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· **Invited Commentary** ·

Orthokeratology and the choroid

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Abstract: The choroid is a multifunctional, highly vascular, and dynamic tissue which contributes to ocular homeostasis and the regulation of eye growth in both animals and humans. Although challenging to reliably measure, recent advances in ocular imaging (particularly optical coherence tomography) has expanded the current understanding of the role of the choroid in ageing and refractive error development during childhood. This commentary considers recent advances in the field, particularly the impact of orthokeratology on choroidal thickness and contour in myopic children, and the potential use of choroidal metrics as a biomarker for future eye growth.

Keywords: choroid; myopia; optical coherence tomography; orthokeratology

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COMMENTARY:

Myopia is a significant public health concern since high myopia can lead to ocular complications and irreversible loss of vision, typically later in life. Pathological retinal changes that arise from high myopia are often related to excessive axial elongation and changes in the underlying highly vascular choroid. The primary role of the choroid is thermoregulation, maintaining intraocular pressure, and nourishment of the retina.[1] Consequently, when the choroidal vascular supply is compromised, retinal complications can arise.

Since the 1990s it has been understood that the choroid plays an active role in the regulation of eye

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Full Text

growth and refractive error development.[2] Experiments across a wide range of animal models have shown that the choroid rapidly responds in a bi-directional manner to imposed defocus compensating for the magnitude of optical blur, which precedes longer term changes in the sclera.[3] The choroidal (and ocular growth) response is region specific, occurring only in the retinal location exposed to defocus,[4-5] and still occurs in the absence of a connection to the brain, suggesting regulation at the retinal level.[6]

In 2010, following significant advances in the resolution of optical biometers (e.g. optical low coherence reflectometry and partial coherence interferometry) compared to previous A-scan ultrasonography, Read et al[7] demonstrated that the adult human retina could detect the sign of imposed defocus and make small alterations to the position of the retina by modulating choroidal thickness. Subsequent studies using optical coherence tomography (OCT) have shown that the human choroidal response to defocus is also localised[8] and varies in response to both spherical[9] and astigmatic[10] defocus. These changes occur very rapidly, likely due to alterations in blood flow.[11]

The introduction of OCT technology has also improved the current understanding of the role of the choroid and facilitated imaging over much larger retinal regions encompassing the posterior pole and surrounding the optic nerve head. This has allowed for a greater understanding of the impact of age and refractive error upon the choroid throughout childhood.[12-14] Numerous techniques have been employed to enhance the visibility of the choroid in OCT images, such as enhanced depth imaging, B-scan averaging, and longer wavelength light sources.[11] Without these methods, the choroidal-scleral interface can be challenging to reliably demarcate. Since the choroid is a vascular dynamic tissue, its thickness and form are affected by a wide range of factors, such as the time of day, level of accommodation, caffeine, nicotine, and exposure to light and dark.[11] The thickness of the choroid may also vary slightly every time a bolus of blood enters the eye. Consequently, studies examining the choroid require a high level of experimental control to minimise the potential confounding effects of these factors.

Recently, several studies have investigated the effect of orthokeratology on the choroid in children.[15] Orthokeratology is a popular method to slow eye growth in myopic children using reverse geometry rigid contact lenses which are worn overnight, flattening the central cornea to correct myopia, allowing clear unaided vision during the day.[16] Orthokeratology induces a number of significant optical changes, including relative peripheral myopic defocus and elevated primary spherical aberration, both of which have been linked to eye growth in children. It has been hypothesised that the optical changes induced by corneal reshaping in orthokeratology generates an optical signal that is interpreted by the retina, resulting in a change in the choroid and a subsequent slowing of eye growth.[16] It should be noted that the coefficient of repeatability for subfoveal choroidal thickness measurements in children undergoing orthokeratology (using high-resolution OCT imaging) is ~10 μm, and therefore thickness changes of less than 10 μm may not be a true change due to orthokeratology, but measurement noise.[17]

The recent study by Xu et al[18] is an analysis of participants from the Atropine Combined or Orthokeratology study (a two-year randomised clinical trial), examining the spectacle control and the orthokeratology treatment groups. This particular analysis aimed to provide new insights into the changes in choroidal thickness and morphology of myopic children undergoing orthokeratology. Previous studies investigating the association between axial length and choroidal thickness in children treated with orthokeratology have typically been of a shorter duration ranging from 1 to 12 months.[15]

Xu et al[18] addressed many of the potential confounding experimental variables associated with choroidal thickness measurements, for example, by controlling for diurnal variation (capturing images at the same time of day) and accommodation (using cycloplegia). High resolution OCT imaging with enhanced depth imaging was also utilised and 100 B-scans were averaged per line scan to enhance the chorio-scleral interface. Changes in central corneal shape were also considered in order to account for some optical changes which impact the transverse scaling of the OCT image. Axial length has also been shown to significantly impact OCT image scaling and is an important factor to consider, particularly in studies examining the choroid at non-foveal locations.[19-20] Xu et al also utilised two independent masked observers to manually segment the retinal pigment epithelium and chorio-scleral interface to determine the choroidal thickness and contour.

Consistent with previous longitudinal analyses of children treated with orthokeratology,[15] an increase in subfoveal choroidal thickness was observed during the first six months of treatment which slowly declined over the next 18 months. Children wearing single vision distance spectacles in the control group showed steady decline in choroidal thickness: a 22 μm reduction over two years compared to a 6 μm thickening in the orthokeratology group. This confirms that orthokeratology can slow choroidal thinning (due to thickening during treatment). This is consistent with the observed choroidal changes in short-term experiments involving adult humans exposed to myopic defocus.[7-9] More choroidal thickening was observed temporally compared to nasally in the orthokeratology group which may be due to the optical effect of orthokeratology, differences in retinal sensitivity to defocus or altered image quality, or a mechanical factor related to the attachment of the choroid to the optic nerve which potentially limits the capacity for expansion nasally to the fovea.

The choroidal contour (q value) was also calculated using a previously described technique.[21] This value was used to describe the asphericity of the chorio-scleral interface, which remained relatively stable in the orthokeratology group but gradually decreased by approximately 0.2 over two years in the spectacle control group. This negative shift in the q value to a more prolate (or less oblate) shaped chorio-scleral interface was moderately associated with the magnitude of axial elongation. The change in choroidal thickness was monitored for two years, with a peak observed after six months. Previous research has also shown that after ceasing long-term orthokeratology treatment the choroid decreased to the baseline thickness but remained thicker than the single vision control group.[22]

This highly controlled two-year prospective randomised trial[18] has built on previous longitudinal studies of myopic children treated with orthokeratology and confirmed that orthokeratology results in choroidal thickening which peaks during the first months of treatment. While this thickening diminishes over time, it ultimately results in a thicker choroid following orthokeratology compared to children wearing spectacles at the end of the treatment period. Future research investigating the utility of changes in choroidal thickness or contour as a biomarker for future eye growth in children are of particular interest. Studies investigating how to potentially amplify and sustain the choroidal thickening effect during and following orthokeratology treatment are also warranted and may provide enhanced myopia control efficacy in children, with improved ocular health outcomes later in life by limiting the development of high myopia.

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