Heads You Win, Tails You Lose

The Optical Advantages and Disadvantages of Spectacle Lenses and Contact lenses

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Agenda

• The correction of ametropia
• Magnification, retinal image size, visual acuity
• Field of view
• Accommodation and convergence
• Binocular vision and anisometropia
• Presbyopia.

Spectacle lenses

• Refractive errors that can be corrected using spectacle lenses:
  – myopia
  – hypermetropia
  – astigmatism
• not so good with irregular corneas
  – presbyopia
• Some binocular vision problems are easily managed using spectacle lenses.

Contact lenses

• Refractive errors that can be corrected using contact lenses:
  – myopia
  – hypermetropia
• apparent size of the eyes and surround in both cases
  – astigmatism
• better for irregular corneas
  – presbyopia
• Binocular vision problems are difficult to manage using contact lenses.

Introduction

• Patients often change from a spectacle to a contact lens correction and vice versa
• Both modes of correction are usually effective in producing in-focus retinal images
• There are of course some differences between modes, most of which are associated with the position of the correction.
Effectivity

- A distance correction will form an image at the far point of the eye.
- Due to the vertex distance this far point will lie at slightly different distances from the two types of correcting lens:
  - the powers of the spectacle lens and the contact lens required to correct a particular eye will therefore be different.

The Correction of Ametropia

- Hydrogel contact lenses
  - When a hydrogel contact lens is fitted to an eye, the lens “drapes” to fit the cornea.
  - This implies that the tear lens formed between the contact lens and the cornea should have zero power and the ametropia is corrected by the BVP of the contact lens.
  - Not always the case but usually assumed in practice.
  - \( F_{\text{CL}} \neq k \)

The correction of ametropia using contact lenses

- RGP contact lenses
  - The back surface of a rigid lens maintains its shape.
  - A tear lens of predictable form and power is formed between the rigid contact lens and the cornea.
  - Ametropia is corrected with a contact lens/tear lens system.
  - \( F_{\text{CL}} \neq K \)

Correction of ametropia - RGP

- The contact lens-tear lens system formed when a RGP contact lens is placed on an eye means that three elements are involved in the formation of the final retinal image:
  - Contact lens
  - Tear lens (liquid lens, lacrimal lens)
  - Eye

The tear lens and the BOZR

- Important to determine the likely magnitude of the tear lens and how it varies as the BOZR is changed.
  - Helps determine BVP required and aids fit evaluation.
- Rules of thumb:
  - Tear lens power increases by 0.25 D for each 0.05 mm that the BOZR is steeper than the cornea.
  - Tear lens power decreases by 0.25 D for each 0.05 mm that the BOZR is flatter than the cornea.
Magnification, Retinal Image Size and Visual Acuity

Spectacle magnification

The ratio of the retinal image size in the corrected ametropic eye compared to the retinal image size in the same eye when uncorrected:

\[ SM = \frac{h_i}{h_u} \]

\[ SM = \frac{K}{F_{eq}} \]

\[ SM < 10F_p \text{ only applies to thin lens systems and model eyes where the entrance pupil coincides with the cornea or the reduced surface} \]

Spectacle magnification

For a contact lens-tear system

\[ SM = \text{power factor} \times \text{shape factor} \]

\[ SM = 1 \]

\[ \frac{a}{F_v} = \frac{a}{x} \]

\[ F_v = \frac{L_1}{x} \times \frac{L_2}{L_3} \times \frac{L_4}{L_5} \]

\[ L_1, L_2, L_3, L_4, L_5 \]

\[ \text{is the BVP of the lens system (L4/L2)} \]

\[ F_{eq} \text{is the equivalent power of the lens system} \]

\[ a \text{is the distance from the back vertex of the lens system to the entrance pupil of the eye} \]

\[ \text{For spectacles} a = \text{vertex distance + 3 mm} \]

\[ \text{For CLs} a = 3 \text{ mm as } d = 0 \]

\[ F_{eq} = \frac{L_1}{x} \times \frac{L_2}{L_3} \times \frac{L_4}{L_5} \]

Spectacles vs CLs

Assumptions regarding visual acuity

Ametropia | Spectacles | CL |
--- | --- | --- |
Myope | \( SM < 1 \) | \( SM = 1 \) |
Hypermetope | \( SM > 1 \) | \( SM > 1 < \text{Specs} \) |

