# Does the cornea take part in the accommodation of the myopic eye?

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**Introduction.** According Helmholtz's theory of accommodation, during near vision there are the follows changes in human eyes: contraction of ciliary muscle, pupil narrowing, decrease of anterior chamber depth, shifting the lenses somewhat anteriarly and downwards, weakening of the tension of Zinn ligaments, decrease of the curvature of anterior and posterior surface of lens.

**Aim:** to study change of corneal refraction during accommodation in children and teenagers with myopia and in young patients after refractive surgery "LASIK" and "PRK".

**Material and methods.** 68 people (135 eyes) were examined. Patients were divided into 4 groups.

- 1st group – 34 patients (67 eyes) aged 8–15 with low myopia.
- 2nd group – 7 patients (14 eyes) aged 8–15 years with moderate myopia.
- 3d group – 16 patients (32 eyes) aged 19–32 examined in different periods after eximer refractive surgery "LASIK". In this group before surgery moderate myopia was detected in 20 eyes, high myopia – in 12 eyes.
- 4th group – 11 patients (22 eyes) aged 19–32 examined in different periods after refractive surgery "PRK". In this group before surgery moderate myopia was detected in 18 eyes, high myopia – in 4 eyes.

All patients were examined using Grand Seiko Binocular Open Field Autorefkeratometer WR-5100 (Fig. 1).

Firstly refraction was determined **in far distance** (fixation target was situated in 5 m) (Fig.1). After it, spherical and cylindrical lenses were put in test frame, which completely corrected refraction errors, and the measuring of refractive power was repeated. It was necessary for stimulate accommodation's response to the target situated on 33 cm from the eye of patients with myopia of different degrees.

Measuring of corneal refraction (**CR**) **during accommodation** (**near distance**) was performed in the same lenses. It allowed excluding systematic errors induced by lenses when we calculated the difference between refraction on 5 m and 33 cm. After it, in front of each eye the text №4 from the table for near vision was put on 33 cm and autorefkeratometry was performed for each eye separately (Fig. 2).

Different CR during gaze fixation at far distance (5 m) and near (33 cm) should testify the participation of the cornea in accommodation of the eye.

**Results.**

*1st group (low myopia)*
Far distance: CR=47.02±0.25 D
During accommodation (-3 dptr) at the 33 cm target: CR=46.93±0.24 D.
Average CR decrease =0.09 D:

- decrease of CR by 0.01–4.95 D (in average 0.53 D) – in 34 (51%) from 67 eyes
- increase of CR by 0.01–2.94 D (in average on 0.44 D) – in 32 eyes
- in 1 eye CR did not change (Table 1).

*2st group (moderate myopia)*
Far distance: CR=50.74±0.72 D
During accommodation (-3 dptr) at the 33 cm target: CR=50.31±0.56 D.
Average CR decrease =0.43 D:

- decrease of CR by 0.25–4.45 D (in average 1.15 D) – in 7 (50%) from 14 eyes
- increase of CR by 0.08–0.63 D (in average on 0.28 D) – in 7 eyes (Table 1).

*3rd group (LASIK)*
Far distance: CR=38.83±0.32 D (without optical correction)
During accommodation (-3 dptr) at the 33 cm target: CR=38.64±0.34 D.
Average CR decrease =0.19:

- decrease of CR by 0.01–4.94 D (in average 0.53 D) – in 18 (56%) from 32 eyes
- increase of CR by 0.01–2.94 D (in average on 0.44 D) – in 14 eyes (Table 1).

*4th group (PRK)*
Far distance: CR=38.18±0.70 D (without optical correction)
During accommodation (-3 dptr) at the 33 cm target: CR=38.29±0.78 D.
Average CR decrease 0.11:

- decrease of CR by 0.08–0.71 D (in average 0.26 D) in 11 (50%) from 22 eyes
- increase of CR by 0.08–1.93 D (in average on 0.47 D) in 10 eyes
- in 1 eye refraction did not change (Table 1).

In 3rd and 4th groups, where biomechanical properties of the cornea were disturbed due to keratorefractive surgery, the change of CR during accommodation was also statistically insignificant (as in myopic children with intact cornea).

Some difference between examined groups consisted in the tendency to the **different change of CR in different meridians** (Diagram 1 and Tables 2 and 3).

*1st group (low myopia)*
Horizontal axis: decrease of CR=0.44 D
Vertical axis: increase of CR=0.27 D

*2st group (moderate myopia)*
Horizontal axis: decrease of CR=0.19 D
Vertical axis: decrease of CR=0.35 D

*3rd group (LASIK)*
Horizontal axis: decrease of CR=0.27 D
Vertical axis: decrease of CR=0.11 D

*4th group (PRK)*
Horizontal axis: increase of CR=0.02 D
Vertical axis: increase of CR=0.19 D

**Fig. 1.** Measuring eye and corneal refractive power for far distance.

**Fig. 2.** Measuring eye and corneal refractive power for near distance.

**Table 1.** Corneal refraction (CR) for different distances to the target in examined groups of myopic patients.

| Group | N | CR* for fixation target on distance | | P | t |
|---|---|---|---|---|---|
| | | 5 m | 33 cm | | |
| 1 group | 67 | 47.02±0.25 D* | 46.93±0.24 D* | 0.796 | 0.259 |
| 2 group | 14 | 50.74±0.72 D* | 50.31±0.66 D* | 0.659 | 0.446 |
| 3 group | 32 | 38.83±0.32 D | 38.64±0.34 D | 0.676 | 0.42 |
| 4 group | 22 | 38.18±0.7 D | 38.29±0.78 D | 0.917 | 0.1 |

* – measured in the condition of full corrected ametropia (in average 4.26 D).

**Table 2.** Corneal refraction (CR) in horizontal meridian at different distances to target in myopic patients.

| Group | CR in horizontal meridian*, 5 m | CR in horizontal meridian*, 33 cm | P | t |
|---|---|---|---|---|
| 1 group | 46.48±0.253* | 46.04±0.254* | 0.614 | 0.505 |
| 2 group | 49.32±0.637* | 49.13±0.562* | 0.825 | 0.223 |
| 3 group | 38.36±0,323 | 38.09±0.35 | 0.576 | 0.562 |
| 4 group | 37.63±0.76 | 37.65±0.78 | 0.982 | 0.023 |

* – measured in the condition of full corrected ametropia (in average 3.22 D).

**Table 3.** Corneal refraction (CR) in vertical meridian at different distances to target in myopic patients.

| Group | CR in vertical meridian *, 5 m | CR in vertical meridian*, 33 cm | P | T |
|---|---|---|---|---|
| 1 group | 47.55±0.407* | 47.82±0.262* | 0.52 | 0.645 |
| 2 group | 52.14±0.893* | 51.49±0.782* | 0.563 | 0.586 |
| 3 group | 39.3±0.32 | 39.19±0.34 | 0.676 | 0.42 |
| 4 group | 38.75±0.71 | 38.94±0.78 | 0.86 | 0.18 |

* – measured in the condition of full corrected ametropia (in average 3.22 D).

