Evidence-Based Refractive Prescribing for Pediatric Patients

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Dr. Erickson has no financial interests to disclose

Overview Of Effective Management of Refractive Errors

- Age-related optical corrections for ametropias
  - Amount of refractive error
  - Age of the patient
  - Developmental milestones
  - Binocular vision status
  - Visual acuity development
  - Wear time & type of correction

Developmental Issues & Theories

- Clinical questions to consider:
  - Emmetropization

Eye Growth

- Multiple studies have found that at birth, there is a relatively high prevalence of refractive errors, typically more hyperopia than myopia.
- There is also a higher prevalence of astigmatism, and in some studies anisometropia, than in older populations.
- The average refractive error in infancy is ~ +2.00

Refractive Error Distribution

<table>
<thead>
<tr>
<th>Refractive Error (D)</th>
<th>Percent of Infants</th>
<th>Percent of Children</th>
</tr>
</thead>
<tbody>
<tr>
<td>+2.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>+4.0</td>
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<tr>
<td>+38.0</td>
<td>100.0</td>
<td>100.0</td>
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</table>

Eye Growth

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- There is also a higher prevalence of astigmatism, and in some studies anisometropia, than in older populations.
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Developmental Issues & Theories

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Eye Growth

- Premature or small babies have a higher prevalence and magnitude of myopia.
- The gestational age of the infant is correlated with refractive error:
  - More premature = higher magnitudes
  - In the absence of ROP, premature infants appear to have normal emmetropization

EYE GROWTH

- Research has demonstrated that both the prevalence and magnitude of myopia, hyperopia, astigmatism & anisometropia decreases between infancy and ~4 yrs of age, resulting in emmetropia or low hyperopia.

EYE GROWTH

- The "end" age of the emmetropization process appears to be 3-5 years, although primate and human studies suggest that most of the emmetropization process is accomplished by 12-18 months for early-onset refractive error.

Theories of Emmetropization

- Errors in optical components resulting in refractive errors are corrected without remediation during growth
  - THE PROCESS IS PASSIVE (genetics)
  - THE PROCESS IS ACTIVE (blur-based)
Active: Environment-based

- Growth changes are based on input from the visual environment.
  - Signal is accommodation & blur
  - Supported by animal and human studies
- IMPLICATIONS:
  - Lens wear prescribed for correction of an ametropia would effect changes with age, since the “error” in the optical system stimulating change toward emmetropia would be eliminated.

Combined Etiology

- Lens wear may be necessary in large RE’s and in the presence of contravening factors that disrupt a normal emmetropization process.

Prerequisites for Successful Emmetropization

- Healthy ocular structures
- Healthy environment
- Operational refractive range
- Intact emmetropization mechanism

EMMETROPIZATION GENERALIZATIONS

- Most refractive compensation is unnecessary in infants
- Hyperopia that doesn’t reduce creates an increased chance that strabismus and/or amblyopia will develop
- Refractive correction (full) may lead to a higher “final” refractive error (hyperopia)
- A strabismic eye will retain a higher refractive error (fixating eye emmetropizes)

EMMETROPIZATION GENERALIZATIONS

- Research has shown that high ametropia or anisometropia (> +/- 3 D) present beyond 1 year of age is probably a genetically determined error in one or more components (esp. axial length).
  - These eyes are not likely to emmetropize and often drift further away...

Emmetropization: Time Course

Don Mutti
OVS 2007
Normal Refractive Error

Mayer et al., Arch Ophthalmol 2001

<table>
<thead>
<tr>
<th>Age in Months</th>
<th>Hyperopic Spherical Equivalent (D)</th>
<th>Mean (SD)</th>
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</thead>
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<tr>
<td>1</td>
<td>+2.0 (1.60)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>+2.4 (1.36)</td>
<td></td>
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<tr>
<td>4</td>
<td>+3.0 (1.36)</td>
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<tr>
<td>6</td>
<td>+3.6 (1.12)</td>
<td></td>
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<tr>
<td>9</td>
<td>+4.2 (1.13)</td>
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<tr>
<td>18</td>
<td>+6.5 (0.39)</td>
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<tr>
<td>24</td>
<td>+1.9 (1.82)</td>
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<td>30</td>
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<tr>
<td>48</td>
<td>+1.1 (0.82)</td>
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Mutti et al, BIBS

3 mo = +2.13 ± 1.31
9 mo = +1.32 ± 1.07
18 mo = +1.09 ± 0.90

Current Clinical Challenges

- Age at which to prescribe lenses correcting ametropias
- Guidelines for prescribing based on the interaction between age and amount of refractive error
- Power of the lenses to prescribe

Age Ranges to Consider

- Infants: 3 - 12 months
- Toddlers: 1-3 years
- Preschoolers: 3-5 years
- School-Aged: > 5 years

