Refraction: What Do Those Numbers Really Mean?

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Understanding Why

• Learning by rote – sometimes out of order
  – The steps
  – The definitions
  – The equations
• Learning what it means
  – The reasons
  – The logic
  – Really understanding – empirically
Emmetropia

- The entire image falls on the retina without refractive intervention
- The eye length is “just right”?
- The goal of every refraction is to manipulate the image to “land” on the retina in its entirety

Refractive Errors

Myopia – “Near Sightedness”
- The “clear image” falls in front of the retina
- Images in the distance are blurred
- Images up close are clear
- The eye length is “too long”?

Refractive Errors

Hyperopia – “Far – Sightedness” - Misnomer
- The “clear image” falls behind the retina
- Images in the distance are clear
- Images up close are blurred – only in presbyopes
- The eye length is “too short”?
Refractive Errors

- Astigmatism – Essentially Two Refractive errors in one eye
  - Multiple classifications
    - Simple
    - Compound
  - Multiple categorizations
    - With-the-rule
    - Against-the-rule
    - Irregular
    - Asymmetrical

Simple Hyperopic Astigmatism

- One image falls on the retina
- One image falls behind the retina

Simple Myopic Astigmatism

- One image falls on the retina
- One image falls in front of the retina
**Compound Hyperopic Astigmatism**

- Both images fall behind the retina

![Diagram of Compound Hyperopic Astigmatism]

**Compound Myopic Astigmatism**

- Both images fall in front of the retina

![Diagram of Compound Myopic Astigmatism]

**Astigmatism & Keratometry**

- Most astigmatism is at the corneal plane
  - The front surface of the cornea is “out-of-round”
  - More like a “football than a basketball”
- One meridian is “steeper” than the other
  - Following the line along the laces of a football is not as curved as the line crossing the laces
Astigmatism & Keratometry

With–The–Rule Astigmatism

• Referencing Corneal Astigmatism
• The Vertical Meridian is steeper than the Horizontal meridian
• Most common category of astigmatism
  – Ratio diminishes with age groups
Against–The–Rule Astigmatism

- Referencing Corneal Astigmatism
- The Horizontal Meridian is steeper than the Vertical meridian
- Less common category of astigmatism
  - Ratio increases with age groups

WTR / ATR Astigmatism

- Assuming the primary meridians (meridia) are 90 degrees apart – Orthogonal
  - Irregular astigmatism – the 2 primary meridia are NOT 90 degrees apart – Non – orthogonal
  - only “seen” on corneal topography
  - Asymmetrical astigmatism – the power across the meridian is unequal – only “seen” on corneal topography / the principal meridian cannot be defined

Corneal Astigmatism
Other Astigmatism

- **Lenticular**
  - The lens is “out of round” and is steeper in one direction than the other
  - *Only diagnosed deductively or empirically*
    - Eliminate corneal explanation for astigmatism

- **Macular**
  - Rare – the macula is tilted
  - *Usually only assumed after cataract surgery*
    - Cornea is spherical, IOL in place, Cylinder is needed refraction. Assumption = macular astigmatism

Spherical Equivalent

- **Simple Algebraic Equation we all have had to learn / memorize**
  - Algebraically combine half of the cylinder power to the spherical power and express the refractive power in one term – spherical
  - Refraction = -2.00 +1.00 x 090
  - Spherical equivalent = -1.50

Blah, Blah, Blah!
How Does This Relate:
The Conoid of Sturm and The Circle of Least Confusion

The Conoid of Sturm

- A theoretical schematic of the two images in an astigmatic eye
  - It illustrates the distance between the two images of the two refractive errors of the one eye
The Circle of Least Confusion

• Equi-distance between the Two Clearest Images of the Two Refractive Errors of an Astigmatic Eye
• In other words
  – The clearest spot you can find without eliminating the astigmatism

More Math
Refraction Transposition

- Converting a Cylindrical refraction from plus to minus or vice versa
  - -2.50 +1.00 x 090
  - -1.50 - 1.00 x 180
- Means the exact same thing in different terms
  - Think meters versus feet
  - Think inches versus centimeters
  - Same measurement expressed in different terms

Enough Already – Get to the Point !!!

