Gas Permeable Back and Bitoric Lens Fitting

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Indications

- correction of high astigmatism
- high astigmatism could be corneal or residual (lenticular)
- flexing spherical lens on toric eye
- uncomfortable spherical lens on toric eye
- variable acuity with spherical lens on a toric eye
High Astigmatic Correction

- Spherical GP (keratoconic)
- Hydrogel Toric (low oxygen alternative)
- Front Surface GP Toric
- Back Surface GP Toric
- Bitoric GP
Gas Permeable Toric Lenses

- Correct both corneal and lenticular astigmatism
- Spec Cyl = Lenticular + Corneal
- Residual Cyl could be:
  - physiological
  - contact lens-induced
Residual Cylinder

- Physiological:
  - lenticular

- CL-induced
  - spherical lens
  - flexure/warpage
  - back toric induces cylinder by making the front surface of tear layer toric
Physiological Residual Cylinder

- posterior corneal/aqueous interface
- varying indices of eye
- tilting of crystalline lens
- oblique incidence of light
GP Induced Residual Astigmatism

- part of corneal cyl not negated by tears
- lens warpage (high Dk, thin lens)
- lens flexure (high tority, thin lens)
- lens tilt (decentred GP)
- toric lens surfaces (back surface)
Correcting Residual Astigmatism

- spherical GP + specs (physiological)
- non-rotating Front Toric GP (physiological)
- thick spherical GP (flexure) (induced)
- bitoric GP (induced)
Correcting Residual Astigmatism - Physiological

- spherical gas permeable lens corrects low to moderate corneal cyl (< 2.50 to 2.87 DC)
- specs correct the residual astigmatism
Correcting Residual Astigmatism - Physiological

- Gas permeable front torics
- ... to be discussed later
Correcting Residual Astigmatism -
CL Induced

**Flexure** Caused by:

- material Dk (rigidity of lens)
- centre thickness (rigidity of lens)
- amount of corneal cylinder (surface tension)
- BOZR/cornea relationship (surface tension)
- force exerted by upper eyelid
Flexure

- Rigidity of lens material:
  - elasticity of polymer
  - Dk (high)
  - CT (thinner)

- Surface tension: tear fluid (steeper), cyl amount (greater) and type....

  WTR....wtr flexure

  ATR.....atr flexure

- Upper Eyelid: exerts ATR flexure
Correcting Residual Astigmatism - CL Induced

Back Surface Toric:

- the back surface toric design is chosen to optimize the lens-to-cornea bearing relationship that would be unsatisfactory with a spherical lens
Back Surface Toric

Fitting Requirements

- corneal cyl of 2.00D or greater
- physical compatibility with the cornea
- stable meridional orientation
- must have physiological cyl to neutralise the CL-induced cyl
Back Surface Toric

Lens Design

- back surface is toric
- front surface is spherical i.e. physiological cyl neutralises CL-induced cyl
- optimal design for each principal meridian
Bitoric GP lens

- A **bitoric lens** is required when a back surface toric/spherical front surface lens results in an unacceptable amount of residual astigmatism.
  - i.e. the physiological cyl does not neutralise the CL-induced cyl
- The residual astigmatism is then corrected by the front toric surface.
Bitoric GP lens

Lens Design
- toric back surface for physical fit
- toric front surface for astigmatism correction
- rotational stability
Toric GP Lenses Indications for Use

- To Improve:
  - Vision
  - Physical fitting
  - Physiological status
Spherical Lenses on Toric Corneas

Some possible problems:

- Poor vision due to flexure
- Poor centration: if WRT, sits high or low, if ATR, sits nasal or temporal
- Lens rocking on flat meridian with the blink
- Unstable fitting
- Lens flexure causing intermittent blur
Spherical Lenses on Toric Corneas

Some possible problems:

- Harsh bearing areas
- Corneal distortion
- Spectacle blur (sphericalising the cornea)
- Discomfort
- Poor blinking
- Epithelial damage
- 3 and 9 o’clock staining due to unequal edge clearance
Limbus-to-Limbus Astigmatism

Spherical Lens on Toric Cornea
SUMMARY: Toric GP Lenses

- FRONT TORIC:
  - Front surface toric, spherical back
- BACK TORIC:
  - Back surface toric, spherical front
- BITORIC:
  - both front and back surfaces toric
- PERIPHERAL TORIC:
  - spherical back and front, toric back periphery
Toric GP Lenses: Advantages