Hypertropic Lens Prescriptions

- Developmental trends and emmetropization
- Visual responses to consider when prescribing

Developmental Trends: Hyperopia

- Older studies (Hirsch’s studies; Orinda Study):
  - Often non-cycloplegic
  - Cross sectional study designs
  - Large gaps between age groups
- More Recent studies (BIBS, OLSN, CLEERE):
  - Cycloplegia
  - Longitudinal designs
  - Refined gaps in age groups
  - More biometric data
**Developmental Trends: Hyperopia**

**SUMMARY OF RESEARCH FINDINGS:**
- Significant loss of hyperopia between 3 and 12 mo.
- Significantly less variability in RE after 12 mo.
- Very little change in RE between 12 and 36 mo.
- Most RE between Plano and +3.00 by 18 mo.
- Very low prevalence of hyperopia after age 6 yrs.
- Highest prevalence in White ethnic group

**Mechanisms for Emmetropization**

- **Eye Growth Changes between 3-9 months:**
  - Axial length increases 1.20 +/-0.51 mm
  - Lens power decreases by 3.62 +/- 2.13 D
  - Compared to a 6 year-old, this is 90% of axial length and 155% of lens power
- In order for hyperopia to decrease, the dioptric effects of axial growth to reduce hyperopia must exceed the effects of losses in corneal and lens power that would increase hyperopia

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**HYPEROPIA: 6-14 yrs**

**TABLE 2.**

<table>
<thead>
<tr>
<th>Refractive error (D)</th>
<th>Asian</th>
<th>Black</th>
<th>Hispanic</th>
<th>White</th>
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<tr>
<td>≥+1.50</td>
<td>5.9</td>
<td>6.2</td>
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<td>≥+2.50</td>
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<td>3.5</td>
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<tr>
<td>≥+3.00</td>
<td>1.0</td>
<td>1.7</td>
<td>1.9</td>
<td>2.3</td>
</tr>
</tbody>
</table>

**Mechanisms for Emmetropization**

- What is driving the axial length growth changes toward emmetropia?
  - Many models based on retinal blur
  - Animal studies clearly demonstrate eye growth changes in response to lenses (stopping or increasing growth)
  - The growth response has even been demonstrated regionally, where a “half lens” can cause growth changes on one half of the eye
- But, how much blur is present with hyperopia <4.00D in an infant?

**Mechanisms for Emmetropization**

- Infants have a very large ability to accommodate
- Infants at 3-6 months demonstrate the ability to accommodate as accurately as older children
- Recent studies show that a simple model of retinal defocus (blur) does not account for the amount of refractive change during emmetropization

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**Mechanisms for Emmetropization**

- Accommodative effort may be a stronger visual signal for emmetropization in hyperopia
- Infants who emmetropized showed a good accommodative response; infants who showed the least robust emmetropization showed the poorest accommodative response.
  (OVS 2009; 88:666–676)
Effect of Hyperopia on VA

- Visual acuity with habitual Rx, without habitual Rx, and Uncorrected

![Graph showing visual acuity with and without correction]

Effect of Hyperopia on VA

- What effect does uncorrected hyperopia have on near VA?
- What effect does uncorrected hyperopia have on near accommodative responses?
  - No Correction: Correlation between RE & Accommodative Lag
  - With Correction: No Correlation
- Conclusion: Hyperopic correction may be effective in reducing accommodative lag

HYPEROPIC LENS PRESCRIPTIONS

- Hyperopia associated with orthophoria at far and near:
  - Where does significant blur start?
- Consider the power based on near accommodative skills
- Accommodative accuracy a better indicator?

Case #1

- 18 mo. old; routine vision exam
- VA: 20/50 OD/OS with PL
- Cover Test: orthophoria at far & near
- M.E.M.: +0.50D O.U.
- Refraction: +3.00 DS O.U.
- Management: monitor/follow-up in 6 mo.
Case #2

Age = 18 mo.; main concern is eyeturn
VA: 20/100 OD/OS with PL
Cover Test: Intermittent ET' of 15-20°
M.E.M.: +1.25D O.U.
Refraction: +3.00 DS O.U.
Management: prescribe per guidelines

Trends vs. Individuals

Hyperopia associated with esodeviations

- General strategy for achieving binocular vision (BV)
- Guidelines to remember for first Rx:
  - Full cycloplegia, if 5 yrs or younger
  - Cycloplegia less 1D, if 6 yrs or older

Hyperopia associated with esodeviations

- Reduction in deviation size via the AC/A ratio
  - High AC/A
  - Normal or Low AC/A
  - Reduction in deviation size so that VT is possible
  - Stabilize accommodation