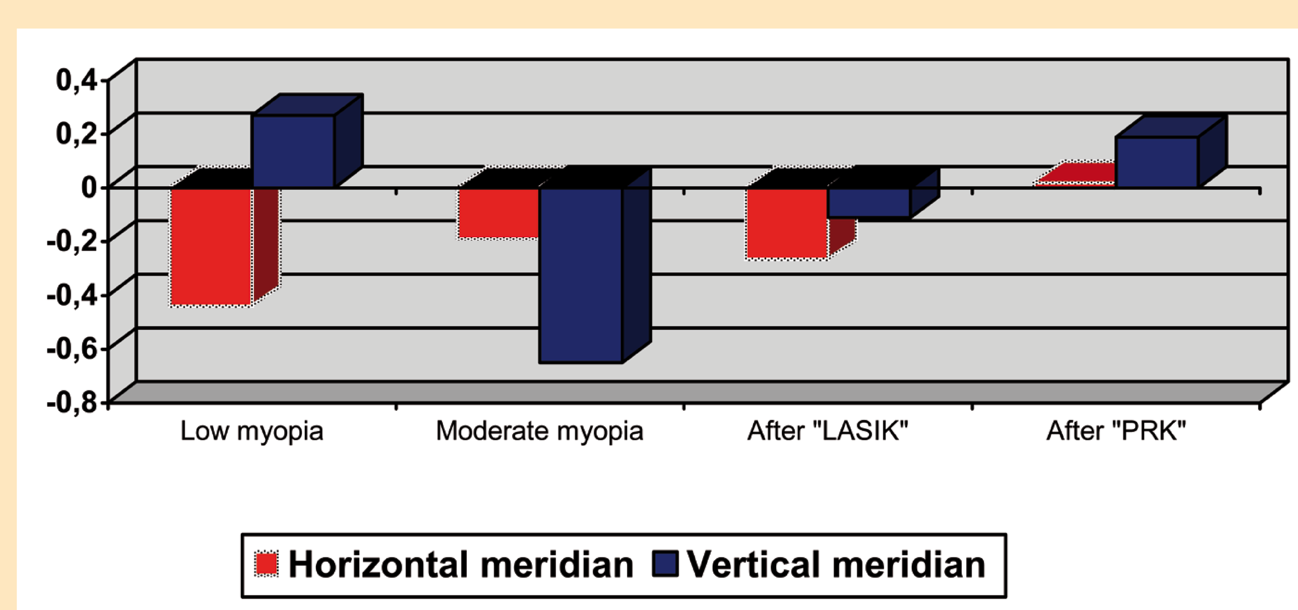


**Diagram 1.** Changing of corneal refraction power during accommodation.

**Conclusions.** Changes of corneal refractive power during accommodation in children and teenagers with low and moderate myopia as well as in young patients with moderate and high myopia after keratorefractive surgery (LASIK and PRK) were not statistically significant. The tendency toward small (insignificant) decrease of corneal refraction in horizontal meridian was revealed. These results do not confirm the meaningful participation of the cornea of myopic eyes in accommodation.

# ORTHOKERATOLOGY AND PERIPHERAL REFRACTION IN MYOPIC CHILDREN

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## INTRODUCTION

- Characteristic peripheral refraction profiles have been found in different refractive groups. Adult myopes typically show relative hyperopia in the periphery whereas adult emmetropes and hyperopes have relative myopia.[1, 2] Similar results have been found in children.[3, 4]
- Peripheral defocus manipulation has been proposed as a possible mechanism of myopia control[5] and orthokeratology (OK) is one method through which this can be achieved.[6, 7]
- OK creates a hyperopic shift in the central 10° to 20° visual field (VF) in myopic adults and thus changes the peripheral refraction profile from relatively hyperopic to relatively myopic.[6,7] It is unknown if the same effect occurs in myopic children wearing OK.
- Apical corneal power change after OK lens wear strongly correlates with central refractive power change[8] and this information is commonly used by clinicians to guide them with OK lens fittings. It is unknown whether the same concept can be applied to para-central corneal power change and peripheral refraction change in OK.

## PURPOSE

- To investigate the peripheral refraction profile in myopic children before and after OK lens wear.
- To determine if there is a relationship between para-central corneal power change and peripheral refraction change after OK lens wear.

## METHODS

### SUBJECTS

- 16 child subjects (age range 11-16 years)
- Inclusion criteria
  - East Asian ethnicity
  - No prior GP lens wear
  - -0.75 to -4.00DS and ≤-1.50DC
  - Good ocular health and no history of ocular injury
- One eye randomly chosen to be fitted with OK lenses (BE; Capricornia Contact Lens, Brisbane) and the other eye fitted with a conventional GP lenses (J-Contour; Capricornia), both in Boston $XO_2$ material
- OK lens worn overnight while GP lens worn during the day
- Lenses both worn over a 3 month period

### MEASUREMENTS

- Non-cycloplegic central and peripheral refraction (Shin-Nippon NVision K5001 autorefractor; Tokyo, Japan)
  - 10°, 20°, 30° and 35° in the temporal and nasal visual fields
- Corneal topography (Medmont E-300; Melbourne, Australia)

### DATA ANALYSIS

- Peripheral refraction and corneal topography analysis
  - Average of 5 refraction measurements at each location, converted to vector components M, $J_{180}$ and $J_{45}$[9]
  - Corneal refractive power analysis along a 4mm chord calculated using Snell's Law at 0.5mm increments
  - RM-ANOVA and Doubly MANOVA, post hoc paired t-tests with Bonferonni correction, critical p-value < 0.05
- Regression analysis to determine the relationship between refractive error change and corneal refractive power change, critical p-value < 0.05
  - Ray tracing determined that refraction measurement taken at 35° nasal gaze corresponds to 1.5mm on the temporal cornea and 35° temporal gaze corresponds to 2.5mm on the nasal cornea.

## RESULTS

### REFRACTION

- M, $J_{180}$ and $J_{45}$ at baseline and after lens wear in the OK lens-wearing eye are shown in Figure 1. M data is also shown in in Table 1.
- No change in peripheral refraction was found after 3 months of GP lens wear (p=0.970).

### CORNEAL TOPOGRAPHY

- Corneal refractive power at baseline and after lens wear in the OK lens-wearing eye are shown in Table 2.
- There was no change in corneal refractive power along the 4mm corneal chord (p=0.768) in the GP lens-wearing eye.

### REFRACTIVE POWER AND M CHANGE

- Decrease in corneal power was correlated with the decrease in myopic refraction at all locations except at 35° nasal VF where there was an increase in corneal power and a corresponding increase in myopic refraction.
- There was a significant correlation between M change and refractive power change after OK at all locations except at 30° and 35° in the temporal VF (Figure 2).

