Spectacle Lens Magnification & Minification

Anisometropia
- Is the difference in refractive power between the two eyes
- When corrected with glasses/spectacles, different lens powers magnify/minify by different amounts leading to different retinal image sizes

Aniseikonia
- A relative difference in size and/or shape of the ocular images
  - Anatomical – due to rods & cones
  - Inherent optical – due to optics of the eye
  - Induced – due to correcting ophthalmic lenses
- Symptoms: eyestrain, headaches, photophobia, visual discomfort

Aniseikonia
- According to the "classical theory" of aniseikonia, the type of ametropia determines how the aniseikonia is corrected.
  (Ametropia is the refractive condition where parallel rays do not focus on the retina, even when accommodation is relaxed.)

Axial Ametropia
- Axial length of the eye is too short or too long
- For myopes (long eyeball): the uncorrected image size will be larger than the image size for a normal eye
- Theory says that spectacle lenses minify the image and bring that image size back to normal, whereas contact lenses leave the size larger
**Axial Ametropia**
- For hyperopes (short eyeball): the uncorrected image size will be smaller than the image size for a normal eye.
- Theory says that spectacle lenses magnify the image and bring that image size back to normal, whereas contact lenses leave the size small.

**Refractive Ametropia**
- Refractive ametropia
  - The refractive components of the eye are not normal (axial length is normal)
  - For both myopia & hyperopia, the uncorrected image sizes will be the same as the image size for a normal eye.

**Refractive Ametropia**
- In correcting refractive ametropia, we want to keep the image sizes the same...
- Contact lenses can correct the refractive error and not change the image size.

**Knapp’s Law**
"When a correcting lens is so placed before the eye that its second principal plane coincides with the anterior focal point of an axially ametropic eye, the size of the retinal image will be the same as though the eye were emmetropic."
In clinical practice, aniseikonia is still present when axial ametropia is corrected with spectacles.

- Contact lenses are much closer to the principal planes of the eye and do not magnify or minify like a spectacle lens.

**Clinical Pearl**

- Regardless of the type of ametropia, correction with contact lenses will eliminate/reduce the amount of induced aniseikonia.

  *(Knapp's Law assumes that the lenses used are thin and flat. This is not realistic in clinical practice.)*

**Limitations of Knapp's Law**

- The ametropia must be purely axial.
- The correcting lens must be located so that its secondary principal point coincides with the primary focal point of the eye.
- The refracting power of the eye must be equal to that of the standard emmetropic eye (+58.50D).
- The shape factor of the lens must be 1.
- Knapp's Law only applies to induced aniseikonia (axial ametropes may also have anatomical aniseikonia due to differences in receptor densities).

**NBEO**

- Important to know how to determine if the ametropia is axial or refractive.
- Take "Ks" (keratometry)...

  - If Ks are relatively equal, likely to be axial ametropia.
  - If Ks = to the anisometropia, likely to be refractive ametropia.

**Axial or Refractive?**

- **Example #1**
  
  Ks: OD 44.50D
  Refraction: OD -2.50
  OS 44.50 D

- **Example #2**
  
  Ks: OD 44.50D
  Refraction: OD -2.50
  OS 42.50 D
Recommended Reading
Brooks & Borish:
Systems for Ophthalmic Dispensing
3rd ed.
- Effective Power: pp 338-341
- Magnification & Minification: pp 491-498
- Spectacle Lens Tilt: pp 410-414

Retinal Image Size
Ametropia vs. Emmetropia

<table>
<thead>
<tr>
<th>Ametropia</th>
<th>No Rx</th>
<th>SRx</th>
<th>CLRx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Axial Myopia</td>
<td>Larger + lens system</td>
<td>Equal</td>
<td>Larger</td>
</tr>
<tr>
<td>Axial Hyperopia</td>
<td>Smaller - lens system</td>
<td>Equal</td>
<td>Smaller</td>
</tr>
<tr>
<td>Refractive Myopia</td>
<td>Equal</td>
<td>Smaller Spec. mini</td>
<td>Equal</td>
</tr>
<tr>
<td>Refractive Hyperopia</td>
<td>Equal</td>
<td>Larger Spec. mag</td>
<td>Equal</td>
</tr>
</tbody>
</table>

Spectacle Magnification

“The ratio between the size of the retinal image in an ametropic eye before and after correction.”

