Gas Permeable Lenses

Principles of Fitting and Evaluating

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Patient Selection

- high motivation
- moderate to high Rx
- corneal toricity = spectacle toricity within +/-0.50D and within 15 degrees
- greater than 1.00D
- any irregular corneal surface due to dystrophy or trauma
Lens Design

- Optimal design that gives optimal vision and comfort
- Optimal Material
  - high DK
  - wettable
  - resists deposits
  - stable
  - easy to manufacture
Design Choices

- spherical or aspheric
- tricurve or multiple curves
- fitting relationship
  - steeper than the cornea
  - flatter than the cornea
  - on-flat $K$ wrt cornea
  - to achieve an aligned fitting relationship
Three Fitting Relationships

On Flat K

Flatter

On Flat K

Steeper
Multicurve (Spherical) Designs

- **Tricurve**
  - 2 peripheral curves (LD = 8.8 to 9.6 mm)

- **Tetracurve**
  - 3 peripheral curves (LD = 9.7 to 10.2 mm)

- **Multicurve**
  - >4 peripheral curves (keratoconus)

LD = lens diameter
MULTICURVE DESIGNS

Spherical back surface curves

Centres of curvature on axis of symmetry

Simple Tricurve
Continuous (Non-Spherical) Designs

- single continuous curve
- approximates corneal shape
- Aspheric
- shape derived from conic sections
- more than one conic section can be combined to form a compound continuous curve
RELEVANT CONIC SECTIONS

Hyperbola $e=1.5$
Parabola $e=1$
Ellipse $e=0.5$
Circle $e=0$

$r_0 = 7.80$ mm
Gas Permeable (GP) Design

Center Thickness (CT)

Back Optic Zone Radius (BOZR)
Secondary Curve Radius (SCR)
Peripheral Curve Radius (PCR)
Overall Diameter (OAD) or Lens Diameter (LD)

Back Optic Zone Diameter (BOZD)
LD = PCW + SCW + BOZD + SCW + PCW

Front Optic Zone Diameter (FOZD)

Back Optic Zone Diameter (BOZD)

Secondary Curve Width (SCW)

Peripheral Curve Width (PCW)
Desired Fitting

- moderate edge width (0.5mm) and clearance (80 to 100µm)
- central and mid-peripheral alignment
- smooth movement (1-2mm straight ahead)
- well centred, with upper lid just over the top edge of the lens
Ideal Fluorescein Pattern
Desired Performance

- comfortable
- clear vision (little residual astigmatism)
- adequate wearing time (8 to 12hrs)
- minimum ocular response (no staining)
- normal facial appearance
Lens Fitting

- Key factors
  - patient selection
  - preliminary measurements
    - Horizontal visible iris diameter (HVID)
    - Palpebral aperture (PA)
  - trial lens design and selection
  - fitting assessment
  - lens ordering
<table>
<thead>
<tr>
<th>LENS ID</th>
<th>K</th>
<th>BOZR</th>
<th>SCR/W</th>
<th>PCR/W</th>
<th>DIA</th>
<th>OZD</th>
<th>PO</th>
<th>AEL</th>
<th>REL</th>
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<td>-5.00</td>
<td>0.128</td>
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</table>

Convert mm/D
337.5/mm or D = D or mm
Key Design Features

- back surface design
- (back optic zone radius = BOZR)
  - base curve/cornea relationship
- back optic zone diameter = BOZD
- front surface design
  - (front optic zone diameter = FOZD)
  - dependent on power
Key Design Features

- secondary and peripheral cure width (SCW, PCW)
- secondary and peripheral curve radius (SCR, PCR)
- lens thickness (CT)
  - dependent on power
- edge configuration (rounded)
- lens diameter
  - (overall diameter = OAD or lens diameter = LD)
Prediction of Lens Parameters

- Step 1: Lens Diameter
- Step 2: BOZR selection
- Step 3: BOZD, SCW and PCW
- Step 4: SCR and PCR
- Step 5: Power determination/CT
- Step 6: Lens material selection
- Step 7: Trial lens selection
### Step 1: LD or OAD

<table>
<thead>
<tr>
<th><strong>PA measurement</strong></th>
<th><strong>Predicted Diameter</strong></th>
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<tbody>
<tr>
<td>&lt; 8 mm</td>
<td>9.0 to 9.3 mm</td>
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<tr>
<td>8-11 mm</td>
<td>9.4 to 9.6 mm</td>
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<tr>
<td>&gt; 11 mm</td>
<td>9.7 to 9.9 mm</td>
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</table>