Fov = 10.00 D SM = 1.25
Same patient wearing CLs SM = 1.05

The monocular static visual field for the right eye

- 60 degrees UP
- 75 degrees down
- 100 degrees Temporal
- 60 degrees NASAL

As enjoyed by an emmetrope or a contact lens wearer

(Assuming that the contact lens or its optic zone is not very small in diameter)
Field of view - Spectacles

- The static field of view of a spectacle lens is the total area visible through the lens – usually expressed in angular measure.
- Defined as the maximum angular extent of vision obtainable through the lens.

Factors affecting the field of view of a spectacle lens

- Aperture size
- Lens power
- Vertex distance
  - To obtain the maximum field, whatever the size of the aperture might be, the spectacle lens should be fitted as close to the eyes as the lashes permit.

Real and apparent fields of view

- Apparent
  - The angle subtended by the empty frame aperture at the eye’s centre of rotation
- Real
  - The field of view obtained when a spectacle lens is glazed into the frame.

Field of view: Positive lens

- The static real field of view provided by a positive spectacle lens is less than the apparent field of view implied by the empty spectacle frame.
- This means that hypermetropes suffer from a decrease in field of view.
- There will be an area around the edge of a lens from which no light can enter the eye – a ring scotoma.

Field of view: Minus lens

- The static real field of view provided by a minus spectacle lens is greater than the apparent field of view implied by the empty spectacle frame.
- This means that myopes benefit from an increase in field of view.
- There will be an annular area around the lens periphery where objects will be seen in diplopia.

Example

- Round lens, 48 mm in diameter fitted at a distance of 25 mm from the centres of rotation of the eyes
- 10.00 myope and 10.00 D hypermetrope
  - Apparent static FOV 87.7°
  - Myope real static FOV 102.7°
  - Hypermetrope real static FOV 71.5°

CL wearer has the widest field of view!
Accommodation and convergence

Ocular accommodation
• The ocular accommodation is the accommodation required to neutralise negative vergence from a near object measured in the plane of the eye.
• \( A_o \) is the symbol for ocular accommodation.
• \( A_o = K - L_2 \) where \( K \) is the ocular refraction and \( L_2 \) is the vergence arriving at the eye from the near object.

Example
• \( F_{sp} = +5.00 \, D \) at 15 mm.
• An object is placed 1/3 m from the spectacle plane.
• Calculate the required ocular accommodation.
• Compare this to a contact lens wearer viewing the same near object.

Example
• \( F_{sp} = -5.00 \, D \) at 15 mm.
• An object is placed 1/3 m from the spectacle plane.
• Calculate the required ocular accommodation.
• Compare this to a contact lens wearer viewing the same near object.

Accommodation
Spectacles Vs contact lenses
• As contact lens wear results in an ametropic patient being considered “artificially emmetropic,”
• the myopic patient will need to accommodate more when wearing contact lenses than when wearing spectacles.
• could be an issue for the emerging presbyope!
• the hypermetropic patient will need to accommodate more when wearing spectacles than when wearing contact lenses.

Convergence
“The movement (rotation) required from the primary position, for the eyes to fixate an object point on the mid-line.”
Convergence

- Convergence and accommodation should be equal for normal binocular vision.
- Convergence can be expressed in degrees, prism dioptres or metre angles.

Convergence

- The "base in" effect of minus lenses means that myopes corrected with spectacle lenses converge less than emmetropes or contact lens wearers.
- The "base out" effect of plus lenses means that hypermetropes corrected with spectacle lenses converge more than emmetropes or contact lens wearers.

Example

- $F_{sp} = -5.00$ D at 15 mm centred for distance vision, the distance PD is 66 mm and the centres of rotation of the eye lie 27 mm behind the spectacle plane.
- An object is placed on the mid-line and 1/3 m from the spectacle plane.
- Calculate the convergence required for a subject corrected using (i) spectacle lenses and (ii) contact lenses.

Spectacles Vs contact lenses

- As contact lens wear results in an ametropic patient being considered "artificially emmetropic" - the myopic patient will need to converge more when wearing contact lenses than when wearing spectacles.
- The hypermetropic patient will need to converge more when wearing spectacles than when wearing contact lenses.

