Cornea and Contact Lenses: An Overview

Tim Edrington, OD, MS
tedrington@scce.edu
714.449.7422

Corneal Topography
- Projects rings or grid pattern
- Uses edge detection or image separation
- Computer enhances
- Topographic contour map produced
  - Rings closer together = steeper
- Qualitative and quantitative data

How to Interpret
- Color maps
  - Cool colors (blue) = flatter areas
  - Hot colors (red, orange) = steeper areas

Data Analysis
- Axial = Sagittal
  - Values relative to visual axis
  - Extreme values averaged; less noise, but less detail
- Tangential = Instantaneous Rate of Curvature
  - Value obtained at foci
  - More accurate for distorted corneas and in periphery; more local detail

How to Interpret
- Color scales
  - Absolute - fixed scale, can compare universally
    - 35 to 52 D range; same curvature always same color
    - Usually lower resolution due to larger increments
  - Normalized - individual scale, specific to patient visit
More Data Analysis

- Elevation = Height data relative to computer generated best fit reference sphere
- Red = higher elevation
- Blue = lower elevation

Indices

- Simulated keratometry value (Sim K)
- Surface asymmetry index (SAI)
- Surface regularity index (SRI)
- Potential visual acuity (PVA)
- Corneal eccentricity index (CEI)
  - + value = prolate
  - 0 = sphere
  - - value = oblate

Prolate versus Oblate

- Normal corneas are prolate
- Post-RK, post-OK, post-LASIK, and a significant percentage of post-PK corneas are oblate

Indications

- All patients?
- All contact lens patients?
- All rigid contact lens patients?
- Orthokeratology (CRT) patients?
- Retractive surgery patients?
- Diseased corneas?
- Irregular or distorted corneas?

Optics Treat # 1

- Vertexing from the spectacle to the cornea plane
  - Formula: \( F_c = \frac{F_s}{1 + dF_s} \)
  - Where: \( F_c \) = power at corneal plane in D
  - \( F_s \) = power at the spectacle plane in D
  - \( d \) = vertex distance
- Example: Spectacle Rx = -5.00 D and vertex is 12mm
  - \( F_c = \frac{-5.00}{1 - (0.12/15.00)} = \frac{-5.00}{1 - 0.008} = -5.00 \) D

Optics Treat # 2

When vertexing from spectacle plane to corneal plane, always more plus

<table>
<thead>
<tr>
<th>Manifest Refraction</th>
<th>Power at Cornea</th>
</tr>
</thead>
<tbody>
<tr>
<td>-1.00 D +3.00 D</td>
<td>-1.00 D</td>
</tr>
<tr>
<td>+0.00 D +4.00 D</td>
<td>+4.00 D</td>
</tr>
<tr>
<td>+1.00 D +5.00 D</td>
<td>+5.50 D</td>
</tr>
<tr>
<td>+2.00 D +6.00 D</td>
<td>+6.50 D</td>
</tr>
<tr>
<td>+3.00 D +7.00 D</td>
<td>+7.25 D</td>
</tr>
<tr>
<td>+4.00 D +8.00 D</td>
<td>+8.87 D</td>
</tr>
<tr>
<td>+5.00 D +10.00 D</td>
<td>+10.00 D</td>
</tr>
<tr>
<td>+6.00 D +11.50 D</td>
<td>+11.50 D</td>
</tr>
</tbody>
</table>
### GP Terminology
- **Permeability (Dk)**
  - D = diffusion of material
  - K = solubility
  - Material's ability to be permeable to O2
- **Transmissibility (Dk/L or Dk/t)**
  - Material's ability at a given thickness to transmit O2
- **EOP (Equivalent Oxygen %)**
  - O2 thirst

### So, What's the Purpose?
- **Comparison shopping**
  - Predicting lens performance
  - Predicting corneal physiology
  - DW vs EW
  - Compromised cornea
- **Product development**

### Wettability
- The ability of a hydrophobic piece of plastic to be hydrophilic
- Why important?
  - Increases comfort
  - Provides better optics
- How measured?
  - Sessile drop
  - Captive bubble
  - Wilhelmy plate (advancing or receding)

### Increase in Dk - What Happens?
- **O2?** Duh!
- **K physiology?** Not 1:1
- **Wettability?** No, but fluorine helps
- ** Deposits?** Yes, but surface only.
- ** Flexure / warp?**
- ** Machinability / Modifiability?**
- ** Durability?**
- ** Scratchability?**

### Silicone
- **Mechanical / Optical Stability**
  - Fair
- **Wettability**
  - Poor
- **O2 Permeability**
  - Excellent!
- **Deposit Resistance**
  - Poor