<table>
<thead>
<tr>
<th><strong>HVID measurement</strong></th>
<th><strong>Predicted Diameter</strong></th>
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</thead>
<tbody>
<tr>
<td>10-11 mm</td>
<td>9.2 to 9.4 mm</td>
</tr>
<tr>
<td>11.5 to 12.5 mm</td>
<td>9.5 to 9.7 mm</td>
</tr>
<tr>
<td>&gt; 12.5 mm</td>
<td>9.8 to 10.0 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>PS in light</strong></th>
<th><strong>Predicted Diameter</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>BOZD = PS + 3.5-4 mm</td>
<td>BOZD + 1.2-1.4 mm</td>
</tr>
</tbody>
</table>
Lens Diameter

- Determined by:
  - average corneal diameter
  - HVID of patient
  - inter-palpebral aperture height only if smaller than 8 or larger than 11
  - lens power (+ or -)

- Affects:
  - centre of gravity
  - stability
  - option to have larger BOZD/FOZD
  - comfort
  - 3 & 9 staining
CENTRE OF GRAVITY
MINUS LENS

Small

C of G

Large

C of G
Small LD: Loose Lens
Large LD: Tight Lens
EFFECTS OF DIAMETER

\[ S_2 > S_1 > S_3 \]

- **Original Fit**:
  - \( D_1 \)
  - \( S_1 \)
  - Flatter BOZR

- **Effectively 'Steeper'**:
  - \( D_2 \)
  - \( S_2 \)

- **'Same'**:
  - \( D_4 \)
  - \( S_4 \)

\[ \frac{S_1}{D_1} \approx \frac{S_4}{D_4} \]

- **Effectively 'Flatter'**:
  - \( D_3 \)
  - \( S_3 \)

same BOZR
### Step 2: BOZR for LD = 9.2/9.4

<table>
<thead>
<tr>
<th>$\Delta K$ (Corneal Cylinder)</th>
<th>BOZR</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 to -1.00 D.</td>
<td>on flat K</td>
</tr>
<tr>
<td>-1.12 to -2.00 D.</td>
<td>$\frac{1}{4} \Delta K + \text{flat } K$</td>
</tr>
<tr>
<td>-2.12 to -2.87 D.</td>
<td>$\frac{1}{3} \Delta K + \text{flat } K$</td>
</tr>
<tr>
<td>&gt;-3.00 D.</td>
<td>back toric</td>
</tr>
</tbody>
</table>

- if LD < 9.2 mm $\rightarrow$ 0.25 D. steeper
- if LD > 9.6 mm $\rightarrow$ 0.25 D. flatter

**NOTE** $\Delta K$ is a positive value
Back Surface Design

- controls lens/cornea interaction:
  - steeper than flat K
  - flatter than flat K
  - on-flat K
  - dependent on LD and corneal cylinder amt

- affects:
  - centration
  - movement
Fluorescein Pattern: Steep
Fluorescein Pattern: Flat
Fluorescein Pattern: Aligned
Step 3: BOZD, SCW and PCW

To maintain an AEL of 0.12 mm:

- **Tricurve:**
  - SCW = 0.25 to 0.35 mm
  - PCW = 0.30 to 0.40 mm

- **Tetracurve:**
  - 1-SCW = 0.20 mm, 2-SCW = 0.30 mm
  - PCW = 0.30 mm

- **BOZD:**
  - LD - 1.1 to 1.6 mm
Small BOZD
Large BOZD
BACK SURFACE PERIPHERY
EDGE WIDTH AND TEAR RESERVOIR

WIDE edge

Excessive reservoir
loose fit

NARROW edge

Inadequate reservoir
tight fit
Step 4: Secondary curve radius (SCR) and Peripheral curve radius (PCR)

To maintain an AEL = .12 mm

<table>
<thead>
<tr>
<th>Tricurve (LD = 9.2 to 9.6 mm)</th>
<th>Tetracurve (LD = 9.7 to 10.2 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCR = BOZR + 0.8 to 1.0 mm flatter</td>
<td>1-SCR = BOZR + 0.8 to 1.0 mm flatter</td>
</tr>
<tr>
<td>PCR = BOZR + 1.5 to 2.5 mm flatter</td>
<td>2-SCR = BOZR + 1.5 to 2.5 mm flatter</td>
</tr>
<tr>
<td></td>
<td>PCR = BOZR + 2.5 to 3.5 mm flatter</td>
</tr>
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</table>
Design Choices