Ex: The retinal image of an uncorrected 3D myopic eye vs. the retinal image of the same eye corrected with a -3.00D lens.

Spectacle Magnification

$$SM = \frac{\text{retinal image size of the corrected eye}}{\text{retinal image size of the uncorrected eye}}$$
Relative Spectacle Magnification
- The image size difference between a corrected ametropic vs. a standard emmetropic eye (that does not need correction).

Ex: The retinal image of a corrected 3D myopic eye vs. the retinal image of an emmetropic (plano) eye.

Relative Spectacle Magnification

\[
\text{RSM} = \frac{\text{image size for a corrected ametropic eye}}{\text{image size for a standard emmetropic eye}}
\]

Spectacle Magnification Concerns
- Usually not a problem unless there are significant differences between the eyes in:
  - Rx
  - Vertex distance
  - spectacles to contacts
  - Lens thickness
  - Lens form i.e., BC & power

Spectacle Magnification
- Power Factor (\(M_p\)) is a function of:
  - lens back vertex power (\(F_v\))
  - distance from the back vertex of the lens to the entrance pupil of the eye (\(h\))

\[
M_p = 1 \div [1 - h(F_v)]
\]

If \(F_v = +5.00\) D and \(h = 15\) mm

\[
M_p = 1 \div [1 - 0.015(5)]
\]

\[
= 1.08
\]

Power Factor
- Shape Factor (\(M_s\))
  - front surface power, center thickness, and index of refraction
Power Factor

- (h): The entrance pupil is assumed to be 3mm from the front surface of the cornea. Unless (h) is given, you must add 3mm to the vertex distance to get (h).

Ex: (h) = vertex distance + 3mm

Shape Factor

- Shape magnification ($M_s$) is a function of:
  - lens front surface power ($F_1$)
  - center thickness ($t_c$), and lens index (n)
- $M_s = 1 \div [1 - (t_c/n) F_1]$
- If $F_1 = +8.00 \text{ D}$, $t_c = 3.5 \text{ mm}$, and $n = 1.52$
- $M_s = 1 \div [1 - (0.0035/1.52) 8] = 1.02$

Spectacle Magnification

Power Factor X Shape Factor

$SM = M_p \times M_s$

Percentage spectacle magnification

$\%SM = (SM-1) \times 100$

Minimizing Magnification

- If the lens thickness was infinitely thin and it was placed at the entrance pupil of the eye, then:
  - $M_p = 1$
  - $M_s = 1$
  - $SM = 1$
- Closest approximation with a contact lens or intraocular lens (IOL)
Example #1

- If $F_v = -8.00$ D, $h = 12$ mm, $F_1 = +2.00$, $t_c = 1.5$ mm, and $n = 1.586$, then calculate $M_p$, $M_s$, $SM$, and $%SM$

- $M_p = 1 \div [1 - h(F_v)]$
- $M_p = 1 \div [1 - .012(-8)]$
- $M_p = 0.912$

Example #1 (cont.)

- $M_s = 1 \div [1 - (t_c/n) F_1]$
- $M_s = 1 \div [1 - (0.0015 /1.586) 2]$
- $M_s = 1.002$

Example #1 (cont.)

- $SM = M_p \times M_s$
  - $SM = 0.912 \times 1.002$
  - $SM = 0.914$

- $%SM = (SM-1) \times 100$
  - $%SM = (0.914 - 1.0) \times 100$
  - $%SM = -8.6$

Example #2

- Your patient is wearing +14.00D glasses with a vertex of 12mm. She desires contact lenses.
  1. What is the required contact lens power?
  2. What is the % change in magnification when contacts are worn vs. glasses?

Example #2 (cont.)

- When going from spectacles to CL:
  \[
  \frac{\text{Retinal size (CL)}}{\text{Retinal size (SRx)}} = \frac{F_{SRx}}{F_{CL}} = \Delta SM 
  \]

- $%SM change = (\Delta SM-1) \times 100$
Example #2 (cont.)