### Methacrylic Acid (HEMA)
- **Mechanical / Optical Stability**
  - Poor
- **Wettability**
  - Excellent!
- **O2 Permeability**
  - Fair
- **Deposit Resistance**
  - Fair

### Methylmethacrylate (PMMA)
- **Mechanical / Optical Stability**
  - Excellent!
- **Wettability**
  - Fair
- **O2 Permeability**
  - Poor
- **Deposit Resistance**
  - Good – Excellent

### Fluorine
- **Mechanical / Optical Stability**
  - Fair
- **Wettability**
  - Good
- **O2 Permeability**
  - Good
- **Deposit Resistance**
  - Excellent!
GP Dk -
What Lurks Out There?
- PMMA (polymethylmethacrylate)
- CAB (Cellulose Acetate Butyrate)
- SA (Silicon Acrylate)
- Polycon II, Paraperm O2, Boston II
- FSA (Fluorinated Silicone Acrylate)
- FluoroPerm 60, Boston XO

GP Contact Lens Prescribing Philosophies
...as many as there are contact lens experts

Most Prevalent for BC
- On K = base curve equal to flat Km
- Nomogram systems - use table
- Lid-attachment
- Topography based - sim K

On K (BC is Flat K Value)
Examples
K = 42.00 DS
BC = 42.00
K = 42.00 / 42.50 @ 90
BC = 42.00
K = 42.00 / 43.00 @ 180
BC = 42.00
K = 42.00 / 44.00 @ 90
BC = 42.00
K = 42.00 / 45.00 @ 180
BC = 42.00

Optics Treat # 3
SAM - FAP
- Steep add minus (SAM)
- Flat add plus (FAP)
Example
42.00 BC / -3.50 Power
OR = plano DS
FP = Apical touch by 0.25 D
Rx = 42.25 BC / -3.75 Power

Lid Attachment
- Lens Position
  - High-rider
  - Mimics upper eyelid
  - Verti pupil is covered by OZ
- Helps if (good candidates)
  - with-the-rule cornea
  - tight eyelids covering superior limbus
  - good blinker

BC Selection as a Function of Lens Diameter and K Cylinder

<table>
<thead>
<tr>
<th>Lens Diameter</th>
<th>K Cyl (D)</th>
<th>9.7 mm</th>
<th>9.3 mm</th>
<th>9.9 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00 to 0.50</td>
<td>0.00 to 0.50</td>
<td>0.25 flat on K</td>
<td>0.25 st</td>
<td></td>
</tr>
<tr>
<td>0.62 to 1.25</td>
<td>0.62 to 1.25</td>
<td>on K</td>
<td>0.25 st</td>
<td>0.50 st</td>
</tr>
<tr>
<td>1.37 to 2.00</td>
<td>1.37 to 2.00</td>
<td>0.25 st</td>
<td>0.50 st</td>
<td>0.75 st</td>
</tr>
<tr>
<td>2.12 to 2.75</td>
<td>2.12 to 2.75</td>
<td>0.50 st</td>
<td>0.75 st</td>
<td>1.00 st</td>
</tr>
<tr>
<td>2.87 to 3.50</td>
<td>2.87 to 3.50</td>
<td>0.75 st</td>
<td>1.00 st</td>
<td>1.25 st</td>
</tr>
</tbody>
</table>

Nomogram Prescribing
If fitting BC on previous nomogram (9.3mm OAD)
Example
K = 42.00 / 43.00 @ 90
MR = -2.75 -0.75 X 180
BC = 42.25 D
CLP = -3.00 D
OAD Nomograms

<table>
<thead>
<tr>
<th>Pupil Diameter (mm)</th>
<th>OAD (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 6 mm</td>
<td>7.0 mm</td>
</tr>
<tr>
<td>6 to 7 mm</td>
<td>7.4 mm</td>
</tr>
<tr>
<td>&gt; 7 mm</td>
<td>7.8 mm</td>
</tr>
</tbody>
</table>

Optic Zone Diameter (OZD)

<table>
<thead>
<tr>
<th>OZD = BC radius in mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 6 mm</td>
</tr>
<tr>
<td>6 to 7 mm</td>
</tr>
<tr>
<td>&gt; 7 mm</td>
</tr>
</tbody>
</table>

Optics Treat # 4

Sagittal height issue
A change in diameter by 0.5mm affects fitting relationship by 0.25 D
- Increasing diameter by 0.5mm steepens fit by 0.25D
- Decreasing diameter by 0.5mm flattens fit by 0.25D

Peripheral Curves

- Blended
- Light = 0.1mm width
- Medium = 0.2mm width
- Heavy = 0.3 mm width
- Tetra-curve
- Hint: tetra means 4
- Aspheric
- Up to lab:
  - Generally, 1 to 1.5mm flatter than BCr

Center Thickness

- ATAP - As Thin As Possible
- plano = 0.19 mm
  - subtract 0.01 mm for every 1D of minus
  - add 0.02 mm for every 1D of plus
- Add 0.02 mm for every 1D of K toricity

Aspherics?