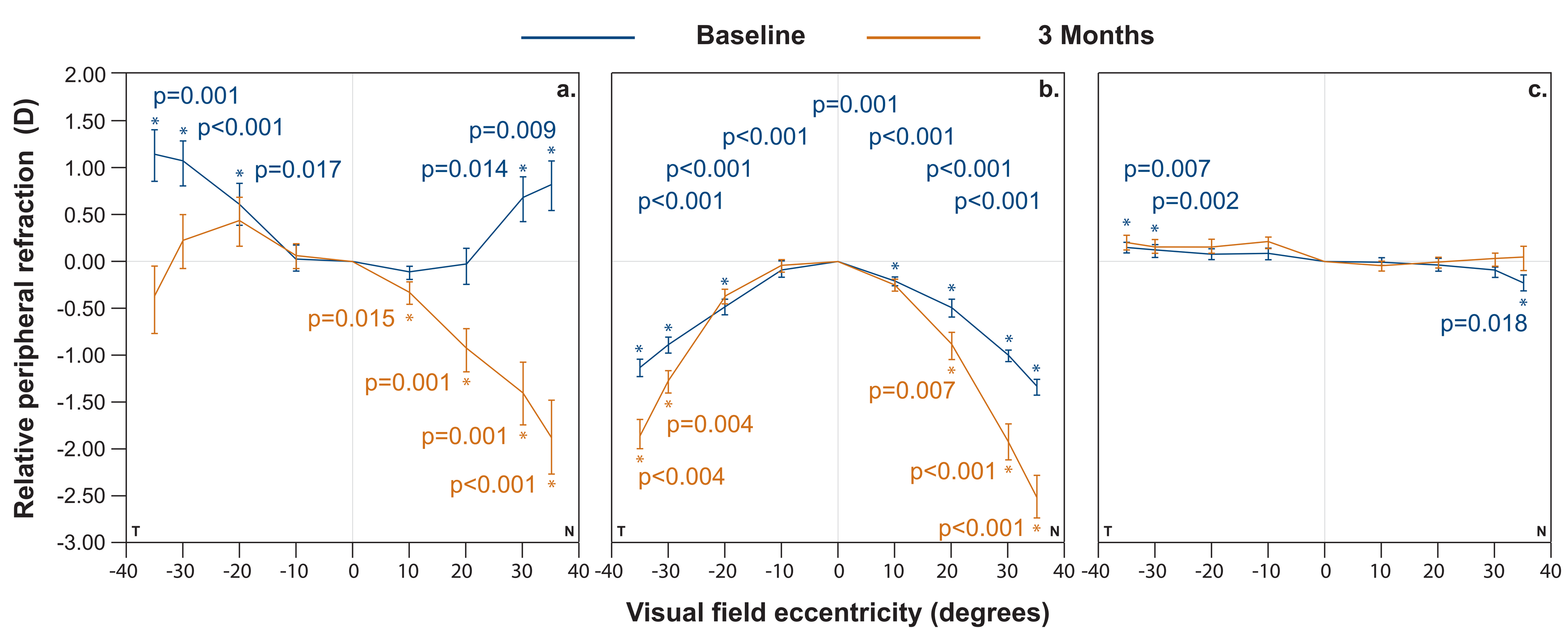


**Figure 1.** Relative peripheral refraction at baseline and after 3 months of OK lens wear for a) M, b) $J_{180}$ and c) $J_{45}$ (D, mean ± SD). T= temporal VF and N = nasal VF. Error bars: 95% confidence intervals of standard error

| | 35°T | 30°T | 20°T | 10°T | Centre | 10°N | 20°N | 30°N | 35°N |
|---|---|---|---|---|---|---|---|---|---|
| Baseline | -1.23 ± 1.23 | -1.31 ± 1.28 | -1.77 ± 1.52 | -2.35 ± 1.10 | -2.37 ± 1.17 | -2.49 ± 1.17 | -2.41 ± 1.24 | -1.70 ± 1.19 | -1.56 ± 1.20 |
| 3 months | -0.95 ± 1.57 | -0.32 ± 1.43 | -0.12 ± 1.59 | -0.48 ± 1.08 | -0.54 ± 0.95 | -0.87 ± 1.16 | -1.47 ± 1.33 | -1.95 ± 1.54 | -2.42 ± 1.59 |
| Difference | 0.28 ± 1.07 | 0.99 ± 0.90 | 1.65 ± 1.27 | 1.86 ± 0.97 | 1.83 ± 1.18 | 1.62 ± 1.01 | 0.94 ± 1.22 | -0.25 ± 1.25 | -0.86 ± 1.29 |
| p-value | 0.319 | 0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.008 | 0.436 | 0.018 |

**Table 1.** M at baseline and after 3 months of OK lens wear (D, mean ± SD). T= temporal VF and N = nasal VF.

| | -1.50 | -1.00 | -0.50 | 0.00 | 0.50 | 1.00 | 1.50 | 2.00 | 2.50 |
|---|---|---|---|---|---|---|---|---|---|
| Baseline | 44.77 ± 1.25 | 44.60 ± 1.22 | 44.69 ± 1.22 | 43.55 ±1.13 | 44.58 ± 1.10 | 44.36 ± 1.09 | 44.43 ± 1.12 | 44.64 ± 1.19 | 44.85 ± 1.21 |
| 3 Months | 42.66 ± 1.65 | 42.48 ± 1.71 | 42.59 ± 1.81 | 41.60 ± 1.84 | 42.77 ± 1.76 | 42.93 ± 1.53 | 43.37 ± 1.48 | 44.26 ± 1.69 | 45.44 ± 1.79 |
| Difference | -2.11 ± 1.12 | -2.12 ± 1.12 | -2.10 ± 1.11 | -1.95 ± 1.12 | -1.81 ± 1.17 | -1.43 ± 1.07 | -1.06 ± 0.93 | -0.37 ± 0.99 | 0.58 ± 0.96 |
| p-value | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.087 | 0.050 |

**Table 2.** Corneal refractive power at baseline and after 3 months of OK lens wear (D, mean ± SD). +ve = nasal cornea and -ve = temporal cornea.

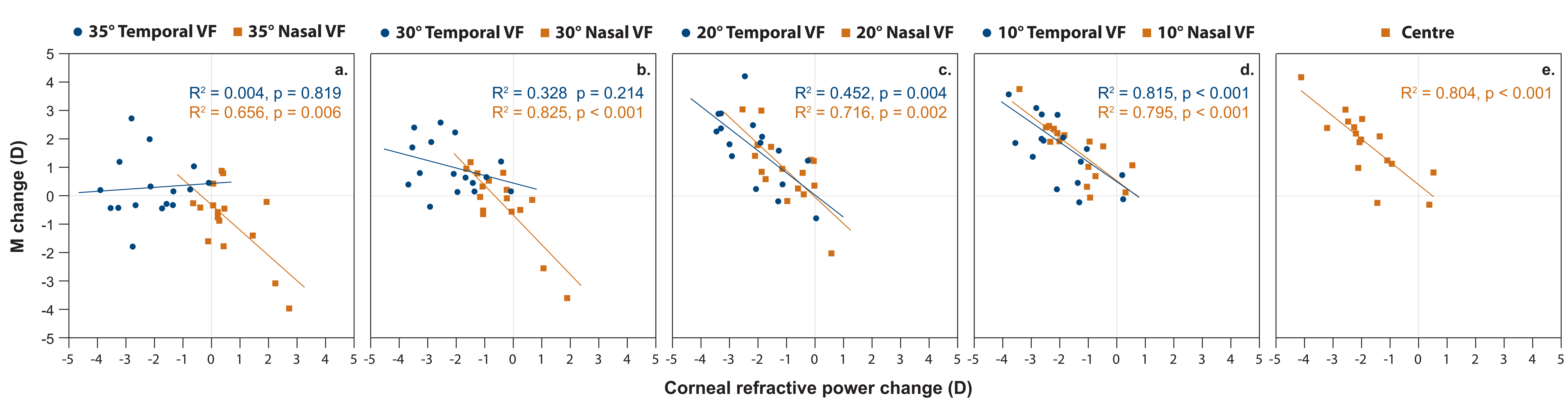


**Figure 2.** The relationship between change in M (D) and corneal refractive power change (D) at a) 35°, b) 30°, c) 20°, d) 10° in the temporal and nasal VF and at e) centre.

