

“I warned you about going to that short-sighted doctor
for your sex change operation”

Myopia

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Nature / Nurture

- Genetic?
 - Pre-determined?
 - Tends to run in families
 - Identical twins
 - Pre-disposition?
- Environment?
 - How much can be attributed to environment?

Prevalence

- >80% Hong Kong, Taiwan, Singapore
- USA, Europe 30-50%
- Australia 10-20%

Prevalence in East Asia

- >80% Hong Kong, Taiwan, Singapore
- 5% in rural uneducated groups
- Grandparents Hong Kong 5% (Lam 1994)
- Rural Mongolia 5.8% (Morgan et al 2006)

Myopia: Genetics

- The recent rapid increase in prevalence suggests environmental factors rather than genetic factors are responsible for common myopia
- **Ian Morgan** ANU considering school myopia concludes “most of the evidence suggests that powerful environmental effects are responsible for the rapid changes in prevalence...”. Previous twin studies have confounded shared genes with shared environments and he concludes that **genetic factors are not important in the common myopias**. (Morgan & Rose 2004)
- (Some rare early onset “pathological” myopias are probably genetic)

Conclusion: Nature/Nurture

- Not primarily genetic!
- Environment!
- At least 80% of humankind have the potential ability to go myopic!

Environment

- Sustained near task?
- Restricted visual space?
- Diet?
- Stress?

Intelligence & Personality

- In Western societies a possible genetic factor may be the “intelligence” and “personality” to concentrate for long periods of time on near tasks.
 - Environmental expression of a latent gene? (Mak et al 2006)
- In Asian societies external pressures & expectations from family & peers may result in the same prolonged concentration on near tasks
 - Stress?

Stress & Myopia

Leon Davies, James Wolffsohn et al 2004 Aston

- Accommodation during cognitive stress (number sorting) in myopes & emmetropes. Shin-Nippon auto-refractor, Badal lens, piezo-electric heart rate pulse transducer, Fast Fourier Transform of cardiovascular function to separate parasympathetic from sympathetic. Both groups showed increased accom lag with increased cognitive demand attributed to decreased parasympathetic activity. Myopes showed higher lag than emmetropes. **Myopes showed a greater increase in sympathetic nervous system activity.**

Environment

- Diet?
 - Exacerbated by deficiencies?
 - Toxins?
 - Ameliorated by supplements?

Environment & Diet

- Jewish ultra-Orthodox boys in the same community in Israel have a higher prevalence (70%) & degree of myopia compared to girls and secular school children (30%) (Ben-Simon et al 2004)
- All have similar general environment and diet but the boys have a higher near-task demand
- Task demand more important than ambient environment and diet

Possible Near-task Factors (Asia)

- Sustained near task from an early age
 - Schooling from 3 years of age
 - Long school hours plus homework
 - Computers and computer games
 - Learning Chinese or Japanese
- Restricted Spatial Environment
 - Restricted ambient horizon for 'zero' setting of distance?
 - Small school rooms, small living rooms in high-rise buildings, small playgrounds

Sustained Near-task

- Accommodation?
- Convergence?
- Lid posture & blink pattern?

Further Questions

- What is Emmetropisation?
- What is the difference between a hyperope and a myope?
- If accommodation dysfunction causes myopia, then why don't hyperopes & emmetropes go myopic as they usually have significant accommodation dysfunction?!?

Accommodation in Myopes, Hyperopes & Emmetropes

- Most myopes have accommodation dysfunction
- Most hyperopes have accommodation dysfunction
- A lot of emmetropes have accommodation dysfunction
- The pattern of accommodation dysfunction is similar for all
- Accom lag, lead, infacility, tonic shifts, proximal, hysteresis not consistently & characteristically different in emmetropes that become myopes (Harb et al 2006)

Animal Studies

Chick, Tree shrew, Monkey

- Active emmetropisation mechanism regulates eye growth from birth
- Degraded optical image quality on the retina induces axial elongation myopia
 - Form deprivation (translucent occluder)
- Minus lenses (hyperopic blur) induce axial elongation myopia
- Plus lens (myopic blur) stop axial elongation and may induce hyperopia during the growth period (choroid swells and axial growth slows)

Animal Studies

- A relatively short period of clear vision each day inhibits the axial elongation and stabilises the refraction
- Total darkness freezes the refractive state

Isolated Retina can go Myopic

Chicks

Ciliary Nerve section:

- Responses to positive & negative lenses NOT affected

Optic nerve section:

- Does NOT stop axial elongation to Form deprivation or the differential response to plus and minus lenses

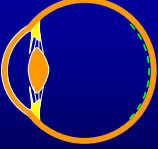
Ref: Wildsoet et al. Vis Res 35: 1175-1194 1995; 1996

