14
Astigmatism

preOP K's | 1 month | 6 months
---|---|---
n = 14

IOL-Master K's

Autorefractor Cylinder

n = 33

n = 14
Summary - Toric

• Modern toric IOLs
  – Rotational stability
• Planning is key
  – Measurement
  – Alignment
• Good uncorrected distance acuity
• High patient satisfaction

KEEP moderate myopic ATR astigmatism!
  – Good distance vision, good intermediate vision, moderate reading vision
Spherical aberration
Functional Vision

Visual acuity (high contrast and photopic) – relevant?

Low contrast

Mesopic conditions
Contrast Sensitivity Tests
Aspheric IOL

Prolate Optic to compensate spherical aberration of cornea

Figure 5. (Mester) Mean ocular spherical aberration coefficients 1 and 3 months postoperatively.

Mester et al, JCRS 2003; 29:652–660
Results

Contrast Sensitivity (Ginsburg box, FACT chart)

![Graph showing contrast sensitivity results for CeeOn Edge and Tecnis lenses. The graph includes spatial frequency (c/deg) on the x-axis and contrast sensitivity score on the y-axis. There are markers at different spatial frequencies (1.5, 3.0, 6.0, 12.0, 18.0 c/deg) with corresponding contrast sensitivity scores. The graph indicates statistical significance at certain frequencies marked with an asterisk (*) and a p-value of less than 0.05.]

54 eyes of 27 patients (76 yrs)
Results

High order aberrations

911A
Tecnis

* p < 0.05
High order aberrations (large pupil)

* p < 0.05
# HOA – aspheric IOL

Pre-OP topography to find best aspheric IOL:

<table>
<thead>
<tr>
<th>Pre-OP corneal spherical Aberration</th>
<th>IOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>negative</td>
<td>Standard spherical IOL</td>
</tr>
<tr>
<td>0 to 0.15µm</td>
<td>Rayner; Akreos AO, B&amp;L</td>
</tr>
<tr>
<td>0.16 to 0.33µm</td>
<td>AcrySof IQ, Alcon</td>
</tr>
<tr>
<td>&gt; 0.33µm</td>
<td>Tecnis, AMO</td>
</tr>
</tbody>
</table>

Beiko G, Ontario
Presbyopia Treatments

1. Multifocal IOL

2. Monovision

3. Accommodating IOLs
   - No evidence that current designs work

4. Corneal approaches
   - Inlays
   - Multifocal profile ablation

5. Scleral incisions
   - No evidence that they work

6. Lens Refilling – Phakoersatz
   - Still experimental – main problem after-cataract
Multifocal IOL - Principle

Diffractive

Refractive
Multifocal IOLs - Principle

Distance

Near
Bifocal diffractive IOL
Multifocal IOL

Simultaneous vision
• 2 images superimposed – one blurred – retinal rivalry
• Brain selects the best image

Resulting disadvantages:
• Loss of image contrast
  – ~ 20% of light lost to higher order diffraction
  – < 50% of incoming light on each focus
• Halos in 100% - perceived by patient in ~ 20%
Diffractive bifocal IOL

Tecnis Multifocal

- Light distribution 50:50
- Loss of 18% to higher order diffraction
Bifocal IOL

AcriLisa

- Light distribution 65:35
Bifocal IOL

ReSTOR

- Apodized optic
  - Central 3.6mm with 12 concentric diffr. Zones
  - Gradual reduction in step height
- Refractive region in periphery
- 2mm pupil 40:40
  5mm pupil 84:10

The ReSTOR® lens (L) and magnified (R)

ReSTOR, Alcon
ReSTOR

Good Near VA

Near VA
Binocular – 6 Months Postop

25% Halos / Glare

Occurrence/Severity of Visual Disturbances, %²

Night Vision
- AcrySof® ReSTOR® (n=459)
  - None/Mild: 87%
  - Moderate: 74%
  - Severe: 76%

- Monofocal (n=156)
  - None/Mild: 94%
  - Moderate: 91%
  - Severe: 97%

Glare
- AcrySof® ReSTOR® (n=459)
  - None/Mild: 74%
  - Moderate: 47%
  - Severe: 32%

- Monofocal (n=156)
  - None/Mild: 91%
  - Moderate: 84%
  - Severe: 78%

Halos
- AcrySof® ReSTOR® (n=459)
  - None/Mild: 76%
  - Moderate: 52%
  - Severe: 32%

- Monofocal (n=156)
  - None/Mild: 97%
  - Moderate: 94%
  - Severe: 92%
Refractive Multifocal IOL

ReZoom

- Distance dominant
- 5 zones
- Aspheric transitions for intermediate vision
- Light distribution is pupil size dependent
Want to have real fun on a Safari?