## DISCUSSION

- Peripheral refraction was relatively hyperopic in myopic children at and beyond 20° temporal VF and 30° nasal VF, as reported in previous studies.[3, 4]
- OK lenses caused a significant hyperopic shift in M at 10°, 20° and 30° temporal VF and at 10° and 20° nasal VF. Consequently, the peripheral refraction profile changed from relatively hyperopic to relatively myopic in the nasal visual field. Temporal decentration of OK lenses, which is commonly reported, is believed to be responsible for this asymmetry in M across the horizontal meridian.
- There were high correlations between corneal refractive power change and M change at all locations except at 30° and 35° temporal VF. Although there was a significant reduction of corneal refractive power at these locations, this was not reflected in the amount of M change. Further investigation is required to detemine the reasons behind this lack of relationship.
- It has been proposed that inducing a relatively myopic defocus on the peripheral retina of myopic individuals may slow down or prevent the progression of myopia.[5, 6] This study confirms that OK is a procedure by which this can be achieved. There appears to be a relationship between the amount of refractive error change and corresponding corneal topography change.

## CONCLUSION

Peripheral relative hyperopia changes to relative myopia after OK lens wear in myopic children, similar to adults. A strong correlation between peripheral refraction change and corneal refractive power change after OK lens wear was found at all but two temporal VF locations. This study reveals that it may be possible to induce a certain change in peripheral defocus by generating a specific amount of corneal topography change.

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# Changes in peripheral refraction in children of different refractive errors and rates of myopic progression – 6 month results

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## *Purposes*

To determine:

- relative peripheral refraction (RPR) in hyperopes (H), emmetropes (E) and myopes (M)
- RPR changes over 6-month in these 3 groups of subjects
- PR profiles & changes in these eyes showing different rates of refractive changes (ΔSPH / 6M)
  - Fast (F) - ΔSPH / 6M ≥ 0.5D more myopic
  - Slow (S) - ΔSPH / 6M < 0.5D more myopic
  - No-progression (N) - ΔSPH / 6M : no change or more hyperopic in any amount

## *Methods*

- RPR of 96 children (6 – 9 yo) were determined by a Shin-Nippon Nvision 5001K auto-refractor
  - 51 subjects have completed baseline and 6-month (6M) visits
- 5 measurements for each eccentricity measured: ±10˚ intervals from central fixation to 30˚ along horizontal field under cycloplegia

## *Results*

- Myopes – RPR was significantly more hyperopic compared to emmetropes and hyperopes at all eccentricities *(p < 0.05, one-way ANOVA)* ***(Figure 1)***
- Baseline RPR were not significantly different among different progression rate groups *(p > 0.05, ANOVA)*
- Changes in RPR over 6-month were not significant among:
  - the 3 refractive groups at any eccentricity
  - *the 3 progression rate groups at all eccentricities except temporal 30˚*

  *(p > 0.05, one way ANOVA)*
- At ±20˚ and ±30˚ ***(Figure 2)***
  - Fast and slow progression groups – more hyperopic RPR
  - No-progression group – less hyperopic RPR
- No-progression group demonstrated myopic RPR within central 40˚ field
- Emmetropes who ***(Figure 3)***
  - Developed myopia in 6M (ΔMyopia = 0.68D ) – larger increase in hyperopic RPR
  - Remained emmetropic in 6M (Δmyopia = 0.21D) – less increase in hyperopic RPR