Peripheral Retina is Sufficient

Earl Smith 2004 Optometry Houston. Monkeys

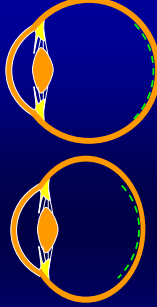
- Form deprivation can induce myopia in adult monkeys as well as infants.
- The minus lens (-3D) or diffuser needs to be maintained 24 hrs/day. 4 X 15 min periods free of lens eliminated myopic effect.
- Diffuser in periphery alone adequate to induce elongation in the foveal region. (Annular diffuser leaving foveal image clear).
- Laser foveal lesion still get emmetropic recovery with hyperopic shift.

Conclusion. Peripheral retina guides emmetropisation and the fovea is NOT necessary.



Eye Shape and Refraction

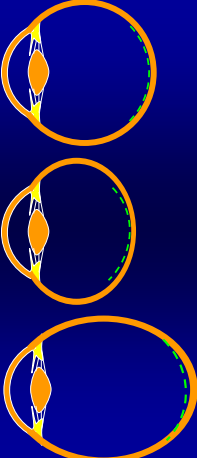
'Simple' Schematic Eye
Spherical retinal image surface
Similar refraction in the periphery



Eye Shape and Refraction

'Simple' Schematic Eye
Spherical retinal image surface
Similar refraction in the periphery

Hyperope & Emmetrope.
Oblate shape
Relatively myopic in the periphery -1D

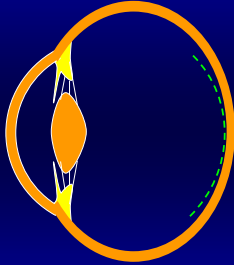


Eye Shape and Refraction

'Ideal' Schematic Eye
Spherical retinal image surface
Similar refraction in the periphery

Hyperope & Emmetrope.
Oblate shape
Relatively myopic in the periphery -1D

Myope.
More Prolate shape
Some less oblate, some spherical
Relatively hyperopic periphery
About +1D



Emmetroptic Oblate Shape is Stable & Functional
Periphery more myopic (-1 D)

- When the fovea is clear in the distance, peripheral objects that are nearer will also be clear
- When the periphery is clear in the distance, the fovea is slightly hyperopic so ensuring good far distance vision
- These clear sharp images on the peripheral retina ensure a stable non-myopic refraction

Prolate Retina Drives Myopia. Periphery more hyperopic

- If the fovea is clear in the distance, the peripheral retina is constantly blurry. This blur will stimulate axial elongation until the peripheral retina comes clear. At this point the fovea will have myopic blur
- Correction with a spherical lens (bottom) restores hyperopic periphery and restarts the axial elongation myopia cycle

From Atchison et al 2005

Eye Shape & Peripheral Retina

Eye shape measurements

- Partial Coherence Interferometry
 - eg Zeiss IOL Master
- 3-D MRI
- A-scan ultrasound (Not as accurate)

References

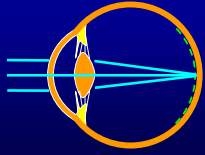
- Stone et al Ann Acad Med Sing 2004
- Stone et al IOVS 2004
- Logan et al OPO 2004
- Atchison et al IOVS 2004, IOVS 2005

Peripheral Refraction

- Free-space autorefractors with peripheral fixation targets
 - Shin Nippon free-space auto refractor can measure out to 20-30 degrees nasal & temporal.
 - Can also objectively measure accommodation at near, dark focus & proximal factors using pin-holes in infra-red filters

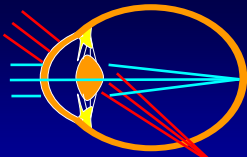
Shin-Nippon NVISION-K 5001

Peripheral Refraction Factors



'Ideal' Schematic Eye

Spherical retinal image surface
Similar refraction in the periphery

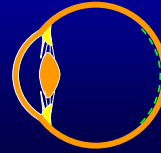


'Real' Eye

Peripheral refraction will be different to foveal refraction. Peripheral cornea, oblique lens, peripheral retina. Accommodation efforts may have a different effect on peripheral image quality than subjectively perceived on the fovea. 'Blur' on the fovea may be clear in the periphery and 'clear' on the fovea may be blurry in the periphery

Eye Shape and Accommodation

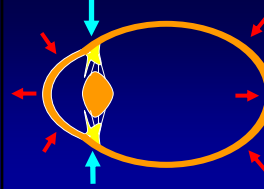
Exaggerated & Diagrammatic Howell



'Ideal' Schematic Eye

Accommodation

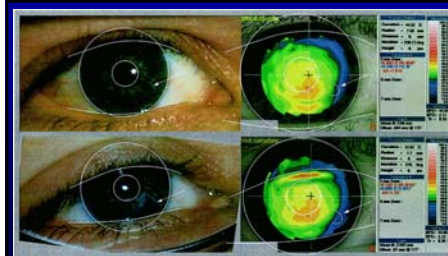
Ciliary muscle insertion pulls on the sclera & choroid
Retina more prolate in shape (Walker & Mutti 2002)
Cornea higher central power?
Cornea more prolate?
Increased on-axis aberrations
Increased peripheral aberrations?