Concept sounds great!
- Minimizes spherical aberration
- "Masks" astigmatism
- More beneficial for higher Rx
- Better in low light situations
- What does it mean?
  - F1 or F2
  - Base curve
  - Generally ellipse
  - Peripheral curve system
  - Generally hyperbola

Design

<table>
<thead>
<tr>
<th>Cyl in OR</th>
<th>K Toricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sphere</td>
<td>≤ 0.75 D</td>
</tr>
<tr>
<td>BC Toric</td>
<td>≥ 0.75 D</td>
</tr>
<tr>
<td>SPE Bitoric</td>
<td>&lt; 0.75 D</td>
</tr>
<tr>
<td>CPE Bitoric</td>
<td>≥ 0.75 D</td>
</tr>
<tr>
<td>F1 Toric</td>
<td>≥ 1.00 D</td>
</tr>
</tbody>
</table>

Lenticular - WHY?

To Decrease Mass and Bulk of Plus Lenses:
- i.e. makes it thinner
- Improves comfort
- Improves centration
- Increases Dk/L
How much thinner?

+4.00 D
0.21 mm center thickness (lenticular)
0.27 mm center thick (non-lenticular)

+10.00 D
0.31 mm center thickness (lenticular)
0.39 mm center thick (non-lenticular)

~25% thinner (lenticulation awesome)

Types of Lenticular Designs

- Plano carrier
- Minus carrier
- Plus carrier
- CN bevel

Bend Me, Shape Me: Lens Flexure

Types of Lenticular Designs

- Contact Lens Spectrum
  February 2002 issue
  Available on-line
  Search by date or author
  (Edrington)

GP Lens Warp

- Why?
  - Heat / Material
- How do you measure?
  - Warp vs bitoric
  - Lensometer
  - Mean is still mean
- So what?
  - OR cylinder changes (by the amt. of warp)
  - Fit – apical relationship doesn't change;
    toricity does (Flat lines up with flat; steep…)

GP Lens Flexure

- Flexure
- in situ
- How measured?
  - Over-K / over-topography
  - OR cylinder change
  - FP toricity change
- Higher Dk GP lenses flex more
- Thinner GP lenses flex more

Warp + Flexure

- Fit
  - Does not alter apical relationship
  - “Reduces” toricity of TL by W+F
- OR
  - Does not alter EDS of OR
  - Changes cylinder by amount of W+F

GP – Complications: Diagnosing and Treatment

- Generally healthier than soft contact lenses
- Smaller OAD, less corneal coverage
- Greater tear exchange
- Complications are fewer and less severe than soft lenses

Peripheral Corneal Desiccation

- Commonly known as 3-9 staining
- Can also be at 4-8 or 6 o'clock
- Most common GP lens complication
- Few or no symptoms reported by patient
  - Complaints of interpupalbral redness
Peripheral Corneal Desiccation

- Mild (1+)
  - Small areas of non-coalescing superficial punctate staining (SPK)
- Severe (4+)
  - Coalescing areas of SPK
  - Heavy / deep fluorescein staining

Reasons for concern
- Avenue for infection
- Long term PCD may lead to dellen formation
- Scarring

Causes of PCD
- Excessive lens edge lift leads to areas of poor re-wetting
  - Tear film becomes disrupted leading to areas of dryness
  - Dryness causes disruption of the corneal epithelium
- Incomplete blink
- Inferior / superior GP lens position
- Other hypotheses exist

Biomicroscopy Signs
- Use yellow filter to observe subtle staining
- Staining shows areas of SPK at the 3 & 9 o'clock (or other time zones) regions
- Position of staining is dependent on lens-cornea relationship and lens position
- Edge lift may lead to tear film disruption which may lead to corneal staining