- **Back surface design**
  - **Axial Edge Lift (AEL)** is the sum of the sags of all the curves on back surface which represents the vertical distance from the edge of the lens to the extension of the base curve.
  - **Radial Edge Lift (REL)** is the sum of the sags of all the curves on back surface which represents the radial distance from the edge of the lens to the extension of the base curve.
  - **Tear Layer Thickness or Edge Clearance (TLT or AEC)** is the vertical distance from the edge of the lens to the cornea, can be seen with fluorescein in the eye.
Tricurve Lens Design

- AEL
- Axial Edge Lift
- TLT
- Axial Edge Clearance
- Cornea
- Lens BOZR Extended
- Radial edge clearance and Radial edge lift
Back Surface Periphery

- width of peripheral fluorescein pattern to = 0.30 to 0.50 mm
- flatter than the BOZR to have corneal clearance
- if height could be measured = 100-120 microns
High AEL/AEC
Low AEL/AEC
Mathematical Note:

- If you follow Steps 1-4 to calculate the SCR, SCW, PCR and PCW, then, depending on the BOZR of the lens a AEL = 0.12 mm may not be exactly achieved.

- Thus a computer program is used to calculate the SC and PC system to maintain that average 0.12mm.
Cont’d

- Your trial lens set is composed of lenses that have SC and PC’s that will for each BOZR have a constant $AEL = 0.12\text{mm}$

- if the cornea does not have an average shape then the AEL must be adjusted either higher or lower than 0.12 mm
### Step 5: Power determination

<table>
<thead>
<tr>
<th>Vertex Rx to ocular plane</th>
<th>Tear Layer compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>on flat K</td>
<td>➔ plano tear layer thus, <em>no change</em></td>
</tr>
<tr>
<td>steeper than flat K</td>
<td>➔ plus tear layer thus, <em>minus</em> to CL Rx</td>
</tr>
<tr>
<td>flatter than flat K</td>
<td>➔ minus tear layer thus, <em>plus</em> to CL Rx</td>
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</table>
## Step 5: CT

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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<tr>
<td>o Plano</td>
<td>➔ Approx. 0.20 mm</td>
</tr>
<tr>
<td>o Minus</td>
<td>➔ subtract 0.02 per dioptre up to a limit of CT = 0.10mm</td>
</tr>
<tr>
<td>o Plus</td>
<td>➔ add 0.02 per dioptre up to a limit of CT = 0.30 mm, then lenticulate, CT vary</td>
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</table>
Lens Thickness

- **Determined by:**
  - rigidity
  - permeability
  - Back vertex power (BVP)

- **Considerations:**
  - on-eye lens flexure
  - correction of corneal astigmatism
  - Dk/t
## Step 6a: Lens Material

- **Low Dk (20’s)** ➞ Small lenses, not used
- **Mid Dk (40’s)** ➞ low Rx, traditionally more rigid and less deposits
- **High Dk (60 and up)** ➞ high Rx, all designs, larger lenses
Step 6b: Edge Design and Front Surface Considerations

- Edge selected to optimise comfort
- Front surface is lenticulated to either thicken or thin out the lens
- Peripheral thickness
  - i.e. > -4.00D are plus lenticulated and all plus lenses are minus lenticulated
Edge Configuration (Profile)

Affects
- comfort
- durability
- tear meniscus
- lens position
EDGE CONFIGURATION

COMFORT vs APEX LOCATION

(Orsborn et al. 1988)

Posterior  Centre  Anterior

Comfort level: Centre > Posterior > Anterior
Front Surface Design

FOZD affects:
- vision
- lid interaction
  - comfort
  - movement
  - centration

Lenticulation affects:
- centre thickness
- lens mass
- $O_2$ transmission
- comfort
Lenticular Carriers

Interaction with Lid

Minus carrier

Wedge shape

(Or Plus)
Step 7: Trial Lens Selection

- go to standard, constant AEL trial lens set first
- select the diameter and BOZr as predicted
- only use -3.00 D. set for powers up to approx. -6.00 D. (use hi - set for higher)
- use plus trial set for all plus Rx, if high use aphakic set
For Example:

- HVID = 11.0 mm, PS = 4 mm, PA = 11.0 mm
- K readings = 43.00@180/44.25
- Corneal cyl = -1.25 x 180
  - (note △K = 1.25 D x 180)
- Spec. Rx = -5.00-1.50 x 180
- Ocular Rx = -4.75 -1.25 x 180 (vertexed back)
Lens Prediction