Hyperopia associated with esodeviations

- General guidelines for prescribing a bifocal
  - Bifocal goals
    - Acceptance of full plus when the ametropia was under- or uncorrected at far
    - Reduction in deviation size via the AC/A ratio

Case #3

cc 10Δ RET, 30Δ RET'; PD = 50mm
AC/A = PDcm / 0.4 (algebraic diff. in <Ds)
= 5cm / 0.4 (20) = 13Δ / +1.00
Expected vergence response:
EVR = 0.8 x 13 = ~10Δ
Add to prescribe for “ortho” would be +3.00
Add to equalize the far and near angle size would be +2.00
Case #4

c c 10° RET, 10° RET') PD = 50mm
AC/A for a basic angle = PD cm = 5° / +1.00
EVR = 4° / +1.00
➢ Add to eliminate eso at near = +2.50
➢ Add if combined w/ 4° BO = +1.50

Hyperopia associated with esodeviations

● General guidelines for prescribing a bifocal
  ✓ Fitting bifocal segment appropriately
  ✓ Age guidelines for type and height:

Hyperopia associated with esodeviations

• Consider the working distance of the add when deciding how much power can be worn satisfactorily.
  ✓ The highest powers usually prescribed are:
    ➢ +2.50 with a working distance of 40 cm
    ➢ +3.00 with a working distance of 33 cm

Bifocal Guidelines

Under 2 years: Intermediate or near SV
3 to 5 yrs: FT 35 or round seg; Set @ mid-pupil
6 to 8 yrs: FT 35 or round seg; Set @ lower pupil margin*
9 and older: Optional @ lower lid margin
*Raise to mid-pupil if compliance is doubtful

Hyperopia associated with esodeviations

• Prescribing PALs for children
  ✓ PALs are successfully worn in place of a conventional bifocal
  ✓ Fitting modifications for children
    ➢ Increase power by up to +0.50D
    ➢ Raise up to 2 mm above mid-pupil
    ➢ Train on use:
      ➢ Tape off top portion + near activities (30 min/day)
Hyperopia associated with exodeviations

- General strategy for achieving BV
  - Prescribe the minimum plus
  - Paradoxically, often in higher amounts of hyperopia, refractive compensation will improve alignment

HYPEROPIA QUESTIONS?

MYOPIC LENS PRESCRIPTIONS

- Clinical Considerations
  - How much do we expect the myopia to change with age?
  - Studies indicate a shift toward emmetropia from birth to 12-18 months, therefore prescribing for "transient" myopia is not desirable.
  - This often necessitates more than one office visit and consideration of other factors before prescribing.

Developmental Trends: Myopia

SUMMARY OF RESEARCH FINDINGS:
- Prevalence of myopia increases to ~15% between the ages of 6 and 15 years
- Highest prevalence in Asian & Jewish ethnic groups
- Recent Taiwan studies found 21% incidence at age 5 yrs, increasing to 84% incidence at 18 yrs
- Higher incidence in Hispanic populations than in Caucasian and African-American populations

Developmental Trends: Myopia

Risk Factors Associated With Developing Myopia:
- Hereditary: Parent(s) with myopia
  - Genetics: 18 named loci (so far)
  - Collagen Type-II
  - Growth factors and early ocular organization loci
  - Mitochondrial function
  - Intelligence: IQ is higher in myopes
- Near Work: More hours of near work = higher myopia
- Outdoor activity: More hours = protective
Myopia Progression Linked To Hours Of Available Daylight

- 2/4/13 (Ophthalmology): study in Denmark found myopia appeared to worsen in children during the winter months when days are at their shortest. Conversely, the progression of myopia was far less during the summer months with longer days.
  - More outdoor activity?

24 New Genes Associated With Myopia

- 2/10/13 (Nature Genetics): researchers derived data from 32 studies encompassing some 45,000 people to identify 24 new genes linked to nearsightedness
  - The newly identified genes include those involved in brain and eye-tissue signaling, eye structure and eye development
  - The genes give a 10-fold increased risk of having nearsightedness

Myopic Changes: What Happened?