The AcrySof® ReSTOR® lens. Sight changing, life changing.

Introducing a breakthrough in vision surgery. Now there’s a revolutionary new way to potentially leave your glasses behind – introducing the AcrySof® ReSTOR® Intraocular lens (IOL), a breakthrough in vision surgery. AcrySof® ReSTOR® has been uniquely designed to improve vision at all distances – up close, far away, and everything in-between – giving cataract patients their best chance ever to live free of glasses.

Learn more about your eyes, cataract surgery, the AcrySof® ReSTOR® IOL, and the potential you may now have for freedom from glasses!

1. AcrySof® ReSTOR® Package Insert.
Want to be a good golfer?
Multifocal IOL Options

Diffractive
- Bifocal
- Good near acuity
- Less intermediate vision

Refractive
- Multifocal
- Moderate near acuity
- Good intermediate vision

Mix & match
- Idea: Good near and intermediate vision
- Concerns about asymmetry of halos
- Binocular function?
Evidence

Cochrane review (Leyland M, 2006):

Metaanalysis of trials that were

• Randomised
• Controlled
• Masked (patient & examiner)

• 8 trials, n ≈ 700 patients
Distance VA
Distance VA – unaided
less than 6/6

Analysis 1.1. Comparison of MULTIFOCAL IOLs versus MONOFOCAL IOLs, Outcome 1: Distance visual acuity - less than 6/6 unaided.

Refractive mIOL

Diffractive mIOL

All mIOL
## Distance VA – unaided

**Mean VA**

### Analysis 1.2. Comparison 1 MULTIFOCAL IOLs versus MONOFOCAL IOLs, Outcome 2 Distance visual acuity - mean unaided.

#### Refractive mIOL

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Multifocal</th>
<th>Monofocal</th>
<th>Std. Mean Difference</th>
<th>Weight</th>
<th>Std. Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (Mean(SD))</td>
<td>N (Mean(SD))</td>
<td>I/Fixed 95% CI</td>
<td>I/Fixed 95% CI</td>
<td></td>
</tr>
<tr>
<td>Refractive IOLs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jowitt 2000</td>
<td>173 -7.73 (1.71)</td>
<td>109 -7.66 (1.34)</td>
<td>191 %</td>
<td>-0.09 [-0.35, 0.16]</td>
<td></td>
</tr>
<tr>
<td>Leyland 2002</td>
<td>45 0.08 (0.13)</td>
<td>16 0.05 (0.15)</td>
<td>191 %</td>
<td>0.22 [-0.35, 0.79]</td>
<td></td>
</tr>
<tr>
<td>Nilkamp 2004</td>
<td>68 0.13 (0.12)</td>
<td>69 0.16 (0.02)</td>
<td>231 %</td>
<td>0.15 [-0.48, 0.19]</td>
<td></td>
</tr>
<tr>
<td>Sen 2004</td>
<td>53 0.66 (0.24)</td>
<td>67 0.56 (0.23)</td>
<td>195 %</td>
<td>0.42 [0.06, 0.79]</td>
<td></td>
</tr>
<tr>
<td>Steinhert 1992</td>
<td>32 -6.33 (1.73)</td>
<td>30 -6.37 (1.93)</td>
<td>105 %</td>
<td>0.02 [-0.48, 0.52]</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td>321</td>
<td>291</td>
<td>106.0 %</td>
<td>0.63 [-0.13, 0.19]</td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: Chi² = 6.48, df = 4 (P = 0.14); I² = 42%
Test for overall effect: Z = 0.39 (P = 0.70)

2. Diffusive IOLs

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Multifocal</th>
<th>Monofocal</th>
<th>Std. Mean Difference</th>
<th>Weight</th>
<th>Std. Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N (Mean(SD))</td>
<td>N (Mean(SD))</td>
<td>I/Fixed 95% CI</td>
<td>I/Fixed 95% CI</td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td>0</td>
<td>0</td>
<td>0.0 %</td>
<td>Not estimable</td>
<td></td>
</tr>
</tbody>
</table>