- Stabilized fitting
- Improved lens to cornea fitting relationship
- Cylindrical correction maybe less than with soft toric lenses
- Better corneal physiology than soft toric lenses (low Dk)
Toric GP Lenses: Disadvantages

- Relatively thick lenses
- Less control over the edge profile
- Possible misalignment of the corneal and spectacle Rx cylinder axes
Back Surface Torics

- In many cases a corneal cylinder of 2.50 D or less can be fitted with a spherical GP lens with appropriate parameters.
- When a spherical lens is unable to provide a satisfactory physical and/or physiological fitting then a lens with a toric back surface is required.
Optics of Toric Lenses

- If a 2.00 D toric cornea is fitted with a 2.00 D toric back surface lens with a spherical front then the corneal cylinder will be over-corrected.

- A residual cylinder is INDUCED by the shape of the back surface of the lens.
  
i.e. $\Delta K(CL) = -2.00 \, \text{D}$

Conversion Factor: for index of PMMA n=1.49 and keratometer, (see chart next page, Conversion Factor of PMMA=1.452*)

$\text{CL power in air} = \Delta K(CL) \times \text{Conversion Factor}$

$= -2.00 \times 1.452 = -2.90 \text{D}$

* See chart next page
The following table lists several RGP materials, their index of refraction, precise *conversion factors* that can be used.

<table>
<thead>
<tr>
<th>Material</th>
<th>Index of Refraction</th>
<th>Precise Conversion Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1.428</td>
<td>1.268</td>
</tr>
<tr>
<td>EO</td>
<td>1.429</td>
<td>1.271</td>
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<tr>
<td>RXD</td>
<td>1.435</td>
<td>1.289</td>
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<tr>
<td>ES</td>
<td>1.443</td>
<td>1.313</td>
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<tr>
<td>xo</td>
<td>1.429</td>
<td>1.271</td>
</tr>
<tr>
<td>Fluorex 700</td>
<td>1.457</td>
<td>1.354</td>
</tr>
<tr>
<td>IV</td>
<td>1.469</td>
<td>1.390</td>
</tr>
<tr>
<td>II</td>
<td>1.471</td>
<td>1.396</td>
</tr>
<tr>
<td>Fluoroperm 92</td>
<td>1.471</td>
<td>1.396</td>
</tr>
<tr>
<td>Fluoroperm 60</td>
<td>1.473</td>
<td>1.401</td>
</tr>
<tr>
<td>Fluoroperm 30</td>
<td>1.475</td>
<td>1.407</td>
</tr>
<tr>
<td>Polycon II</td>
<td>1.48</td>
<td>1.422</td>
</tr>
<tr>
<td>PMMA</td>
<td>1.49</td>
<td>1.452*</td>
</tr>
</tbody>
</table>
Optics of Toric Lenses

- An astigmatic effect is created in the contact lens/tear fluid system by the *toroidal back optic zone* bounding two surfaces of different refractive index.

- The amount of the induced cylinder is dictated by the refractive index of the lens plastic and the pre-corneal fluid, and the amount of cylinder on the lens back surface.
Calculating Induced Cylinder Power In Situ

- **Method #1:**
  - Induced Cylinder Power Using the Lensometer Cyl

- **Method #2:**
  - Induced Cylinder Power Using the $\Delta K(\text{CL})$
Formulas

\[ \text{CL power in air} = \Delta K(\text{CL}) \times \text{Conversion Factor}^* \]

*Conversion factor from chart

**Method #1:** Induced Cylinder Power Using the Lensometer Cyl

\[ \text{Induced cyl power in situ} = \text{CL power in air} \times \text{Calculated Factor} \]

**Method #2:** Induced Cylinder Power Using the \( \Delta K \) (CL)

\[ \text{Induced cyl power in situ} = \Delta K \text{ (CL)} \times \text{Calculated Factor} \]

Note: the Calculated Factor in #1 and #2 are **NOT** the same value
Method #1: Induced Cylinder Power Using the Lensometer Cyl

Calculated Factor = \( \frac{n_{(\text{tears})} - n_{(\text{lens})}}{n_{(\text{air})} - n_{(\text{lens})}} \)

\[
\frac{1.336 - 1.49}{1.0 - 1.49} = 0.314
\]

Indexed Factor:
Index of tears and plastic (CL of PMMA \( n = 1.49 \)) is 0.314

Induced cyl power in situ = CL power in air x Calculated Factor

Induced cyl = \(-2.90 \text{ DC} \times 0.314 = -0.91 \text{ D of induced cyl}\)
Induced Cylinder Power

