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The Possible Role of Peripheral Refraction in Development of Myopia

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ABSTRACT

Recent longitudinal studies do not support the current theory of relative peripheral hyperopia causing myopia. The theory is based on misunderstanding of the Hoogerheide et al. article of 1971, which actually found relative peripheral hyperopia to be present after, rather than before, myopia development. The authors present two alternative theories of the role of peripheral refraction in the development and progression of myopia. The one for which most detail is given is based on cessation of ocular growth when the periphery is at an emmetropic stage as determined by equivalent blur of the two line foci caused by oblique astigmatism. This paper is based on an invited commentary on the role of lens treatments in myopia from the 15th International Myopia Conference in Wenzhou, China in September 2015.
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Key Words: image shells, myopia, peripheral refraction

One treatment approach for myopia is based on the principle that peripheral hyperopia leads to the development of myopia; spectacle and contact lenses with excess positive power corresponding to the peripheral field could then prevent or slow the progression of myopia. This approach is based on a misunderstanding of the 1971 Hoogerheide et al. study.[1] It is widely believed that this study found that young male hyperopes and emmetropes with peripheral hyperopia along the horizontal visual field went on to develop myopia. In actuality, peripheral refraction was measured after, rather than before, people did or did not develop myopia.[2]

Several studies in the last decade have found that myopes have relative peripheral hyperopia (i.e. the peripheral visual field is less myopic than the fovea), at least along the horizontal field meridian.[3] However, this refraction pattern might merely be a consequence of the development of myopia rather than evidence that peripheral hyperopia leads to myopia progression. Three recent longitudinal studies compared peripheral refraction patterns of children who did and did not go on to develop myopia.[4–7] These studies did not find that peripheral hyperopia leads to progression of myopia. There was weak evidence in one of the studies that relative peripheral hyperopia was a protection against developing central myopia (Fig. 1).[4]

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The findings of the longitudinal studies have obvious ramifications for the manufacturers of spectacle and contact lenses intended to slow myopia progression by inducing relative peripheral myopia.

Assuming that the peripheral retina has a role in myopia development and progression and if peripheral hyperopia does not lead to myopia, how might peripheral myopia be the trigger? We present two other theories here.

One theory is that the favored state is relative peripheral emmetropia, or perhaps a slight bias towards relative peripheral hyperopia, when the eye is corrected. Fig. 2 shows ramifications for this theory in which the visual system compares the tangential and sagittal image shells (based on refraction along and perpendicular to the visual field meridian, respectively). The balance point, which if achieved will stop growth, might be biased slightly towards the (inner) tangential shell, which is considered the more important because it alters more quickly with changes in optics than the (outer) sagittal shell. The modeling in the figure assumes that the image shells do not change shape and that as myopia develops the retina elongates to become less oblate or more prolate in shape.

In the top left of Fig. 2, a hyperopic eye accommodates to see targets clearly on-axis and the tangential shell is very blurred, stimulating axial growth so that the retinal shape becomes less oblate (or more prolate); accommodation relaxes until the shells are equally clear when the eye is emmetropic as shown at the top right. The middle row shows a situation where the tangential shell is yet more blurred (left) and balance between the shells is not achieved until the eye is myopic (right); a lens treatment involving negative correction in the periphery, somewhere between the emmetropic and myopic states shown here, may be beneficial in stopping myopic

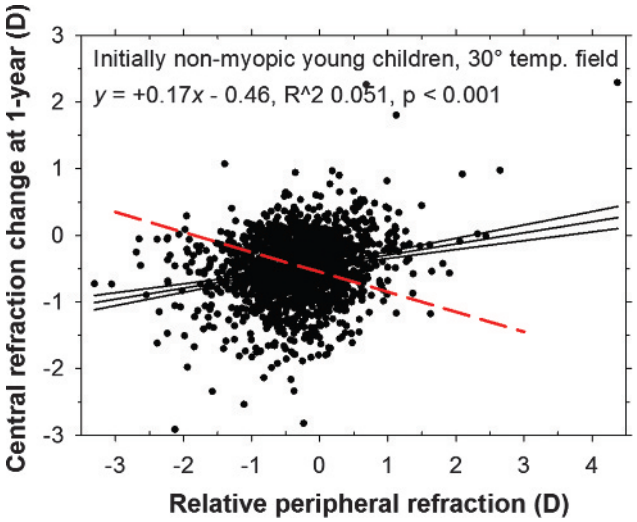

FIGURE 1.

Change in central refraction between baseline and 1 year later for initially 7-year-old children, who were not myopic at baseline, as a function of relative peripheral refraction at 30° temporal visual field angle. Lines are the regression fit and its 95% confidence limits. The dotted red line shows the trend based on the prediction that peripheral hyperopic refraction should lead to myopia. Reproduced with permission from Atchison et al.[4]

progression. Myopia may continue to develop because growth has gone past the point where a balance is possible. There may be a mechanical limitation like the confines of the orbit to stop growth (bottom left), although this limitation is mainly horizontally and not vertically, but otherwise the eye may continue to grow (bottom right). One weakness with this theory is that it does not take into account that eyes have more peripheral myopia (or less peripheral hyperopia) along the vertical than along the horizontal meridian.[3]

Another theory is derived from Wallman's hypothesis[8] of ocular development that retinal activity, such as that provided by high-contrast images, inhibits eye growth. Thibos et al.[9] pointed out that negative spherical aberration combined with lag of accommodation would produce the conditions under which retinal image quality would be poor and would stimulate growth. This idea was extended into the periphery, with some global index of "cone" activity taking into account the sizes and densities of cones across the visual field and optical modulation transfer functions (Thibos L, Liu T. Towards a biological model for detecting the sign of defocus, 15th International Myopia Conference, Wenzhou, China, September 27, 2015). Once present, myopia may continue to develop because growth has already gone past the point where high activity is possible.