Heterogeneity: not applicable
Test for overall effect: not applicable

**Total (95% CI)** 321 291 106.0 % 0.63 [-0.13, 0.19]

Heterogeneity: Chi² = 6.48, df = 4 (P = 0.14); I² = 42%
Test for overall effect: Z = 0.39 (P = 0.70)
## Distance VA – best corrected less than 6/6

### Analysis 01.03. Comparison 01 MULTIFOCAL IOLs versus MONOFOCAL IOLs, Outcome 03 Distance visual acuity - less than 6/6 best-corrected

- **Review**: Multifocal versus monofocal intraocular lenses after cataract extraction
- **Comparison**: 01 MULTIFOCAL IOLs versus MONOFOCAL IOLs
- **Outcome**: 03 Distance visual acuity - less than 6/6 best-corrected

<table>
<thead>
<tr>
<th>Study</th>
<th>Multifocal n/N</th>
<th>Monofocal n/N</th>
<th>Ratio Odds Ratio (95% CI)</th>
<th>Weight (%)</th>
<th>Ratio Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>01 Refractive IOLs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kamleh 2001</td>
<td>1/20</td>
<td>5/20</td>
<td></td>
<td>3.8</td>
<td>0.22 [0.04, 1.20]</td>
</tr>
<tr>
<td>Leyland 2002</td>
<td>4/45</td>
<td>2/16</td>
<td></td>
<td>3.1</td>
<td>0.67 [0.10, 4.48]</td>
</tr>
<tr>
<td>Percival 1993</td>
<td>9/25</td>
<td>6/25</td>
<td></td>
<td>7.8</td>
<td>1.75 [0.53, 5.80]</td>
</tr>
<tr>
<td>Sen 2004</td>
<td>23/53</td>
<td>48/67</td>
<td></td>
<td>20.9</td>
<td>9.31 [0.15, 56.65]</td>
</tr>
<tr>
<td>Steinar 1992</td>
<td>12/32</td>
<td>9/30</td>
<td></td>
<td>10.2</td>
<td>1.39 [0.49, 3.95]</td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td>175</td>
<td>158</td>
<td></td>
<td>45.7</td>
<td>0.60 [0.36, 0.98]</td>
</tr>
<tr>
<td>Total events: 49 (Multifocal), 70 (Monofocal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test for heterogeneity chi-square: 9.9, df=4, p=0.04 I² = 59.8%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test for overall effect z=2.04, p=0.04</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **02 Diffractive IOLs** |               |               |                          |            |                          |
| Allen 1996       | 39/116        | 19/101        |                          | 30.8       | 2.12 [1.16, 3.87]         |
| El-Magraby 1992  | 9/28          | 8/33          |                          | 9.0        | 1.47 [0.48, 4.48]         |
| Rossetti 1994    | 18/38         | 19/42         |                          | 14.5       | 1.09 [0.45, 2.61]         |
| **Subtotal (95% CI)** | 192           | 176           |                          | 54.3       | 1.67 [1.06, 2.63]         |
| Total events: 66 (Multifocal), 46 (Monofocal) |
| Test for heterogeneity chi-square: 1.58, df=2, p=0.45 I² = 0.0% |
| Test for overall effect z=2.22, p=0.03 |
| **Total (95% CI)** | 357           | 334           |                          | 100.0      | 1.04 [0.75, 1.46]         |

| Total events: 116 (Multifocal), 114 (Monofocal) |
| Test for heterogeneity chi-square: 20.59, df=7, p=0.004 I² = 66.0% |
| Test for overall effect z=2.05, p=0.05 |