- Refractive index (n):
  - Lens Material = 1.49 (PMMA)
  - Lens Material = 1.446 (Boston EO)
  - Lens Material = 1.457 (Boston XO)
  - Air = 1.0
  - Tears (Fluid) = 1.336
  - Keratometer (B&L) = 1.3375
Optics of Toric Lenses

- Recall:
  - CL power in air (lensometer cyl) converts to CL power in situ (on eye)

\[
\text{Induced cyl power in situ} = \text{CL power in air} \times \text{Calculated Factor}
\]

\[
\text{Induced cyl} = -2.90 \text{ DC} \times 0.314 \\
= -0.91 \text{ D of induced cyl}
\]

- The actual cylinder (not correcting cyl) induced by any back surface toricity is always a minus cylinder of the same axis as the flatter principal meridian.
Method #2
Induced Cylinder Power Using the $\Delta K$ (CL)

Calculated Factor = $n$ (tears) - $n$ (lens)
                  $n$ (air) - $n$ (keratometer)

\[
\frac{1.336 - 1.49}{1.00 - 1.3375} = 0.456
\]

- $n$ of keratometer = 1.3375
- Material of lens is PMMA, $n$=1.49

\[\text{Induced cyl} = \Delta K \ (CL) \times \text{Calculated Factor}\]
\[= (-2.00) \times 0.456\]
\[= -0.91 \text{ D of induced cyl}\]
Induced Cylinder Power: Example

- Keratometry: 45.00 @ 180 \( \Delta K = 4.00 \times 180 \)  49.00D @ 090

- Select Lens BOZR from chart based on \( \Delta K \) 7.54/7.03 mm (44.75/48.00), spherical front surface

- \( \Delta K \) (CL) = -3.25D

- Material PMMA, \( n = 1.49 \), Calculated Factor = 0.456

**Induced cyl power** = \( \Delta K \) (CL) \( \times \) Calculated Factor

\[
= (-3.25 \text{ D}) \times 0.456 \\
= -1.50 \text{D} \times 180
\]

(the actual cylinder induced is always a minus cylinder the same axis as the flatter meridian)

- **Correction** for induced = +1.50D x 180
Trial Fitting with Back Toric Lens
Fitting Set: Determining BOZR’s

<table>
<thead>
<tr>
<th>If $\Delta K$(cornea)</th>
<th>then Flat $K$...</th>
<th>then Steep $K$...</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.00D</td>
<td>on $K$</td>
<td>0.50D flat</td>
</tr>
<tr>
<td>2.50D</td>
<td>0.25D flat</td>
<td>0.50D flat</td>
</tr>
<tr>
<td>3.00D</td>
<td>0.25D flat</td>
<td>0.75D flat</td>
</tr>
<tr>
<td>3.50D</td>
<td>0.25D flat</td>
<td>0.75D flat</td>
</tr>
<tr>
<td>4.00D</td>
<td>0.25D flat</td>
<td>1.00D flat</td>
</tr>
<tr>
<td>4.50D</td>
<td>0.25D flat</td>
<td>1.25D flat</td>
</tr>
</tbody>
</table>
Material Selection

- Need to Consider
  - Dimensional stability
  - Oxygen transmissibility
  - Optical stability
  - Manufacturing problems
Lens Design Philosophies

- Empirical ordering
- Trial fitting
Empirical Ordering

- Need to supply:
  - Refraction details
  - Keratometry
  - HVID
  - Palpebral aperture
Empirical Ordering

- Problems with:
  - Inaccurate keratometry
  - Limited value of keratometry data
  - No knowledge of peripheral corneal shape
  - Time delay for the patient
**Trial Fitting with Back Toric Lens**

**Fitting Set: Determining BOZR’s**

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</tr>
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<td>2.50D</td>
<td>0.25D flat</td>
<td>0.50D flat</td>
</tr>
<tr>
<td>3.00D</td>
<td>0.25D flat</td>
<td>0.75D flat</td>
</tr>
<tr>
<td>3.50D</td>
<td>0.25D flat</td>
<td>0.75D flat</td>
</tr>
<tr>
<td>4.00D</td>
<td>0.25D flat</td>
<td>1.00D flat</td>
</tr>
<tr>
<td>4.50D</td>
<td>0.25D flat</td>
<td>1.25D flat</td>
</tr>
</tbody>
</table>
Back Surface Toric With a Spherical Front

- Limited application
- Induced cylinder corrects the lenticular astigmatism (cancel each other out)
- May be useful in cases of ATR corneal astigmatism
Back Surface Toric With a Spherical Front: Example