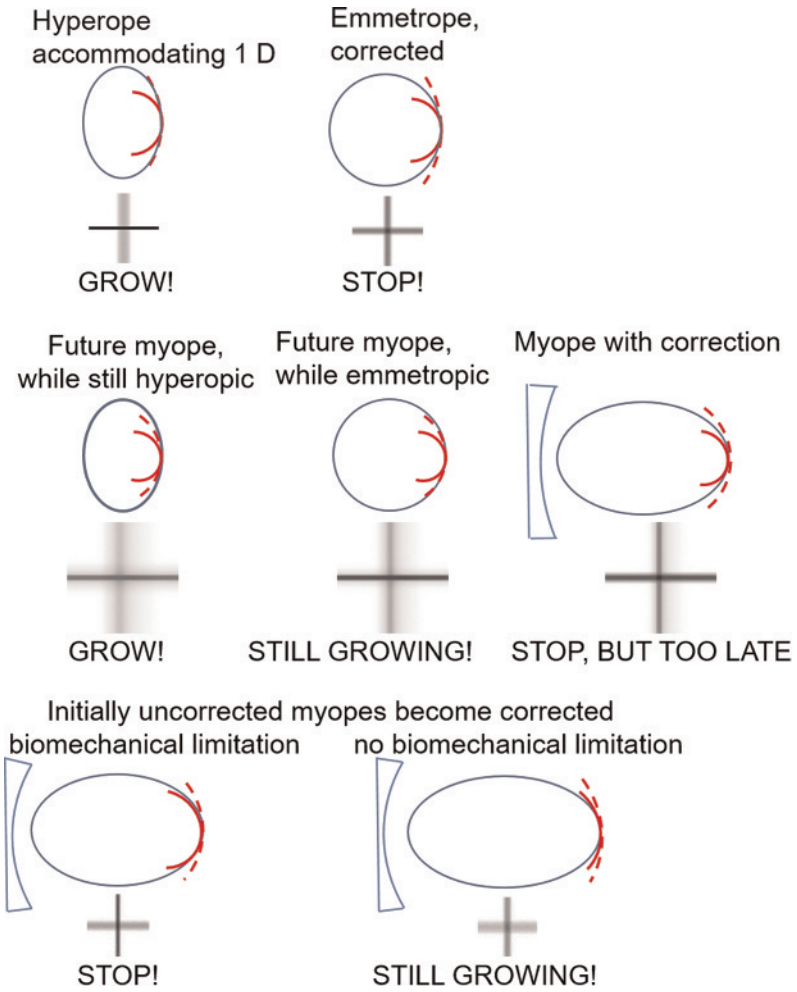

FIGURE 2.

Development of myopia in eyes according to a theory in which the optical quality of the tangential and sagittal image shells are compared. Tangential shells are represented by solid red curves and the sagittal shells are presented by dotted red curves. See text for further details.

Four additional points will be mentioned that complicate the considerations given above. Firstly, in many situations, central and peripheral vision are in considerably different focus states, e.g. when someone is reading a book with peripheral vision outside the region including the book.[10,11] In that case, it would be akin to the person having additional peripheral myopia. An example of the opposite, as stated by Flitcroft,[10] is when the person looks outside through the window, focusing in the distance with the peripheral objects being closer, which produces peripheral hyperopia. This complicates the case for the theory that peripheral myopia protects against myopia development because there is no evidence that reading exerts a protective effect.[12]

Secondly, peripheral refraction and ''retinal activity'' will be affected by the state of correction, so where and when a correction is worn may influence development of myopia. For example, conventional spectacles to correct myopia induce peripheral hyperopia,[13] whereas there is evidence that undercorrecting (i.e. inducing less peripheral hyperopia) enhances rather than inhibits myopia progression.[14]

Thirdly, higher order aberrations cause sign-dependent asymmetries in the impact of defocus. For example, the combination of coma, astigmatism, and spherical aberration typical for peripheral vision can decrease the visual impact of hyperopic defocus.[15] This can change if aberration patterns are altered. Therefore, care must be taken to include not only peripheral refraction but also the peripheral higher order aberrations when myopia control aids such as bifocal contact lenses[16] and orthokeratology[17] are evaluated.

Fourthly, the use of simultaneous bifocal contact lenses complicates the issue as there are at least four image shells, rather than two, to consider. In a commentary in this journal issue, Troilo[18] argues that multifocal contact lenses are particularly effective for myopia control.

Some lens treatments that provide additional positive power in the periphery, thus correcting peripheral hyperopia or inducing peripheral myopia, have some success in reducing myopia progression.[18] These would seem to support the theory of peripheral hyperopia causing myopia, but there may be other reasons for success. Although these multifocal contact lenses provide a myopic shift, the magnitude is small rendering them ineffectual even under the most generous models of peripheral myopia causing hyperopia. Rather, it should be noted that these contact lenses can substantially increase the peripheral depth of focus, which would facilitate the blur of the image shells being closer to each other.

To conclude, recent longitudinal studies do not support the popular theory of relative peripheral hyperopia causing myopia. The theory is based on a misunderstanding of an article from 1971, which actually found relative peripheral hyperopia to be present after, rather than before, myopia development. One finding suggests that relative peripheral hyperopia may exert a small protective effect against myopia development. We have presented an alternative theory, based on cessation of ocular growth when the periphery is at an emmetropic stage as determined by equivalent blur of the two line foci caused by oblique astigmatism.

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