---

**Refractive mIOL**

**Diffractive mIOL**

**All mIOL**
Contrast Vision

Fine spatial detail (visual acuity) is not everything

Low contrast  Low illumination
## Contrast Vision

<table>
<thead>
<tr>
<th>Study ID</th>
<th>Method</th>
<th>Outcome</th>
<th>Multifocal</th>
<th>Monofocal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allen 1996</td>
<td>VCTS chart (6500 for distance, 6000 for near)</td>
<td>Mean of CS at 5 spatial frequencies, at 3 light levels (log units)</td>
<td>CS 57.9 to 83.9 lower</td>
<td>CS 57.9 to 83.9 higher</td>
</tr>
<tr>
<td>El-Maghraby 1992</td>
<td>Not tested</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Javitt 2000</td>
<td>Not tested</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kamlesh 2001</td>
<td>Pelli-Robson chart</td>
<td>Mean CS score (log units)</td>
<td>1.38</td>
<td>1.56</td>
</tr>
<tr>
<td>Leyland 2002</td>
<td>Pelli-Robson chart</td>
<td>Mean (SD) CS score (log units)</td>
<td>1.66 (0.16)</td>
<td>1.74 (0.15)</td>
</tr>
<tr>
<td>Nijkamp 2004</td>
<td>Not tested</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percival 1993</td>
<td>Regan Contrast Acuity Charts</td>
<td>Acuity at 96%, 50%, 25%, &amp; 11% contrast (lines read)</td>
<td>CS lower at all levels, Statistical significance not assessed</td>
<td>At 11%: 2.1 lines higher</td>
</tr>
<tr>
<td>Rossetti 1994</td>
<td>Pelli-Robson chart</td>
<td>Mean CS score (log units)</td>
<td>1.70</td>
<td>1.73</td>
</tr>
<tr>
<td>Sen 2004</td>
<td>VCTS chart</td>
<td>Mean CS measured at 5 different spatial frequencies</td>
<td>CS lower at lower spatial frequencies, but not</td>
<td></td>
</tr>
<tr>
<td>Steinert 1992</td>
<td>Regan Contrast Acuity Charts</td>
<td>Acuity at 96%, 50%, 25%, &amp; 11% contrast (lines read)</td>
<td>CS lower at all levels, Statistically significant at 11%: 2.59 (SD2.01)</td>
<td>At 11%: 4.37 (SD2.05)</td>
</tr>
</tbody>
</table>

**Different evaluation methods – monofocal slightly better CS**
### Analysis 01.05. Comparison 01 MULTIFOCAL IOLs versus MONOFOCAL IOLs, Outcome 05 Near visual acuity - less than J3/J4 unaided

- **Review**: Multifocal versus monofocal intraocular lenses after cataract extraction
- **Comparison**: 01 MULTIFOCAL IOLs versus MONOFOCAL IOLs
- **Outcome**: 05 Near visual acuity - less than J3/J4 unaided

<table>
<thead>
<tr>
<th>Study</th>
<th>Multifocal n/N</th>
<th>Monofocal n/N</th>
<th>Petro Odds Ratio 95% CI</th>
<th>Petro Odds Ratio 95% CI</th>
</tr>
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<tbody>
<tr>
<td>01 Refractive IOLs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Javitt 2000</td>
<td>4/172</td>
<td>27/109</td>
<td></td>
<td>0.17 [0.04, 0.74]</td>
</tr>
<tr>
<td>Leyland 2002</td>
<td>31/45</td>
<td>13/16</td>
<td></td>
<td>0.55 [0.15, 1.93]</td>
</tr>
<tr>
<td>Percival 1993</td>
<td>5/25</td>
<td>10/25</td>
<td></td>
<td>0.39 [0.12, 1.30]</td>
</tr>
<tr>
<td>02 Diffractive IOLs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allen 1996</td>
<td>14/116</td>
<td>92/101</td>
<td></td>
<td>0.04 [0.03, 0.07]</td>
</tr>
<tr>
<td>El-Maghraby 1992</td>
<td>3/23</td>
<td>7/24</td>
<td></td>
<td>0.39 [0.10, 1.55]</td>
</tr>
<tr>
<td>Rossetti 1994</td>
<td>5/38</td>
<td>25/42</td>
<td></td>
<td>0.14 [0.06, 0.35]</td>
</tr>
</tbody>
</table>

multi

Favours multifocal

mono

Favours monofocal
## Spectacle Dependence

### Analysis 1.7 - Comparison of Multifocal IOLs versus Monofocal IOLs, Outcome 7 Spectacle dependence

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Multifocal</th>
<th>Monofocal</th>
<th>Rate Odds Ratio</th>
<th>Weight</th>
<th>Rate Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refractive IOLs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jaiti 2000</td>
<td>84/124</td>
<td>102/109</td>
<td></td>
<td>0.20</td>
<td>(0.11, 0.38)</td>
</tr>
<tr>
<td>Kamlesh 2001</td>
<td>7/20</td>
<td>19/20</td>
<td></td>
<td>0.10</td>
<td>(0.03, 0.37)</td>
</tr>
<tr>
<td>Layland 2002</td>
<td>32/145</td>
<td>16/16</td>
<td></td>
<td>0.18</td>
<td>(0.06, 0.57)</td>
</tr>
<tr>
<td>Nuckamp 2004</td>
<td>6/68</td>
<td>6/66</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harvald 1996</td>
<td>14/123</td>
<td>73/73</td>
<td></td>
<td>0.16</td>
<td>(0.09, 0.26)</td>
</tr>
<tr>
<td>Svendsen 1999</td>
<td>17/17</td>
<td>17/17</td>
<td></td>
<td>0.11</td>
<td>(0.07, 0.18)</td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td><strong>313</strong></td>
<td><strong>264</strong></td>
<td><strong>61.7%</strong></td>
<td><strong>0.22</strong></td>
<td>(0.14, 0.34)</td>
</tr>
</tbody>
</table>