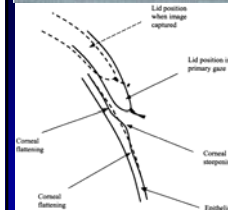
Monochromatic Wave-front Aberrations.

Each can be Plus or Minus

- First order: Prism
- Second order: Spherical & Astigmatic error
- "Higher order"
- Third order: Coma
- Fourth order: Spherical aberration
- Field distortion etc
- Usually measured on foveal axis
- Also chromatic aberration
- Aberrations increase the depth of focus of the normal emmetropic eye. Normal eye is 'multi-focal' & probably beneficial
- All aberrations are higher in myopic eyes & not necessarily beneficial



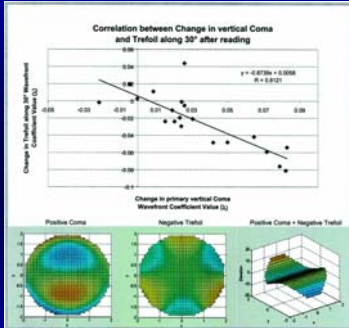
Effect of lid pressure on corneal topography during 1 hr reading



- Down gaze posture reduces palpebral aperture. Lid distorts epithelium
- Induces higher aberrations

Beuhen et al 2001, 2003

Lid induced Aberrations



- Positive coma & negative trefoil add to produce a “wave-like” distortion
- Worse with “squinting”? (Myopes!)
- Worse in Asian eyes? (Genetic factor in Asian myopia prevalence?)

Beuhen et al 2003

Summary

- Axial elongation is triggered by ‘hyperopic’ blur on the peripheral retina persisting over a 24 hour period
- ‘Blur’ on the fovea may not be as important as blur on the peripheral retina
- Periods of ‘clear’ vision on the fovea, either in the distance or near may not be sufficient to stop the axial elongation
- The peripheral ‘blur’ may be a combination of spherical, astigmatic, third order coma & fourth order spherical aberrations

- This image degradation could be caused by sustained accommodation while maintaining protracted concentration on near tasks
- May be worse in down-gaze
- May be worse in restricted space environments

A Model for Myopia

Howell 2006

- Hyperopic & emmetropic eyes are oblate. This provides a stable refractive structure
- ‘Blur’ on the peripheral retina sustained for all waking hours will initiate axial elongation of the posterior pole
- A hyperopic eye will emmetropise to the plane of the furthest clear image on the peripheral retina. A restricted environment will produce a more myopic eye
- NORMAL ciliary m., EOM, & lid muscle activity causes blur and aberrations on the peripheral retina. This blur may take time to resolve after a sustained near task.

A Model for Myopia II

Howell 2006

- If the near-task & post-task blur is maintained all day then axial elongation myopia will be triggered
- This axial elongation will change the oblate eye shape in a prolate direction. If the eye becomes prolate then the only stable state is a clear image on the peripheral retina & myopic blur on the fovea
- Correction with minus spheres will destabilise this & precipitate more elongation
- 'Squinting' to clear the foveal myopic blur may blur the periphery & initiate myopic elongation

Myopia Management

Drugs

- Atropine & pirenzepine are very effective in controlling myopia progression.
- Probably act directly on the retina-choroid-sclera as well as accommodation
- Probably need to be maintained throughout myopia risk period. Long-term side effects?

Surgery

- Lasik corneal reshaping
 - Aspheric wave-front aberration guided?
- Implants?
 - Intra-corneal, Anterior chamber

Contact Lenses

RGP

- Mould & maintain corneal surface profile
- Protect from lid distortions?
- Ortho-K central flattening & peripheral steepening

Soft lenses

- Concentric multi-focal contact lenses could correct peripheral hyperopia as well as assist accommodation
- Aspheric design could correct undesirable higher order aberrations

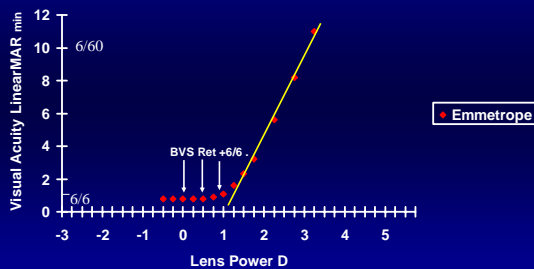
Lens Prescribing for Myopia Distance Correction

- Over minus in the distance may stimulate further myopia
- Significant under correction in the distance may stimulate further myopia (Chung et al 2002, expt'l group kept at worse than 6/12 acuity). This blur may initiate 'squinting' that results in increased myopia
- 'Slight' under correction may stabilise the refraction?