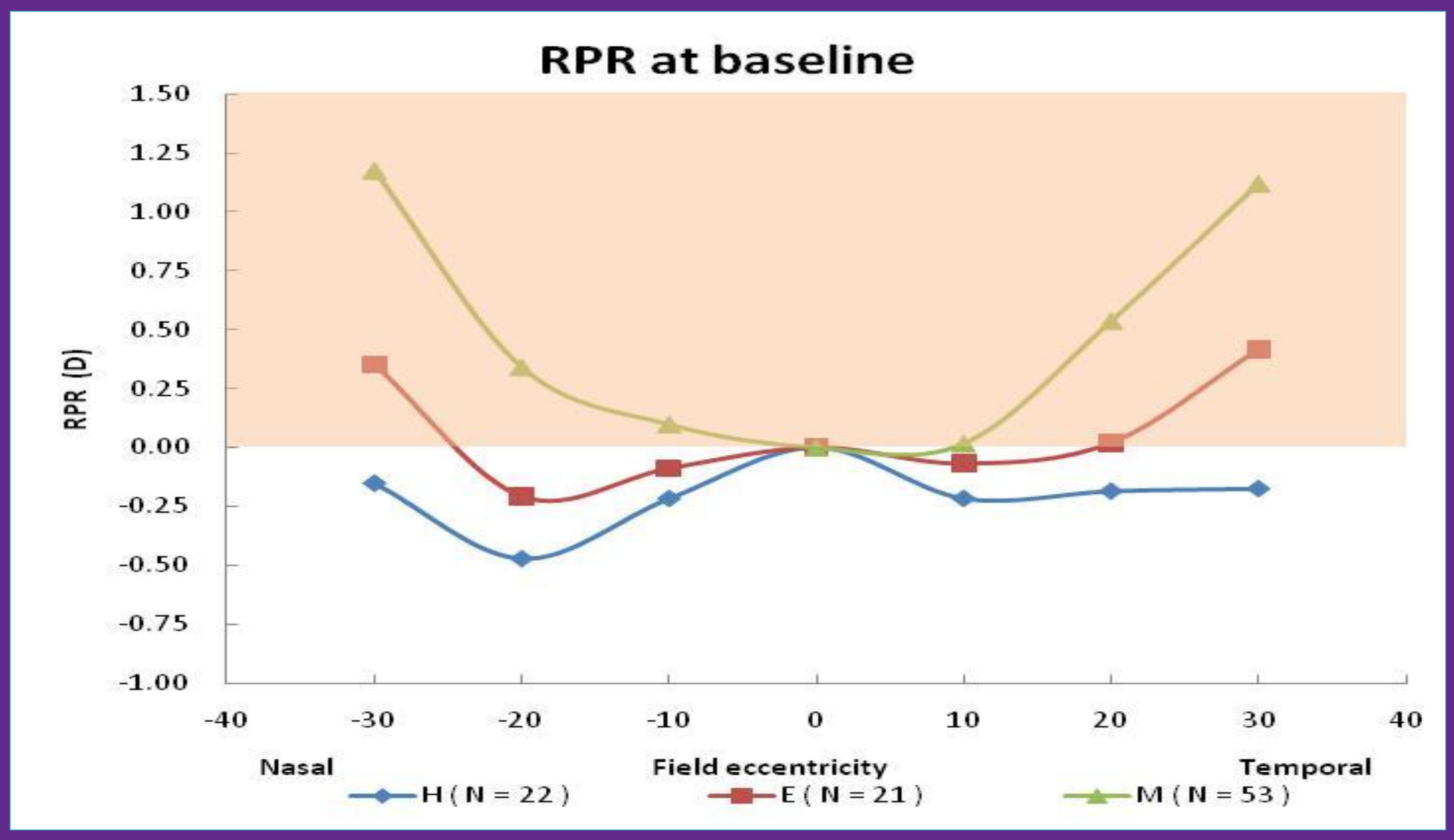


*Figure 1. RPR in hyperopes (H), emmetropes (E) and myopes (M)*

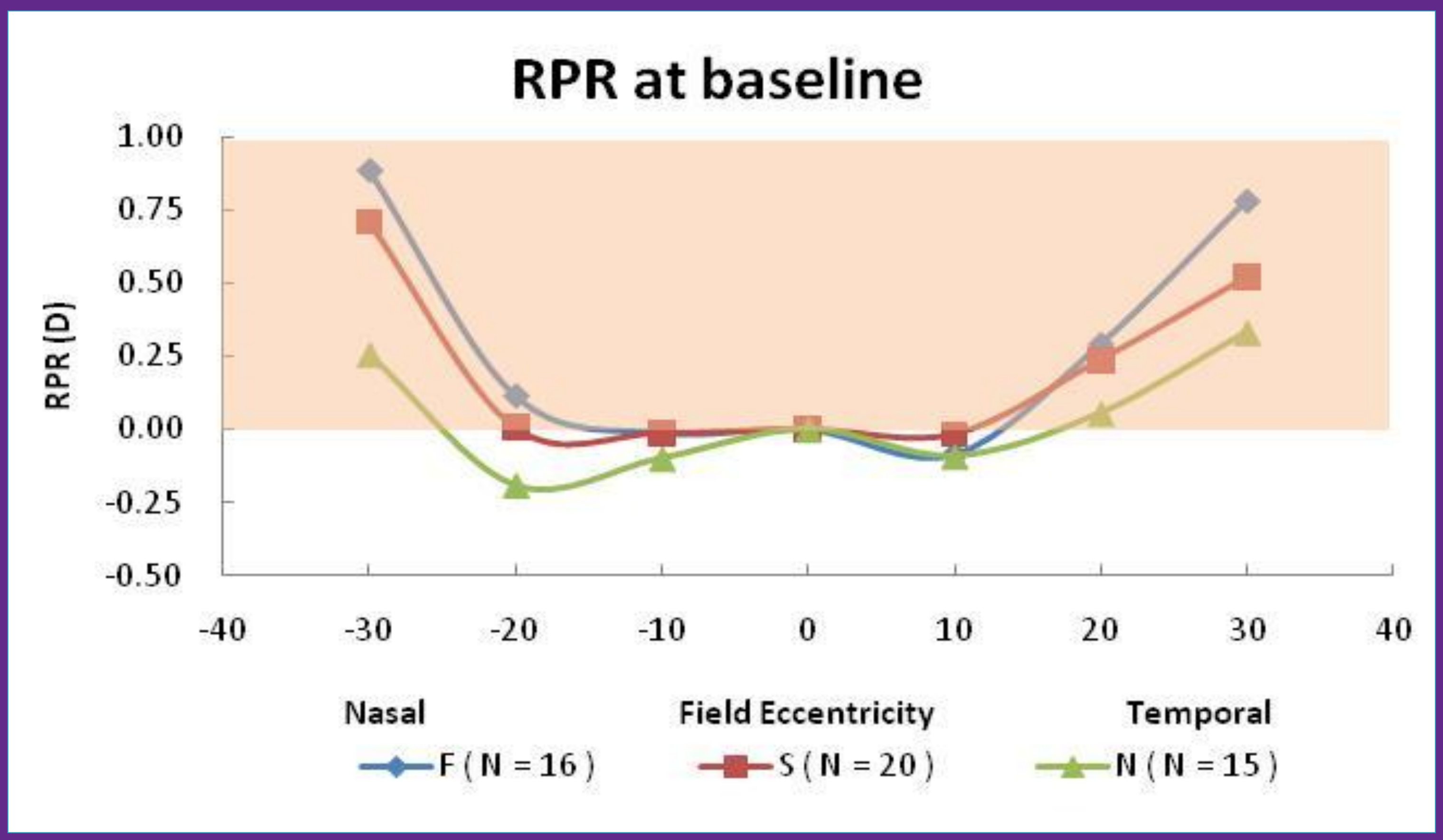


*Figure 2. RPR in fast (F), slow (S) and no (N) progression groups*

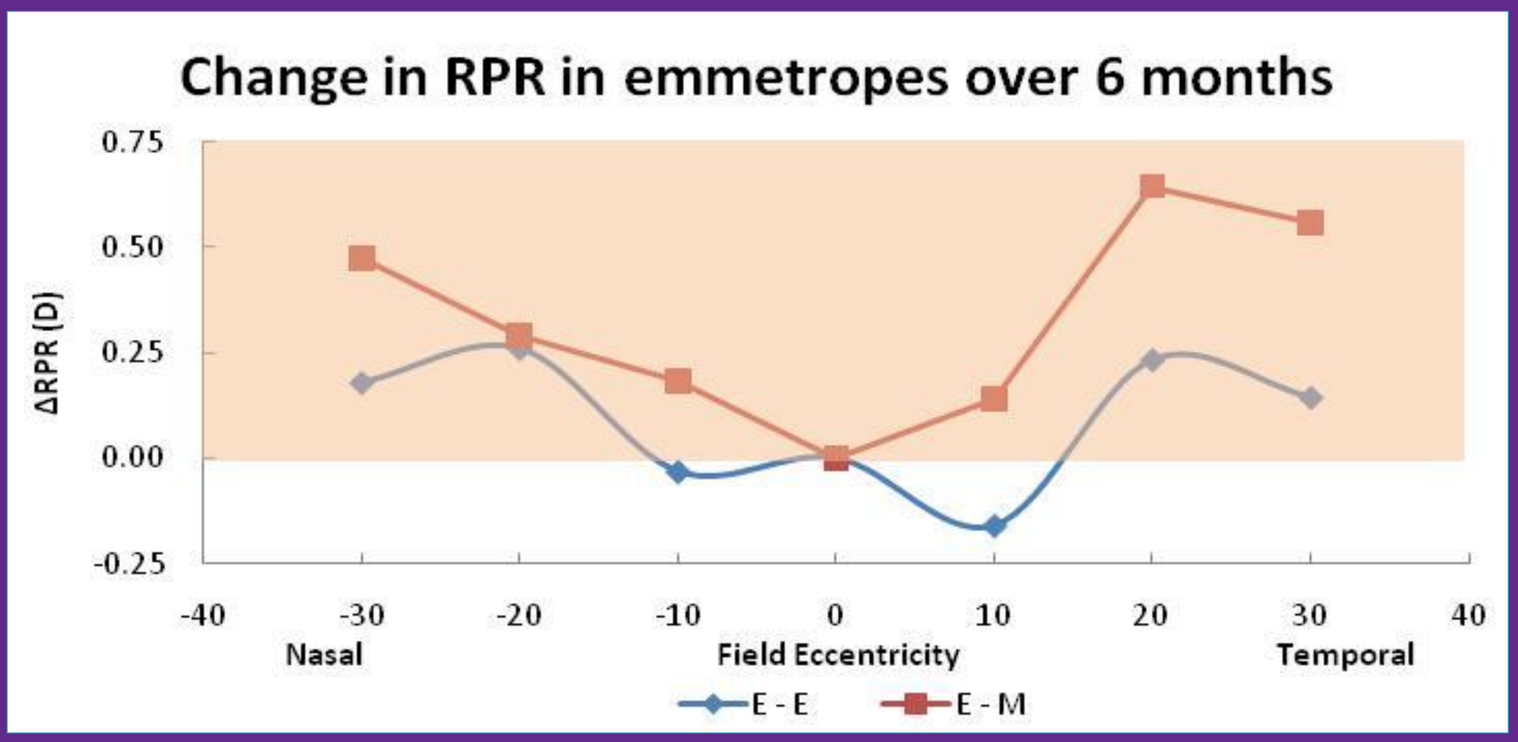


*Figure 3. Change in RPR in emmetropes who became myopic (E – M) and who remained emmetropic (E – E) over 6 months*

## *Conclusions*

- Myopes had a hyperopic RPR profile which was significantly different from non-myopes
- Although RPR and its changes were not significantly different among groups with different progression rates, larger hyperopic RPR were observed with faster progression rate and in emmetropes who developed myopia in 6 months
- PR appears to play an important role in myopic development and progression

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# The Influence of Target Spatial Content and Aberrations on Perceptual Blur Sensitivity

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***Purpose:***

Perception of blur occurs at the edge of a subject's depth of focus. When a target moves outside of our depth of focus, blur is perceived and a change in accommodative response is required to maintain target clarity. Perceptual blur sensitivity is poorer in myopes than emmetropes. Poorer blur sensitivity has been implicated in reduced accommodative accuracy and may contribute to the development or progression of myopia.