Accommodation and convergence - A Summary

- Myopia
  - Accommodation and convergence: more with contact lenses than spectacles.
- Hypermetropia
  - Accommodation and convergence: less with contact lenses than spectacles.
- So, when changing from CLs to spectacles (and vice versa) the accommodation convergence ratio is only minimally disturbed.
Binocular Vision

Introduction

- For some BV anomalies contact lenses offer advantages over spectacles
- For other BV anomalies contact lenses are contraindicated
- A knowledge of the orthoptic status of a patient is important before they are fitted with contact lenses.

Essential BV investigations

- History:
  - double vision, a turning eye, a lazy eye, eye muscle surgery?
- Symptoms:
  - eyestrain, headaches, blurring or diplopia associated with a visual task?
- Accurate measurement of current spectacles to detect prism or decentration
- Cover test at distance and near
- Ocular motility.

Orthoptic indications for contact lenses

- Optical problems associated with the correction of some refractive errors with spectacles lenses
  - off-axis aberrations particularly in high ametropia
  - prismatic effects
- Minimised in CL wear because the lens moves with the eye
- Improving the clarity of the optical image may improve sensory fusion which might improve the orthoptic status.

Orthoptic and heterophoria

Covering one eye whilst the subject continues to focus on a distant object will dissociate the eyes and any heterophoria may be detected.

Orthophoria: Normal muscle balance - Visual axes do not deviate when eyes are dissociated.

Heterophoria: Visual axes deviate when eyes are dissociated. Bilateral fusion is maintained when the cover is removed.

Classification of heterophoria

<table>
<thead>
<tr>
<th>Classification of heterophoria</th>
<th>Movement of eye under cover</th>
<th>Commonly used abbreviations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Esophoria</td>
<td>adduction</td>
<td>Eso  or  SOP</td>
</tr>
<tr>
<td>Exophoria</td>
<td>abduction</td>
<td>Exo  or  XOP</td>
</tr>
<tr>
<td>Hyperphoria</td>
<td>elevation</td>
<td>L Hyper  or  L/R</td>
</tr>
<tr>
<td>Hypophoria</td>
<td>depression</td>
<td>R Hyper  or  R/L</td>
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Ocular motility

The diagnostic positions of gaze

<table>
<thead>
<tr>
<th>Muscle pair</th>
<th>Field of action</th>
</tr>
</thead>
<tbody>
<tr>
<td>R lateral</td>
<td>L medial</td>
</tr>
<tr>
<td>R inferior oblique</td>
<td>L superior</td>
</tr>
<tr>
<td>R inferior</td>
<td>L superior oblique</td>
</tr>
<tr>
<td>R superior oblique</td>
<td>L inferior</td>
</tr>
<tr>
<td>R superior</td>
<td>L inferior oblique</td>
</tr>
</tbody>
</table>

If motility is normal, the subject’s eyes should move steadily in all directions of gaze with no diplopia.
Orthoptic indications for contact lenses

- The most commonly encountered refractive error where there are marked orthoptic advantages to wearing contact lenses is anisometropia
  - differential prismatic effects
  - aniseikonia.

Anisometropia

- Spectacles vs contact lenses
  - Axial ametropia
    - Spectacles are better if anisometropia is axial as aniseikonia will be less and binocular vision will be more comfortable
  - Refractive ametropia
    - Contact lenses are better if anisometropia is refractive as the right and left retinal images will be the same size
    - However, …….

Orthoptic indications for contact lenses

- Two eyes
- One percept
- Motor fusion
- Sensory fusion
- Fusional reserves

Simple model of binocular function

(Adapted from Evans 2007)

Motor fusion: Eyes accurately aligned
Sensory fusion: Monocular images combined

Orthoptic indications for contact lenses

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Anisometropia

- Spectacles vs contact lenses
  - Axial ametropia
    - Spectacles are better if anisometropia is axial as aniseikonia will be less and binocular vision will be more comfortable
  - Refractive ametropia
    - Contact lenses are better if anisometropia is refractive as the right and left retinal images will be the same size
    - However, …….