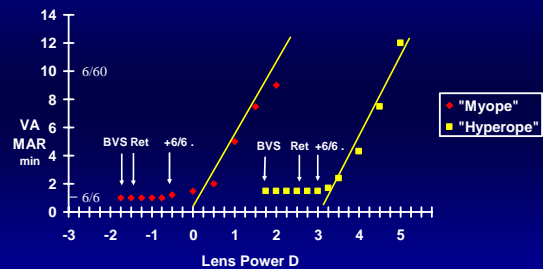
Refraction & Myopes

- Myopes tend to "ask" for greater minus than necessary for good acuity (Radhakrishnan et al 2004 attribute this to higher minus 4th order spherical aberrations in myopes)
- This is particularly observed in auto-refractors, phoropters and for low light levels

Blur Function (Howell)



Blur Function



Multi-focals and Myopia

- Multi-focals significantly reduce the progression of myopia
- Effect is greater for esophoric myopes with accommodation insufficiency at near
- Multi-focals provide plus 'correction' of the peripheral hyperopia in the lower field
- Multi-focals may assist with asthenopia & fatigue independent of myopia progression

Multi-focal Clinical Trials:

Leung & BROWN (Optometry & Vision Science 76 June 1999)
Hong Kong Polytechnic University

After two years, the mean spherical increase in myopia and axial length measured:

Group	No.	Sphere Incr.	Axial Length
Single Vision 0.74mm	32	- 1.23	+
ADD +1.50	22	- 0.76	+ 0.49mm
ADD +2.00	14	- 0.66	+ 0.41mm

Multi-focal Clinical Trials: COMET Study USA

Gwiazda et al IOVS 2003, 2004, Arch Ophthalmol 2005

- 469 children, 234 SV, 235 PAL
- Change over 3 years: Statistically significantly less myopia progression with PAL lenses
- PAL's showed the greatest ethnic effect in Asian children (reducing the progression by 0.39D over 3 years)
- Esophores with accommodation lag showed the greatest benefit with PAL lenses
- COMET2 has been announced to further investigate the esophoria group
- Greatest rate of myopia progression in 6-7 year old age group

COMET Trial

Myopia progression over 3 years

Group	PAL	SV	PAL Benefit
Whole	-1.28D	-1.48D	0.20D
Asian	-1.22D	-1.61D	0.39D
Esophore	-1.08D	-1.72D	0.64D

Myopia Prescribing

- Myopes that are progressing and/or have accommodation dysfunction should be prescribed a near add
- The myopes with esophoria at near and accommodation dysfunction may respond better to treatment than those with exophoria
- The near add should firstly improve the accommodation and convergence control resulting in less asthenopia and fatigue. Secondly, the progression of the myopia may be reduced.

Prism and Myopia

- Single vision spectacle lenses can have significant induced prism for directions of gaze away from the optical axis

Vertical prism

- Typically the distance line of sight is above datum in a spectacle frame. This would induce Base Up prism in each eye for minus lenses.
- Most people find Base Up yoked prism more "Stressful" and uncomfortable whereas most people find small amounts of Base Down prism tolerable and sometimes relaxing.
- Base Down will tend to lift the eyes and widen the palpebral aperture
- High power single vision lenses should fitted on distance height rather on the frame datum.
- Multi-focal lenses correctly fitted for height do not have this problem.

Final Spectacle Prescription for Myopia

- Prescribe the distance refraction that is just acceptable or slightly blurry in the distance.
- Preferably the balanced plus-to-first-blur (6/6, 20/20, 1.0) if the patient is prepared to accept that value.
- If not acceptable, then prescribe the minimum minus that is acceptable. Do not prescribe excessive minus as it may make accommodation worse and increase the myopia progression.
- Plus add +1.50D (eg SOLA MC Myopia Control lens)
- Consider Base Down yoked prism component. (<3 PD OU)

General Reference & Review

Josh Wallman & Jonathan Winawer 2004
Neuron 43: 447- 468
Homeostasis of Eye Growth and the
Question of Myopia



Ayers Rock Central Australia