In this study, we investigated how the spatial frequency content of a visual target influences blur perception. Effects of high-order aberrations on blur sensitivity were also considered.

***Methods:***

- 13 subjects , all <35 years, 9 myopes and 4 emmetropes (see Table 1)
- Cycloplegic refraction was conducted (2 drops of 1% Cyclopentolate )

| Refractive Error Group | n | Refractive error (mean SD; range) | |
|---|---|---|---|
| Emmetropes | 4 | +0.32DS | 0.3; +0.38D to -0.50D |
| Myopes | 9 | -3.17DS | 2.1; -1.13D to -7.75D |

**Table 1. Refractive error range of each group**

- A paragraph of N10 size Times New Roman text. Text was bandpassed with different spatial frequency filters using MATLAB (see Figs. 1 & 2)
- Subjective depth of focus was found by measuring the proximal and distal limits of just noticeable and non resolvable blur, with the target moving at a constant speed on a motorised track. The targets were presented via a 5D Badal optometer
- Wavefront aberrations were measured using the COAS wavefront aberrometer

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**Figure 1. Text Targets: Bandpass filters for different spatial frequencies**


**Figure 2: Fourier Amplitude Spectra**
A: Unfiltered text B: Bandpass filters

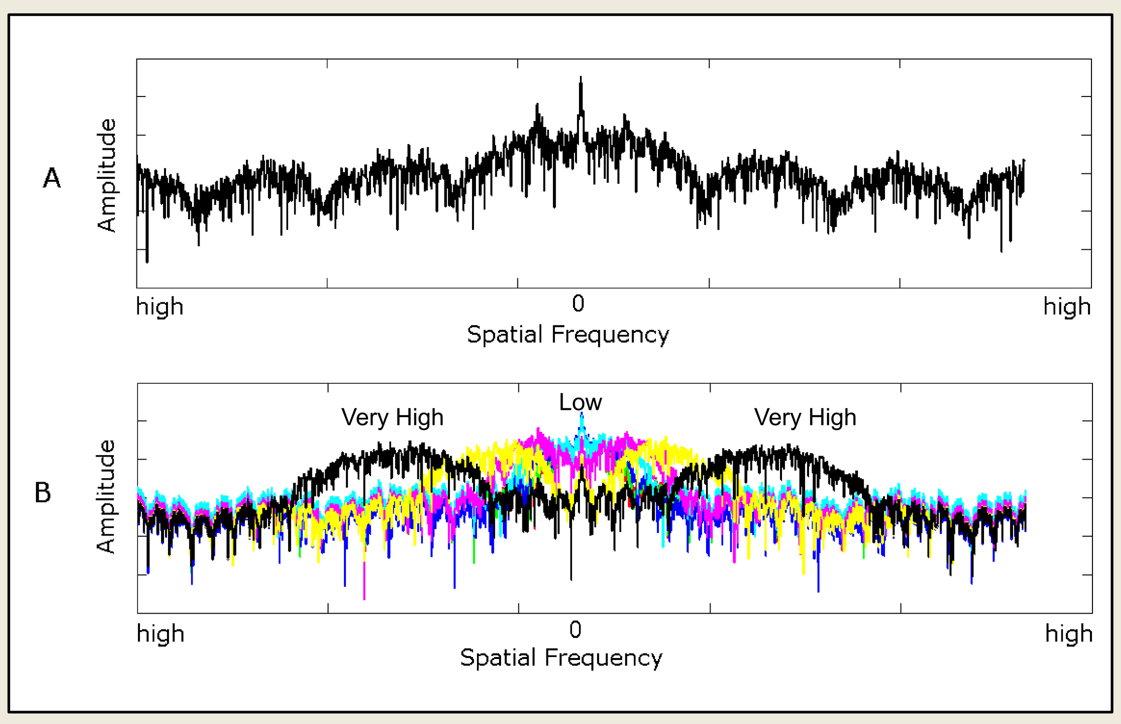
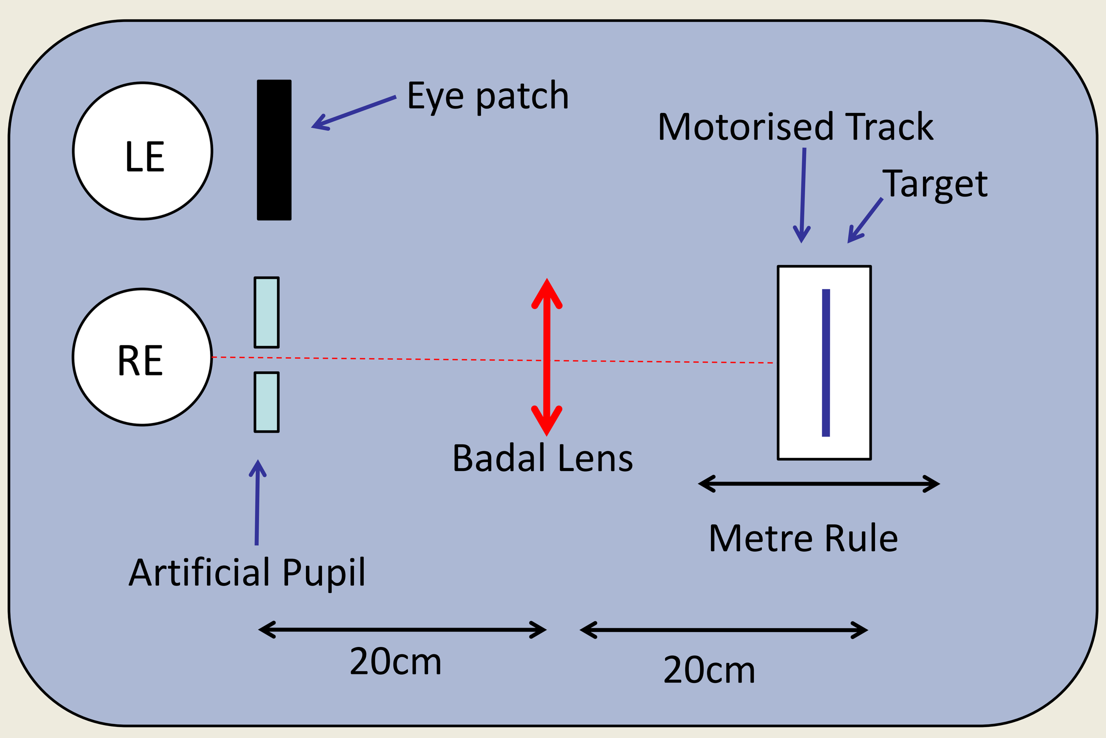