Total events: 574 (Multifocal), 747 (Monofocal)
Heterogeneity: $\chi^2 = 20.8$, df = 1, $p = 0.003$, $I^2 = 36$
Test for overall effect: $Z = 6.85$, $p < 0.00001$

<table>
<thead>
<tr>
<th>Diffractive IOLs</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Allen 1996</td>
<td>72/116</td>
<td>97/99</td>
<td></td>
<td>0.11</td>
<td>(0.04, 0.21)</td>
</tr>
<tr>
<td>Hoosier 1984</td>
<td>23/24</td>
<td>29/24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td><strong>154</strong></td>
<td><strong>140</strong></td>
<td><strong>38.3%</strong></td>
<td><strong>0.11</strong></td>
<td>(0.07, 0.20)</td>
</tr>
</tbody>
</table>

Total events: 464 (Multifocal), 583 (Monofocal)
Heterogeneity: $\chi^2 = 307$, df = 1, $p = 0.000001$, $I^2 = 93$
Test for overall effect: $Z = 10.16$, $p < 0.000001$

<table>
<thead>
<tr>
<th>All IOLs</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>487</td>
<td>404</td>
<td><strong>100.0%</strong></td>
<td><strong>0.17</strong></td>
<td>(0.12, 0.24)</td>
</tr>
</tbody>
</table>

Test for subgroup differences: $\chi^2 = 2.6$, df = 1, $p = 0.09$, $I^2 = 70$

### Refractive mIOL

### Diffractive mIOL

### All mIOL

68% multi  95% mono
Glare / Halo
## Analysis 1.6. Comparison of MULTIFOCAL IOLs versus MONOFOCAL IOLs, Outcome 6 Glare/halo.

**Review:** Multifocal versus monofocal intraocular lenses after cataract extraction.

**Comparison:** 1 MULTIFOCAL IOLs versus MONOFOCAL IOLs

**Outcome:** 6 Glare/halo.

<table>
<thead>
<tr>
<th>Study or subgroup</th>
<th>Multifocal n/N</th>
<th>Monofocal n/N</th>
<th>Peto Odds Ratio</th>
<th>Weight</th>
<th>Peto Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Refractive mIOL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Refractive IOLs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kamish 2001</td>
<td>12/20</td>
<td>7/20</td>
<td></td>
<td>17.9 %</td>
<td>2.66 [ 0.78, 9.05 ]</td>
</tr>
<tr>
<td>Percival 1993</td>
<td>3/23</td>
<td>0/25</td>
<td></td>
<td>5.0  %</td>
<td>8.05 [ 080, 81.12 ]</td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td>45</td>
<td>45</td>
<td></td>
<td>22.9 %</td>
<td>3.39 [ 1.15, 10.01 ]</td>
</tr>
<tr>
<td>Total events: 15 (Multifocal), 15 (Monofocal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity: Chi² = 0.69, df = 1 (P = 0.41); I² =0.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test for overall effect: Z = 2.21 (P = 0.027)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Diffractive mIOL</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Diffractive IOLs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Allen 1996</td>
<td>21/79</td>
<td>9/70</td>
<td></td>
<td>41.9 %</td>
<td>2.33 [ 1.05, 5.19 ]</td>
</tr>
<tr>
<td>Russell 1994</td>
<td>29/38</td>
<td>13/42</td>
<td></td>
<td>35.2 %</td>
<td>6.03 [ 252, 1443 ]</td>
</tr>
<tr>
<td><strong>Subtotal (95% CI)</strong></td>
<td>117</td>
<td>112</td>
<td></td>
<td>77.1 %</td>
<td>3.60 [ 2.00, 6.49 ]</td>
</tr>
<tr>
<td>Total events: 50 (Multifocal), 22 (Monofocal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity: Chi² = 7.47, df = 1 (P = 0.11); I² =59%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test for overall effect: Z = 4.26 (P = 0.000021)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total (95% CI)</strong></td>
<td>162</td>
<td>157</td>
<td></td>
<td>100.0 %</td>
<td>3.55 [ 2.11, 5.96 ]</td>
</tr>
<tr>
<td>Total events: 65 (Multifocal), 29 (Monofocal)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heterogeneity: Chi² = 3.16, df = 3 (P = 0.37); I² =5%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test for overall effect: Z = 4.79 (P &lt; 0.00001)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test for subgroup differences: Chi² = 0.01, df = 1 (P = 0.92), I² =0.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