- Spec Rx: -1.00 -3.00 x 090  Spec cyl = -3.00D x 090
- Corneal K’s: 44.00 @ 180 and 42.00 @ 090
- ΔK(cornea) is - 2.00 D x 090
  - From chart: fit Flat K → “on K” and Steep K → “0.50 D flat”
  - Flat K = 42.00
  - Steep K = 44.00 - 0.50 = 43.50 D
  - ΔK(CL) = 42.00 - 43.50 = -1.50 D
- Calculated Residual Cyl = -1.00 x 090
- Material calculated factor = 0.456 for PMMA
- Induced cyl power = ΔK (CL) x Calculated Factor
  Induced cyl power = (-1.50 D x 090) x 0.456
  = -0.684 x 090 ≈ -0.75 D x 090
- Therefore correction for induced cyl is +0.75 x 090
- Net front surface is virtually spherical
Bitoric Lenses

- When residual astigmatism is induced where the lens back surface is toric and is not cancelled by the lenticular astigmatism, the correcting cylinder can be cut on the lens front surface (>0.75D)

- This results in toric back and front surfaces or a *bitoric* lens design
Bitoric Lenses: Fitting

- Bitoric lenses are essentially two spherical lenses of different design and power:
  - one for the flatter meridian of the cornea
  - the other for the steeper meridian
Bitoric Lenses: Fitting

- empirical calculation based on:
  - accurate K readings
  - accurate refraction
- spherical lenses with over-refraction
- back surface toric trial lenses
Types of Bitoric Lenses

- **Spherical Power Effect (SPE)**
- **Cylindrical Power Effect (CPE)**
Spherical Power Effect

- where $\Delta K$ of cornea = Spec (Ocular) $K$
  - that is, Lenticular (physio) cyl = 0.00
- thus, residual cyl = CL induced cyl
- correction for induced on the front surface
Spherical Power Effect

- an equal **plus** cyl, whose axis is the same as the induced cyl, applied to the front surface of the lens will correct the residual (in this case induced cyl) cylinder power

- such a lens has a *spherical power effect* on the eye
Spherical Power Effect

- as the back surface toricity is known, the magnitude of the induced cyl can be calculated
  - (eg. $\Delta K \text{ (CL)} \times 0.275$ for Boston 7 lenses)
    - Induced cylinder = $\Delta K \text{ (CL)} \times$ Calculated Factor
    - Calculated Factor for Boston 7 lenses is 0.275

- the manufacturer can then cut a front surface cyl to negate the induced cyl power
Spherical Power Effect: Advantages

- can rotate on the cornea without compromising the vision
- air cylinder power is 1X the back surface toricity (radiuscope)
- Lensometer cyl = ΔK (CL) when you verify the lens
- can use trial lenses
- can assess residual astigmatism
Cylindrical Power Effect

- where $\Delta K$ (cornea) > Spec (Ocular) $K$
- now residual astigmatism is composed of both the induced and lenticular clys
- the front surface cyl is either > or < the induced amount
  - thus, lens cannot rotate on the cornea without compromising the vision
- may need to stabilise the lens
Front Toric GP Contact Lenses

created by: L Sorbara, OD, MSc, FAAO, Dipl C&CL
presented by: M. Steenbakkers, OD, FAAO
Uses of Front Toric GP

- to correct residual astigmatism
- residual astigmatism that is physiological
- when corneal astigmatism is also present but is less than 2.00D!
- when soft torics don’t work
- when cornea is compromised
Front Surface Toric

- Spherical back surface
- Cylindrical front surface
- Base Down prism
- Truncated design
Methods of Stabilization

- Prism ballast
- Prism ballast + truncation
- others:
  - peri-ballast
  - double truncation
  - single truncation
Fitting Front Surface Toric

- Computation
- Diagnostic Fitting Set
  - spherical
  - sphere + prism (base dotted)
Fitting Front Surface Toric

- Record K’s with axis
- Vertex spec Rx to ocular Rx
- Calculate CRA = Ocu. Cyl - \( \Delta K \)
- Select diagnostic lens
- Evaluate lens performance
- Over-refract sphero-cyl with axis
- Adjust cyl axis or prism axis
Prism Ballast FT GP

- prism stabilises lens (to return to same rotated position) from rotation induced by the action of the lids
- residual cyl must be kept on axis
- used when:
  - lower lid at or below the lower limbus
  - large palpebral apertures
  - loose lids
  - if unsuccessful with truncated lens
Prism Ballast FT GP