Management of PCD
- d/c lens wear?
- Rx artificial tears for temporary treatment
- If chronic, bandage soft contact lens
- If severe, consider antibiotic
- Educate patient on awareness of a complete blink
  - Except if edge is bad (modify to improve)
Localized area of reversible thinning
Due to thinning of epithelium, Bowman’s, and stroma
Caused by dessication or dehydration of the peripheral cornea
Usually no symptoms because not inflammatory
If untreated, vascularization and scarring can occur

Saucer shaped depression, usually at the limbus
Usually adjacent to an area of elevation (ex. a GP lens or pinguecula)
Fluorescein pooling, minimal staining
No:
- infiltrate
- AC reaction
- hyperemia

Management a Dellen
- Eliminate the cause
  - steepen peripheral curves for increased corneal apposition
  - thining edge profile of lens
  - surgical removal of pinguecula?
- Copious lubrication
  - tears in the AM
  - viscous gel in the PM

Optics Treat # 5
- Water content
  - % H2O = Wet weight - Dry weight
  - Wet weight
- Example
  - Wet weight = 70mg
  - Dry weight = 42mg
  - Water content = 7 % (hint: 40%)

Increase Water Content
- What Happens?
  - Increases permeability (Dk)
    logarithmically (traditional SCLs)
    Except Silicone Hydrogels
  - Decreases durability
  - Increases dry eye symptoms (thickness more important)
  - Increases deposit formation (esp. protein)

FDA Classifications
- Group 1 = low (<50%) water, nonionic polymer
  Group 2 = high (>50%) water, nonionic polymer
  Group 3 = low water, ionic polymer
  Group 4 = high water, ionic polymer
- Group 1 least deposits
- Group 4 most deposits
- What about silicone hydrogels?
Silicone Hydrogels
(aka SiHi, SiHy, S-H; whatever)

- Launched in Europe in 1999
- FDA approved in 2001
- CIBA Night & Day and B+L PureVision
  - for up to 30 days continuous wear (CW)
- Silicone hydrogels are the majority of soft CLs prescribed in US today

~5X the O2

- Acuvue 2  \( Dk = 28 \)
  - \( ct @ -3.00D = 0.084 \text{mm} \)
  - \( Dk/t = 33 \)
  - \( ct @ +3.00D = 0.17 \text{mm} \)
  - \( Dk/t = 16.5 \)
- Acuvue Oasys  \( Dk = 103 \)
  - \( ct @ -3.00D = 0.07 \text{mm} \)
  - \( Dk/t = 147 \)
  - \( ct @ +3.00D = 0.147 \text{mm} \)
  - \( Dk/t = 70 \)

Silicone Hydrogels Currently in US Market

<table>
<thead>
<tr>
<th></th>
<th>% Water Content</th>
<th>Modulus (Mpa)</th>
<th>Dk</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIBA Air Optix</td>
<td>23</td>
<td>1.9</td>
<td>140</td>
</tr>
<tr>
<td>Night &amp; Day Aqua</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CooperVision Biofinity</td>
<td>48</td>
<td>0.75</td>
<td>128</td>
</tr>
<tr>
<td>CIBA Air Optix</td>
<td>33</td>
<td>1.2</td>
<td>110</td>
</tr>
<tr>
<td>Aqua Oasys</td>
<td>38</td>
<td>0.72</td>
<td>103</td>
</tr>
<tr>
<td>B+L PureVision</td>
<td>36</td>
<td>1.1</td>
<td>99</td>
</tr>
</tbody>
</table>

Silicone Hydrogels Currently in US Market

<table>
<thead>
<tr>
<th></th>
<th>% Water Content</th>
<th>Modulus (Mpa)</th>
<th>Dk</th>
</tr>
</thead>
<tbody>
<tr>
<td>CIBA Air Optix Custom (Custom Lathe Cut)</td>
<td>32</td>
<td>1.1</td>
<td>82</td>
</tr>
<tr>
<td>Acuvue Advance and Advance Plus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Definitive by Contacmas (Custom Lathe Cut)</td>
<td>47</td>
<td>0.43</td>
<td>60</td>
</tr>
<tr>
<td>1-Day Acuvue TrueEye (Daily Disposable)</td>
<td>46</td>
<td>0.71</td>
<td>55</td>
</tr>
</tbody>
</table>

Generally True Statements

- Conventional non-silicone hydrogels
  - Increased water content = increased Dk (because water transports oxygen)
- Silicone hydrogels
  - Increased water content = decreased Dk
  - Increased silicone content = increased Dk (because oxygen is more soluble in silicone than water)

Silicone Hydrogel Trends
(not absolute truths)

- Increased silicone content
- Increased Dk
- Increased modulus (stiffness)
- More water means decreased modulus
- Decreased wettability
- Surface treatments and wetting agents have been utilized to enhance wettability
- Increased lipid deposition
- Rub is more important