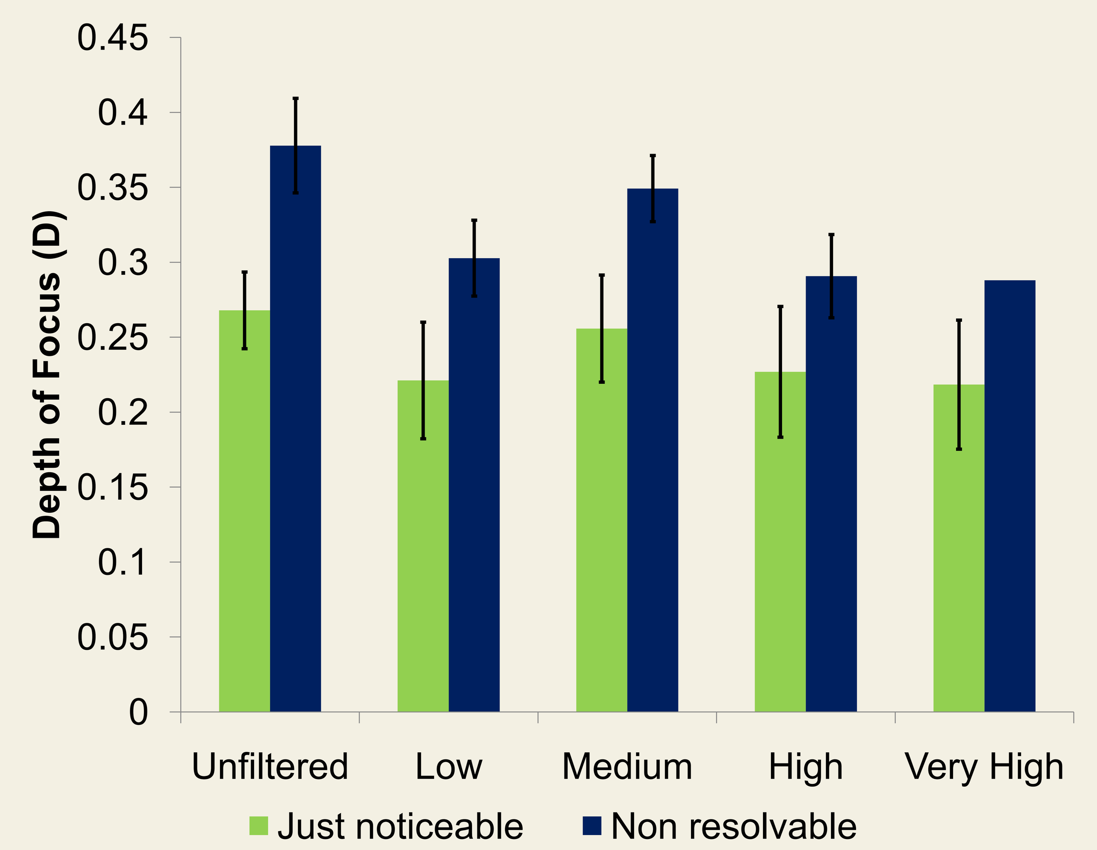

**Figure 3: Experimental set up**




***Results:***

- 1-way ANOVA showed a significant effect of target spatial frequency content on perceptual blur sensitivity pooling myopes and emmetropes ($F(4,44)=5.27$, $p=0.001$). Higher blur sensitivity was obtained with the lowest and highest bandpass filters compared to unfiltered images and with the filter containing the text's peak frequency (see Fig. 4)
- Initial analysis suggest that blur sensitivity is slightly poorer in myopes compared with emmetropes (just noticeable $p=0.27$, non resolvable $p=0.81$); more participants are needed.
- High-order RMS aberrations were significantly correlated with blur sensitivity for just noticeable ($r=0.41$, $p=0.001$) and non resolvable ($r=0.45$, $p=0.001$) respectively
- 3rd order aberration: Z3,-3 was significantly correlated with just noticeable blur sensitivity ($r=-0.39$, $p=0.001$)
- 4th order aberration: Z4,-2 showed a significant correlation to just noticeable blur sensitivity ($r=0.31$, $p=0.011$)

**Figure 4: Subjective depth of focus shown as a function of target observed**




***Conclusions:***

The spatial content of the target was found to influence perceptual blur sensitivity, and was higher when only a narrow band width of high or low spatial frequency information was available. When a range of spatial frequency information was available (unfiltered condition) blur sensitivity was significantly poorer.