Correcting Refractive Errors

- Spherical lenses – Moving the Circle of Least Confusion back or forth
  - Minus Spherical lenses (back)– Diverge the rays – pushing the image further away from the lens equally in all meridians
  - Plus Spherical lenses (forth)– Converge the rays - bringing the image closer to the lens equally in all meridians
Plus Spherical (Converging) Lenses

• The Steeper the curve the higher the power
  – Rise and run – like stairs
  – The ratio of vertical climb to horizontal travel
  – The greater the ratio the closer the image is moved – focal length
  – Think +1.00 trial lens vs +10.00 trial lens – the central thickness is very different

Minus Spherical (Diverging) Lenses

• The Steeper the curve the higher the power
  – Drop and run – like stairs
  – The ratio of vertical drop to horizontal travel
  – The greater the ratio the further the image is moved – focal length
  – Think -1.00 trial lens vs -10.00 trial lens – the central thickness is very different compared w/ the periphery

Keratometry Again

• What are you measuring with keratometry
  – The curvature of the anterior surface of the cornea
  – What does that mean for the refractive power of the eye?
  – Are all myopic eyes “too long”?
  – Are all hyperopic eyes “too short”?
Cylindrical Lenses

- Converge in one direction only
  - Plus Cylinder
- Diverge in one direction only
  - Minus Cylinder
- Where there is no curvature there is no power

Putting it All Together

The Phoropter
Plus Spheres Bring the Whole Image Forward

Minus Spheres Push the Whole Image Backward

Spheres Move the Circle of Least Confusion
Circle of Least Confusion

- Equivalent to the two parts of the astigmatic correction straddling the retina

Cylinders Collapse the Conoid of Sturm

- Plus Cylinder brings the posterior part of the image forward
- Leaving the anterior part of the image in place

The Sphere Replaces the Circle of Least Confusion

- The distance between the two images is now closer but only part of the image is "on the retina"
- The sphere moves the whole image back to straddle the retina
The Sphere Replaces the Circle of Least Confusion

- The distance between the two images is now closer
- For every +0.50 cylinder you dial in- 0.25
- The sphere moves the whole image
- The two images once again straddle the retina
- What is the SE of -0.25 +0.50?

The Cylinder Collapses the Conoid of Sturm Further

- Again dial in -0.25 for every +0.50 cylinder added
- The SE is synonymous with the circle of least confusion
- Constantly seeking the middle image until there is no difference

Cylinders Collapse the Conoid of Sturm

- Minus Cylinder pushes the anterior part of the image backward
- Leaving the posterior part of the image in place
The Sphere Replaces the Circle of Least Confusion

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Correcting Astigmatism One Refractive Error at a Time

- Using Spherical Lenses Only –
  - Retinoscope the two primary meridians
  - Mathematically figure the prescription whether in plus or minus cylinder

Mathematically Determine Prescription

- What is the integer difference between the two measurements?
- On a number line –
  - From minus to “more” minus for minus cylinder
  - From minus to “less” minus for plus cylinder
- Conversion SE
  - -2.00 – 1.00 X 180
  - -3.00 +1.00 X 090

Sidebars
Little Things We Need to Understand
Accommodation

Relaxes Tension on the Zonules Allowing the Lens to Thicken

If the Lens becomes thicker, what does that do to the refractive power?

The Plus Power of the Lens Increases pulling the image forward. Needing more Minus refractive power to counter
Land on “More Plus”

- When giving patients choices of lenses always have the first choice being more minus and the 2nd choice more plus
  - The greater “wait time” is on the least minus choice
    - Eliminates Accommodation
    - You can slow down for the patient to choose without compromising the outcome

Phoropter Design

- 3 Diopter Ring
- Sphere Wheel = 4 clicks
  - Top → Bottom = +1D
  - Bottom → Top = -1D
- Cylinder Wheel
  - Roll = Circumference of Thumb
  - Choice on Axis + 0.12 D
    - Use Larger Angular Target

Balancing

- Equal Sight in Each Eye
- Patients ~ 50 years or younger
  - Latent Hyperopes
- Especially ~35 years or younger
  - Large Accommodative Amplitudes
- Binocular Methods
  - Fogging / Alternate Cover
  - Vertical Prism Displacement
- Monocular Method
  - Red-Green Split Screen
Balancing

Example: Fogging / Alternate Cover
1. Both Oculars Open
2. 4 Clicks to The Plus
3. Isolate 20/40 Line– Make sure it is fuzzy
4. Compare OD w/ OS – add “+” to better eye until “same”
5. Isolate 20/25 Line – Click to the minus until just seen
6. Repeat Step 4
7. Isolate 20/20 Line – Ask Patient to Read
8. One click minus – Ask Patient if it “Better” or “Smaller & Blacker”
9. If “Better” – One click minus/ “Smaller and Blacker” One click plus
10. Isolate new 20/20 Line – May have to repeat step 9

In Summary

• Spherical Lenses
  – “Move” the entire image (circle of least confusion)
    • Minus – back
    • Plus – forward
• Cylindrical Lenses
  – “Move” 1meridian (collapses circle of least confusion)
    • Minus – back
    • Plus – forward
• Refractive Goal - entire image “lands” on the Retina

Questions