Relative spectacle magnification

The ratio of the retinal image size in the corrected ametropic eye compared with the retinal image size in the standard emmetropic eye when for a given distant object

RSM is used when a comparison is needed between two different eyes, for example, in anisometropia

\[
RSM = \frac{K_{\text{E}}}{K_{\text{S}}} \times \frac{K_{\text{E}}}{K_{\text{S}}}
\]

Anisometropia

- Spectacles vs CLs: Comparison of RSM

<table>
<thead>
<tr>
<th></th>
<th>Axial</th>
<th>Refractive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectacles</td>
<td>RE 0.675 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LE 0.392 %</td>
<td>LARGER THAN EMET EYE</td>
</tr>
<tr>
<td>Contact Lenses</td>
<td>RE 1.04 %</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LE RSM = 1</td>
<td>LARGER THAN EMET EYE</td>
</tr>
</tbody>
</table>
Anisometropia

• Spectacles Vs contact lenses
  • this theoretical prediction, known as Knapp’s law was disproved by research that revealed that contact lenses reduce aniseikonia in all forms of anisometropia (Winn et al 1998).

• refractive (non-strabismic) anisometropes are likely to achieve their best binocular visual acuity and stereovision when wearing contact lenses as opposed to spectacles.
  • refractive correction without patching can improve the best corrected acuity in an amblyopic eye and this therapeutic effect may be enhanced with contact lenses.
  • remember that patients with pure anisometropic amblyopia (no strabismus) can respond to treatment at almost any age.

Correction of motor deviations with contact lenses

• Some cases of decompensated heterophoria or strabismus can be treated with a refractive correction
  • accommodative esotropia
    • plus lenses
  • decompensating exophoria
    • minus lenses
  • Possible prismatic corrections with CLs
    • base-down prism on a RGP contact lens
    • horizontal prism with some soft toric contact lens designs.

Orthoptic contraindications for contact lenses

• Monovision
  • contact lenses are well suited to monovision because of the lack of differential prismatic effects
  • monocular blur is dissociating and monovision is contraindicated in patients whose binocular status is easily compromised

• High myopia
  • base-in prism with a spectacle lens centred for distance when reading can be helpful in cases of near exophoria
  • this base-in prism is lost when contact lenses are fitted
  • A similar effect occurs with high hypermetropes who have a near esophoria.
Orthoptic contraindications for contact lenses

- Superior oblique palsies
  - Decompensation can occur if the patient is forced to fixate in the field of action of the weak muscle i.e. to look down and in
  - Alternating vision multifocals are contraindicated in such cases
  - Applies to contact lenses and spectacles.

Recent cases from practice

- Miss B
  - -3.00 D right and left with fitted with continuous wear silicone hydrogel CLs
  - 28 year student veterinary nurse
  - Complaining of near vision and display screen problems at the end of the day
  - Binocular vision assessment
    - Marked exophoria at 40 cm (greater at near)
    - Poor recovery at 40 cm
    - Small vertical deviation
    - Low base out fusional reserves
    - 0.50 base in aligning prism and 0.50 base in vertical prism indicated with the Mallett near test
  - Over-spectacles were prescribed with low minus Rx and base in prism

- Mr. T
  - Right +3.00/-1.75 x 60 left +4.00/-2.25 x 160 fitted with daily wear monthly disposable hydrogel CLs
  - 18 year old college student
  - Fitted with hydrogel toric CLs 6 months ago
  - Now complaining of horizontal diplopia at distance
  - Binocular vision assessment
    - At last eye examination 6/12 ago he displayed a moderately well controlled esophoria with 2 base out LE in spectacles
    - Now left esotropia
    - 140 base out LE to give BSV with both spectacles and contact lenses
  - Patient referred for orthoptic and ophthalmological assessment

Presbyopia

Spectacles lenses for presbyopia

- Single vision
- Bifocals
- Trifocals
- Enhanced reading lenses
- Progressive power lenses
- Occupational lenses
  - Bifocal
  - Progressive

Contact lenses for presbyopia

- Monovision
  - Partial
  - Modified
  - Enhanced
- Alternating (translating) vision bifocals
- Simultaneous vision bifocals.
We had better stop there!

- 86 slides for 1 CET point!
- Lots more we could have said but......
  -- time for a cuppa

Thank you for your attention!