40% multi 0.2 0.5 1 2 5 monono 18%
Evidence multifocal IOLs

Cochrane review (Leyland M, 2006):

✓ No adverse effects on distance acuity (high contrast)
✓ Improvement in near vision
✓ Less spectacle dependence

○ Trend for slightly lower contrast vision
○ More dysphotopsias (halos)
Safety
## IOL Explantation

- ESCRS / ASCRS survey
- 10 year trend: increasing number of explanted mIOL

<table>
<thead>
<tr>
<th></th>
<th>multi</th>
<th>mono</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explantation 2007</td>
<td>24%</td>
<td>76%</td>
</tr>
<tr>
<td>Approx. marketshare</td>
<td>&lt; 10%</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>Main reasons</td>
<td>Glare / Halo (70%)</td>
<td>Dislocation / Decentration</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Incorrect power</td>
</tr>
</tbody>
</table>

N. Mamalis, ESCRS 2008 Berlin
Patient selection is key!

Include:
- Wish to be spectacle independent (most of the time)
- Binocular implantation

Avoid:
- Night time drivers (truck driver, taxi driver)
- Overcritical patients
Monovision - concept

- One eye for distance, one eye for near
- Brain selects image
  - Suppresses one eye in case of conflicting images – **binocular rivalry**
  - Integrates common features – **binocular fusion**
- Long track record with
  - contact lens wearers
  - cataract surgery
Monovision - concept

Use of monofocal IOLs

- Preserve **full contrast** (100% light)
  - Safe in cases of subsequent AMD
- No (less) halos, less glare
- Easily accessible – IOLs available
- Less dependent on centration / tilt
<table>
<thead>
<tr>
<th></th>
<th>Multifocal</th>
<th>Monovision</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vision</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>+ (+)</td>
<td>++</td>
</tr>
<tr>
<td>Intermediate</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td>Near (30cm)</td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td><strong>Contrast vision</strong></td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><strong>Binocular function</strong></td>
<td>++</td>
<td>+</td>
</tr>
<tr>
<td><strong>Halos</strong></td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><strong>Glare</strong></td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td><strong>Price</strong></td>
<td>$$$</td>
<td>$</td>
</tr>
</tbody>
</table>
Accommodating IOLs: Do they work?
Accommodating IOLs

No financial interest!
Focus-Shift Principle

Far

Near

3 D

Forward shift of apex

Radial compression

Vitreous pressure ??

2.2 mm

4.0 mm

730 µm ~ 1 D
Focus-Shift Principle

Using 3D-UBM Data of presbyopic phakic subjects from:
O. Stachs et al. Graefe’s Arch Clin Exp Ophthalmol
Partial Coherence Interferometry

- measured eye fixates the laser beam
- parallel to the optical axis
- high precision: 3 µm
- AC-Master (Zeiss)
Acco-IOLs: pilocarpine movement

1 CU
n=30

Crystalens
n=30

forward

backward

JCRS 2005: 1290-7
1CU – haptic infolding 1

1d

1w

4w

6w
1CU – haptic infolding 2
Crystalens - tilt

Cazal et al., ESCRS 2004, Poster

Pronounced IOL tilt – Z-phenomenon
Crystalens - PCO

YAG-rate at 2 years: 35%
Crystalens

Transition

AT-45

5-0

HD Multifocal IOL
Future concepts - Dual optic

Synchrony, Visiogen

Graefes 2007:473-89
Summary

- Toric IOL – effective
- Aspheric IOL – mesopic contrast better
- Presbyopia correcting IOL
  - Multifocal IOL
    - Effective
    - Side effects
  - Monovision
    - appears less appealing to most patients
  - Accommodating IOLs
    - No evidence that current designs work