Silicone Hydrogels versus Conventional (low Dk) Hydrogels

- Decreased hypoxia/swelling adverse responses (2 to 5% overnight swelling with S-H compared to 7 to 15% with low-Dk lenses)
- Decreased neovascularization
- Decreased limbal hyperemia (DW and EW)
- Decreased incidence of striae and microcysts
- Decreased endothelial cell morphology
Modulus – Stiffness
- When is higher modulus better?
  - To improve handling and A/R of lens
- When is lower modulus better?
  - To decrease incidence of mechanical complications
    - Mucin balls
    - Papillary conjunctivitis (CLPC / GPC)
    - Superior epithelial arcuate lesions (SEALs)

Mucin Balls
- The Bottom Line
  - No complications over short-term
  - If “severe”
    - Reduce nights of continuous wear
    - Use rewetting drops am and pm
    - Fit steeper base curve or S-H with a lower modulus

Giant Papillary Conjunctivitis (GPC)

Silicone Hydrogel CLPC
Photo courtesy of Cheryl Skotnitsky, OD

Superior Epithelial Arcuate Lesion (SEAL)
- Due to lens modulus
- Tx
  - Re-fit with different BC or lower modulus material

Corneal Ulcer

Microbial Keratitis
- Risk of MK with 30 day S-H CW is similar to 7 day EW of low Dk lenses
- Risk of MK with 30 day S-H CW is ~5X risk with DW
- However, most infiltrates observed were inflammatory instead of infectious
Post-Market Risk Factors for Infiltrative Keratitis
Robin Chalmers, OD

- Age
  - Under 25: 1.65
  - Over 50: 2.01
- Refractive error
  - >5.00 D: 1.57
- Geographical (tropical)
- Smoking

Bottom Line
- Oxygen driven complications dramatically reduced with S-H
- Mechanically induced complications remain
- Déjà vu all over?
  - PMMA (dinosaur); replaced by GP
  - Conventional low-Dk; replaced by S-H

Optics Treat # 6
- Soft Lens Base Curves
  - flatter than rigid contact lenses (e.g. 8.3, 8.6, 8.9mm)
  - 8.6 mm = 39.25 D., 8.9 mm = 37.87 D.
- If you change soft contact lens base curve, do you need to change power?
  - No, because there is no change in tear lens

TORIC SOFT CONTACT LENSES

ROTATIONAL STABILIZERS
- Prism - Watermelon Seed Effect
  - increased prism
  - increased stabilization
  - decreased OD (especially inferior)
- Eccentric (off center) lenticulation
  - Periballast is similar, but different
- Back Surface vs Front Surface Toric
  - Double Slab-Off / Thin Zone (CIBA) / Dynamic Stabilization (Vistakon)
  - Truncation – of historic note
  - Combinations

BACK SURFACE PRISM BALLAST

PureVision® Toric
- Rotational stability enabled by prism ballasting geometry
  - in 360° comfort chamber
  - Refined vertical thickness profile
  - (3) Refined optic zones

O2OPTIX™ Toric for Astigmatism

THIN ZONE (DYNAMIC STABILIZATION)
**Realigns lens when rotated**

**Accelerated Stabilization Design**

- Works with lids to balance lens when eye is open.

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**Multifocal Contact Lenses**

**Optics Treat # 7**

**Correcting Presbyopia with CLs**

- Monovision
- Multifocal designs
  - Simultaneous designs
  - Translating designs
- The Good
  - "Easy"
  - All lens types (soft, GP, toric)
  - "Optimal" vision at distance and near or distance and intermediate
  - But not distance, near, and intermediate (unless modified monovision)
- But amount is not critical
- Rotational stability is critical
- For every 30 degrees misalignment, full amount of cylinder in OR
- If 15 degrees misalignment, one-half the amount of cylinder in OR
- If 10 degrees misalignment, one-third the amount of cylinder in OR

**Monovision**

- The Good
  - "Easy"
  - All lens types (soft, GP, toric)
  - "Optimal" vision at distance and near or distance and intermediate
  - But not distance, near, and intermediate (unless modified monovision)
- The Bad
  - Decreased stereopsis

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**GP Multifocals**

- Aspheric
  - Flatter surface, generally HT steep
  - Additional add may be fabricated on the front surface
- Concentric / Annular
  - Generally center distance
  - Center near referred to as reverse central
- Translating
  - Generally prism "ballast"
  - Best on patients with low w/t-r
  - Need lower yield to support