- \( \frac{F_{\text{SRx}}}{F_{\text{CL}}} = \Delta SM \)
  - \( F_{\text{SRx}} / F_{\text{CL}} = +14.00D / +16.83D = 0.832 \)
  - \( F_{\text{SRx}} / F_{\text{CL}} = 0.832 = \Delta SM \)

- \( \%\text{SM change} = (\Delta SM - 1) \times 100 \)
  - \( (.832 - 1) \times 100 = -16.8\% \)

Shape Factor Considerations

- \( M_s = 1 \div [1 - (t_c/n) F_1] \)

\( M_s \) and therefore \( \text{SM} \) increases with:
- Increase in front surface power \( (F_1) \)
- Increase in lens thickness \( (t_c) \)
- Decrease in index of refraction \( (n) \)

Power Factor Considerations

- \( M_p = 1 \div [1 - h(F_v)] \)

\( M_p \) and therefore \( \text{SM} \) vary directly with back vertex power \( (F_v) \):
- Retinal image size ↑ with ↑ plus power
- Retinal image size ↓ with ↑ minus power

If \( h \) is decreased (decrease in vertex distance):
- For a plus lens: decrease in retinal image size
- For a minus lens: increase in retinal image size

Spectacle Magnification and Vertex Distance

- If the lens vertex distance is changed there is a change in the retinal image size. \( M_p = 1 \div [1 - h(F_v)] \)
- This holds true for both contacts and glasses.
- How can you change vertex without sliding the frames down your nose?

"First Pass Method"
(Brooks & Borish, p. 496)

- Use a frame with a short vertex distance
- Use a frame with small eyesize (secondarily reduces vertex distance)
- Use an aspheric design (flattens BC)
- Use a high index material (thins plus lens center thickness)
How to Alter Spectacle Magnification

- \( M_p = 1 \div [1 - h(F_v)] \)
- \( M_s = 1 \div [1 - (t_c/n) F_v] \)

- **Plus lenses**: To ↓ spectacle magnification; ↑ the index, and/or ↓ the vertex, base curve, or center thickness.
- **Minus lenses**: To ↓ spectacle minification; ↓ the index or vertex, and/or ↑ base curve, or center thickness.

Estimate of %Magnification Difference

1% per diopter

Reducing Aniseikonia (+/+)

- If the patient is hyperopic in both eyes:
  - Keep eye size small
  - Use a frame with a short vertex distance

Reducing Aniseikonia (-/-)

- If the patient is myopic in both eyes:
  - Choose a frame with a short vertex distance
  - Keep eye size small
  - High (-) lens
    - ↓ vertex distance by moving the bevel
    - Steepen BC, thicken lens, and move bevel forward (decreases vertex)
  - Low (-) lens
    - ↑ vertex distance by moving the bevel
    - Do not thin the lens

Reducing Aniseikonia (+/-)

- If the patient is hyperopic in one eye and myopic in the other:
  - Choose a frame with a short vertex distance
  - Keep eye size small
  - (+) lens
    - Flatten BC
    - Thin the lens
    - ↓ vertex distance
  - (-) lens
    - Flatten BC
    - Thin the lens
    - ↑ vertex distance
    - Do not thin the lens
Measuring %Magnification Differences
- Space Eikonometer
- The Aniseikonia Inspector

Points to Consider
(Brooks & Borish, p. 498)
- Reduce the vertex distance for both lenses
- Changing the BC of even one lens may help (reducing the higher BC to equal the lower BC can make a big change in magnification difference)
- Use an aspheric design. For plus lenses both BCs will be flatter; allowing a ↓ in thickness of the thicker lens. The thinner lens can then be made equal to the thicker lens
- Increasing the index will thin the lens

Points to Consider
(Brooks & Borish, p. 498)
- If the least plus lens is thick enough increasing the vertex distance by moving the bevel back can help
- For plus lenses using a nonaspheric design with a steeper base curve for the weaker lens, and an aspheric design for the stronger lens can help
- Using an anti-reflection coating can help reduce lens visibility and other noticeable differences between the two lenses