- Axial length changes
  - Equatorial stretching
  - Prolate vs Oblate growth
- Lens thickness changes
  - Growing/adding layers
  - Overall thinning?
- Lens radii changes
  - Net loss of power
  - Role of ciliary muscle

Myopia Changes: Biometric info

- Clinical Considerations
  - Effect of uncorrected ametropia on development
    - Consider the power based on the uncorrected VA at far
    - Consider the working distance for "clearness" when uncorrected
    - Consider the effect on accommodative-convergence when uncorrected

MYOPIC LENS PRESCRIPTIONS
**Age Guidelines for Prescribing**
- **Infants:** Consider Rx at 5 D*
- **Toddlers:** Consider Rx at 2 D
- **Preschoolers:** Consider Rx at 1 D
- **> 5 D:** Rx & monitor frequently

**MYOPIC LENS PRESCRIPTIONS**
- **Clinical Considerations**
  - Effect on binocularity/amblyopia
  - Eso deviations
  - Exo deviations
  - Full correction vs. Partial correction
  - Cut no more than -0.50D
  - Spectacles vs. Contact Lenses
  - Progressive myopia in school ages?
  - Follow-up Evaluations
    - Initial
    - Long term

**Options for Progressive Myopia**
- Near add in bifocal/multifocal
  - Effect appears strongest with EP
- Single Vision spectacle lens designs
- Multifocal CLs (~ +3D add)
- Orthokeratology (CRT)
- Atropine (very low dose = 0.01%)

**Case #5**
- cc 20\(^\circ\) RXT, 5\(^\circ\) XP’ (cc = wet ret)
- PD = 60 mm; Age 7 yrs
- Wet Ret: RE -1.00 DS, LE -1.00 DS
- sc AC/A = 6 + 0.4 (+ 15) = 12\(^\circ\) / +1.00
- EVR = 0.8 x 12 = 9.6\(^\circ\)/1.00 = ~10\(^\circ\)/1.00
- Rx given: Minus overcorrection (2D), OD -3.00 DS & OS -3.00 DS
- Add = +2.00 DS; Referral for VT

**Myopia Questions?**
Clinical Considerations

- Results of developmental research
- Effect of uncorrected astigmatism
  - WTR
  - ATR
  - Oblique

Summary of Research Findings:

- Depending on use of cycloplegia, method of refractive assessment, and ethnicity, incidence of astigmatism in infants is between 17 & 63%.
- Significant loss of astigmatism between 3 & 12 mo.
- Average incidence of astigmatism between 18 & 29 mo.
- Prevalence of astigmatism remains relatively stable at ~10% starting at school age.
- There are variations in prevalence and type of astigmatism by ethnicity that needs further study.

Prevalence and Type of Astigmatism by Ethnicity

- There is considerable variability in the literature about the predominant orientation of infant astigmatism.
  - Many studies find a preponderance of ATR orientation; others report that WTR orientation is more common.
  - Oblique orientations are found in infancy but tend to be the least common orientation.
  - Resolution of astigmatism appears to be a separate process from resolution of the spherical equivalent refractive error.

Age Guidelines for Prescribing

- Infants: Monitor stability; Rx if strab/amb
- Toddlers: Monitor stability; Rx > 1.25 D (3x3 Rule)
- Preschoolers: Rx > 1.25 D
- > 5 D: Rx and monitor

Clinical Considerations

- Effect on binocularity/amblyopia
- Full correction vs. Partial correction
- Spectacles vs. Contact Lenses
- Follow-up Evaluations
  - Initial
  - Long term

Astigmatism Questions?
Clinical Considerations
- Results of developmental research
- Effect of uncorrected anisometropia
  - Hyperopic
  - Myopic
  - Astigmatism
  - Aniseikonia

SUMMARY OF RESEARCH FINDINGS:
- Depending on use of cycloplegia, method of refractive assessment, and ethnicity, incidence of anisometropia in infants is reported between 4 and 7%
- Incidence is ~11% in astigmatic children
- Anisometropia is typically due to axial length differences
- Cross-sectional studies show a stable percentage of infants & toddlers with anisometropia, but longitudinal studies show that different infants & toddlers may be affected at different times.

Developmental Trends: Anisometropia
- Anisometropia can be transient up to age 4 yrs.
- Anisometropia >3.00D tends to persist, and is strongly linked with strabismus & amblyopia
- Children <4 yrs with strabismus are more likely to have an increase in amount of anisometropia, indicating a disruption of emmetropization.
- How much anisometropia does it take to cause amblyopia and/or strabismus?

Spherical Anisometropia

Cylindrical Anisometropia

PRESCRIBING FOR ANISOMETROPIA

Age Guidelines for Prescribing
- Infants: Monitor stability; Rx if strab/amb
- Toddlers: Monitor stability; 3 x 3 rule Rx if strab/amb
- Preschoolers: Rx at initial visit if >1D
- > 2-3 D: +/- Rx at initial visit
### PRESCRIBING FOR ANISOMETROPIA

- Clinical Considerations
  - Effect on binocularity/amblyopia
  - Full correction vs. Partial correction
  - Spectacles vs. Contact Lenses
  - Follow-up Evaluations
    - Initial
    - Long term

### Final Considerations

**For Lens Prescribing**

- Effects on Function and Behavior
- Compliance with Wear
- Compliance with Follow-Up
- Pediatric Eyewear

### Anisometropia Questions?

### QUESTIONS?