# ‚My Europia‘ - structured European education for ambitious young researchers in myopia research

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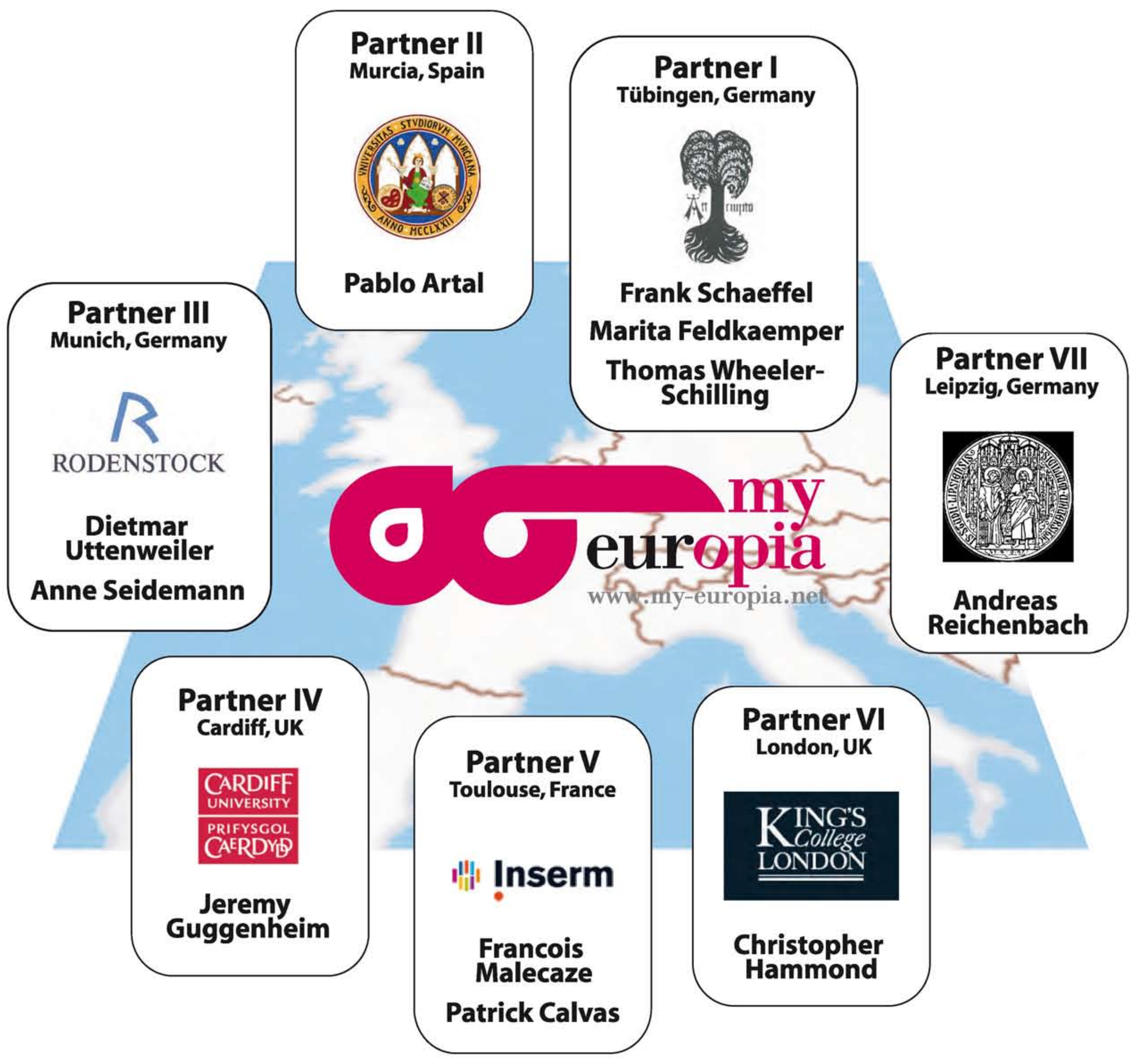
*5: King's College London, UK, 6: University of Leipzig, Germany, 7: Rodenstock GmbH, Munich, Germany*

## Participating Teams




## Research Topics

**Optics**

PARTNER 1, 2 & 3

a. - Design and testing of new spectacle lenses to reduce myopia progression
b. - Development of optical techniques to obtain continuous scans of the refraction across the visual field

**Genetics**

PARTNER 4, 5 & 6

a. - Large scale human screening studies with the goal of mapping new loci on the genome carrying genes linked to myopia development
b. - Testing the inheritance of susceptibility to myopia in chickens

**Signalling Cascade**

PARTNER 1 & 7

Studies on the biochemical signalling cascades in the fundus of the eye controlling axial eye elongation during myopia development & potential ways to interfere with them

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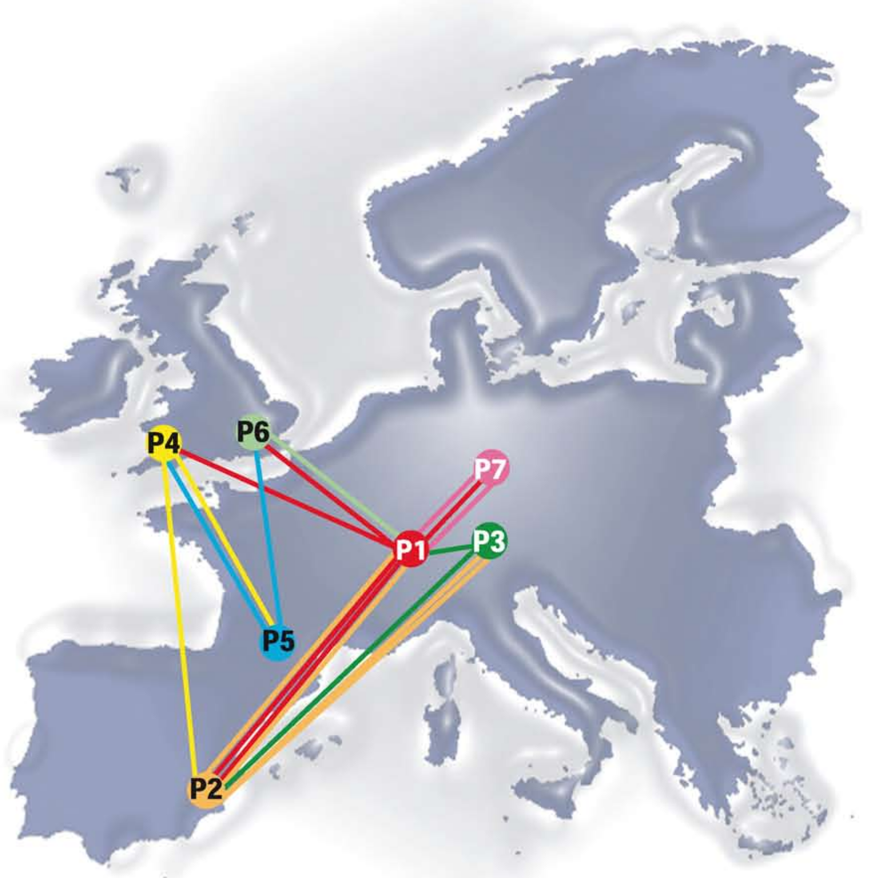
**My Europia - European Training in Myopia Research** is a Research Training Network (RTN) funded by the European Commission since October 2006.
The coordinators of My Europia (Prof. Frank Schaeffel and Dr. Thomas Wheeler-Schilling) realized the need in Europe for a more bundled approach to arrest myopia development.
My Europia's unique consortium is formed by seven partners from four different European countries and their young researchers. Jointly they realize a common goal: To create a European network of expertise in research on myopia, thereby providing an excellent and effective platform for the training of sixteen ambitious PhD and post-doctoral students with different scientific backgrounds.

A high value is set on the training of the young researchers in order to enhance their career prospects. Within My Europia, each of them is provided with a personalised and supervised scientific project. Training, however, is not restricted to 'training-through-research.' It is complemented by a systematic training in additional scientific skills and skills beyond science. Also, to promote transfer of knowledge, ideas and techniques, the young researchers are obliged to undertake lab exchanges.

## Training

### Lab-Exchanges & Summer Schools




**Year 2**
**Tuebingen, Germany**
**F. Schaeffel**
**M. Feldkaemper**

**Year 3**
**Cardiff, UK**
**J. Guggenheim**

**Year 4**
**Murcia, Spain**
**P. Artal**

- ☑ Lectures
- ☑ External Speakers
- ☑ Soft Skills
- ☑ Progress Reports
- ☑ Excursions

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