- LD = 9.4 mm
- BOZR = \( \frac{1}{4} (1.25) + 43.00 = 43.31 \) (7.79 mm)
- BOZD = 9.4 - 1.2 = 8.2 mm
- SCW = 0.25 mm
- PCW = 0.35 mm
- SCR = 7.79 + 1.0 = 8.79 mm
- PCR = 7.79 + 2.5 = 10.29 mm
- BVP = -4.75 + (-0.3125) = -5.0625 D
  \( \approx -5.12 \) D
Lens Prediction

- CT = .13 mm
- Blend = medium
- Lens Material = High Dk
- Colour = Blue
- FOZD = 8.4 mm, Lenticulate with plus carrier
- Dot OD lens
Procedures for Lens Assessment

1a,b) Assess centration/lens diameter
2a,b) Assess movement of the lens/lag
3) Assess the Fluorescein Pattern (NaFl)
4) Assess the over-refraction and lens flexure
5) Assess best sphere balanced visual acuities
6) Assess lens comfort
1a. Lens Diameter/BOZD

- Too small:
  - flare and excessive decentration
  - has the BOZR been adjusted properly so that it is not too loose?

- Too large:
  - ride over the limbus in various positions of gaze
  - has BOZR been adjusted properly so that not too steep?
1b. Lens Centration

- Factors affecting:
  - centre of gravity
  - fluid attraction
  - fluid frictional force
  - lid force
Lens Position Relative to Upper Eyelid

- Ideally centred around the pupil just under upper eyelid
- Not lid attached or high riding and definitely not low riding
Reasons for Decentration:

- Related to centre of gravity?:
  - Lens diameter
  - Power

- Related to the BOZR/cornea relationship?:
  - Too steep: low and nasal
  - Too flat: high or fall down if excessively flat
Low Riding Lenses: Centre of Gravity

- Moved anteriorly:
  - increase in plus power
  - too flat BOZR
  - thicker lenses
  - smaller diameter
  - decreased lens adherence
High Riding Lenses: Centre of Gravity

- Moved posteriorly:
  - increase in minus
  - increased diameter
  - decreased CT
  - too steep BOZR
  - increased lens adherence
2a. Movement

- Movement after blinking:
  - amount - post blink up to 3 mm, recentring after the blink 1-2 mm
  - type - smooth, not apical rotation, rocky, lid attachment, two part
  - speed - medium or fast, not slow
  - direction - vertical, not oblique
2b. Lag

- Have patient look left and right and see if:
  - No displacement/mov’t: too steep
  - Lens moves in opposite direction to eye mov’t and then catches up and centres on apex: perfect
  - Lens moves in opposite direction to eye mov’t but does not catch up and crosses the limbus: too flat
3. Fluorescein Pattern

- Static Fitting Assessment:
  - evaluate in primary position
  - centre lens on cornea
  - no lid influence
  - fluorescein and cobalt light with yellow filter
  - assess the tear layer thickness
    - Central
    - Mid-peripheral
    - Peripheral
Tight Fitting Characteristics

Static:
- excessive central clearance
- heavy mid-peripheral contact zone
- narrow edge width
- reduced edge clearance

Dynamic
- centred, stable, fast vertical movement
- <1 mm
Loose Fitting Characteristics

Static
- excessive central zone touch
- flat mid-peripheral zone
- excessive edge clearance
- excessive edge width

Dynamic
- decentred, high, low nasal or temporal
- unstable, apical rotation
- > 2 mm
4. Over-K and Over-Refraction

- Keratometry over the lenses to assess lens flexure
- Sphero-cylindrical over refraction
- Should have only small amount of residual astigmatism
- If significant amount of cyl
  - Check lens flexure
  - Check K’s and refraction for error
5. Best Balanced Sphere/Visual Acuities

- Check with sphero-cyl over-refraction
- Then proceed to best sphere over-refraction and acuities
  - Remove cylinder
  - Adjust the sphere (equivalent)
  - Balance with a plus to blur prism subjective
  - Ensure acuities are equal
  - If unequal acuities use red/green balance
6. Assess comfort

- Adjust lens fit if needed:
  - If lens is decentred
  - If fluorescein pattern is not aligned
- Then:
  - Adjust any of lens parameters to improve the fit
  - Re-insert new lens
  - Or calculate new lens parameters and order a trial lens