- Amount of prism:
  - least amount that stabilises lens
  - dependent on lens power
- Mod. to high minus: 0.75 to 1Δ
- Low minus to plus: 1.25 to 1.5Δ
- Centre thickness:
  - \[ CT = \frac{\text{Prism} \times \text{OAD}}{100} \]
  - Add to normal thickness in most + meridian
Prism Ballast FT GP

- Evaluate lens rotation due to:
  - lid configuration, location, tightness
  - forcefulness of blink
  - natural alignment or symmetry of upper-lid

- Methods:
  - slit lamp reticule eyepiece
  - trial frame
  - guess-timate
Prism Ballast FT GP

- On average prism lenses rotate 10 to 15 degrees nasally OU
- Lens will sit on eye in rotated position
- Adjust CL cyl axis accordingly:
  - clockwise rotation add amount to cyl axis
  - counterclockwise rotation subtract amount from cyl axis
Prism Ballast FT GP

Example (OD):

- Subjective: -1.50/-1.50 x 180
- Base-Apex Rotation/lens rotation: 10° CCW
Prism rotation (OD)

Compensate for lens cylinder axis by 10 degrees

10 degrees CCW

Final axis

10 degrees CCW
Prism Ballast FT GP

- Lens Order:
  - BOZR = 7.76mm
  - Power = -3.00/+1.50 X 080 (plus cyl form)
  - OAD = 9.0mm
  - SCR/W = 8.8/.3
  - PCR/W = 10.8/.3
  - CT = 0.26mm (0.09 + 0.16)
  - Prism = 1Δ BD, double dot base (RE)
  - Minus Carrier, FOZD = 7.6mm
Prism Ballast with Truncation FT GP

- To aid in rotational stability
- Where lower lid superimposes on inferior cornea
- Includes prism ballasting to counter lens rotation
- Truncation sits on the lower aspect of the lid (may sit slightly nasally)
- Cyl axis is thus with respect to lower truncation
Prism Ballast with Truncation FT GP

Features:
- truncation is 0.4 to 0.5mm
- optic zone is decentred up by same amount
- Prismatic effect is reduced for a minus lens
- Prismatic effect is increased for a plus lens
- minus lenses: 1.25 to 1.50Δ
- plus lenses and low minus: 0.75 to 1.00Δ
- measure lens rotation (usually nasal ≈ 15°)
- truncation ordered 15° temp. to base-apex line
- adjust cyl axis according to truncation/lid angle only
Example 1 (OD):

- Subjective: -1.50/-1.50 x 090
- Lid Angle: Zero i.e. truncation sits on lower lid without rotation
- Base-Apex Rotation/lens rotation: 15º CCW
Prism Ballast with Truncation FT RGP

- **Lens Order:**
  - BOZR = 7.76mm
  - Power = -3.00/+1.50 $\times$ 180 (plus cyl form)
  - OAD = 9.4mm/8.9mm
  - BOZD = 7.8mm decentred 0.5mm up
  - SCR/W = 8.8/.3
  - PCR/W = 10.8/.3
  - CT = 0.27mm (0.11 + 0.16)
  - Prism = 1.25$\Delta$ BD, double dot base (RE)
  - Truncation = 15º temporal wrt prism
Truncation wrt Base-Apex Line

15 degrees

Order truncation 15 degrees from the vertical base apex line
Example 2 (OD):

- Subjective: -1.50/-1.50 x 090
- Lid Angle: 15deg CCW
- Base-Apex Rotation/lens rotation: 8º CCW
Prism Ballast with Truncation FT RGP

- **Lens Order:**
  - BOZR = 7.76mm
  - Power = -3.00/+1.50 X 165 (plus cyl form)
  - OAD = 9.4mm/8.9mm
  - BOZD = 7.8mm decentred 0.5mm up
  - SCR/W = 8.8/.3
  - PCR/W = 10.8/.3
  - CT = 0.27mm (0.11 + 0.16)
  - Prism = 1.25Δ BD, double dot base (RE)
  - Truncation = 8° temporal wrt prism
Truncation wrt Base-Apex Line

8 degrees

Order truncation 8 degrees from the vertical base apex line
Limitations of Prism Ballast and Truncated Lenses

- blurred vision from rotation (intermittent)
- constant blur if incorrect axis
- discomfort from Δ and/or truncation (thicker)
- inferior decentration causing flare and corneal desiccation
- inability to modify front surface
- if unilateral, asthenopia from vertical imbalance
- oedema if low Dk