

Monochromatic ocular wave aberrations in young monkeys

Ramkumar Ramamirtham^{a,b}, Chea-su Kee^{b,1}, Li-Fang Hung^{a,b}, Ying Qiao-Grider^{a,b},
Austin Roorda^{a,2}, Earl L. Smith III^{a,b,*}

^a College of Optometry, University of Houston, Houston, TX 77204-2020, USA

^b The Vision CRC, The University of New South Wales, Sydney, NSW 2052, Australia

Received 9 January 2006; received in revised form 12 April 2006

Abstract

High-order monochromatic aberrations could potentially influence vision-dependent refractive development in a variety of ways. As a first step in understanding the effects of wave aberration on refractive development, we characterized the maturational changes that take place in the high-order aberrations of infant rhesus monkey eyes. Specifically, we compared the monochromatic wave aberrations of infant and adolescent animals and measured the longitudinal changes in the high-order aberrations of infant monkeys during the early period when emmetropization takes place. Our main findings were that (1) adolescent monkey eyes have excellent optical quality, exhibiting total RMS errors that were slightly better than those for adult human eyes that have the same numerical aperture and (2) shortly after birth, infant rhesus monkeys exhibited relatively larger magnitudes of high-order aberrations predominately spherical aberration, coma, and trefoil, which decreased rapidly to assume adolescent values by about 200 days of age. The results demonstrate that rhesus monkey eyes are a good model for studying the contribution of individual ocular components to the eye's overall aberration structure, the mechanisms responsible for the improvements in optical quality that occur during early ocular development, and the effects of high-order aberrations on ocular growth and emmetropization.

© 2006 Elsevier Ltd. All rights reserved.

Keywords: Refractive error; Wave aberrations; Emmetropization; Rhesus monkeys

1. Introduction

In many animal species, optically altering visual experience early in life by imposing defocus with positive- or negative-powered lenses produces compensating changes in axial growth that eliminate the imposed refractive errors (Graham & Judge, 1999; Hung, Crawford, & Smith, 1995; Schaeffel, Glasser, & Howland, 1988; Shaikh, Siegrwart, & Norton, 1999; Smith & Hung, 1999). Thus, emmetropization is a vision-dependent process and optical defocus can guide early ocular growth in a manner that

eliminates refractive errors that are common in neonates (Norton & Siegrwart, 1995; Smith, 1998; Wallman & Winawer, 2004; Wildsoet, 1997). It has also been established that chronic viewing conditions that degrade the spatial characteristics of the retinal image and prevent the formation of a clear retinal image disrupt emmetropization and typically result in a phenomenon called form deprivation myopia (FDM) (Smith, Harwerth, Crawford, & Von Noorden, 1987; Troilo & Judge, 1993; Wallman, 1993; Wiesel & Raviola, 1977). Even mild degrees of chronic image degradation that are equivalent to the reductions in image contrast produced by small amounts of defocus are capable of producing FDM (Bartmann & Schaeffel, 1994; Smith & Hung, 2000). These results emphasize that the potential for a clear retinal image is essential for normal refractive development.

In addition to the effects of spherical and astigmatic refractive errors, the optical quality of the retinal image

* Corresponding author. Fax: +1 713 743 0965.

E-mail address: esmith@uh.edu (E.L. Smith III).

¹ Present address: New England College of Optometry, Boston, MA, USA.

² Present address: School of Optometry, University of California at Berkeley, Berkeley, CA, USA.

is influenced by high-order aberrations that are caused by optical imperfections such as surface irregularities and tilts or misalignments in the eye's optical components. All eyes suffer from such aberrations (Campbell & Gubisch, 1966; Howland & Howland, 1976; Jenkins, 1963; Liang, Grimm, Goelz, & Bille, 1994; Liang & Williams, 1997; Smirnov, 1961). Although the retinal image degradation due to high-order aberrations is usually modest, the degree of high-order aberrations (however, not necessarily the pattern of aberrations) (Cheng et al., 2004a; Thibos, 2002) is relatively constant over time, which is critical for a myopic stimulus to produce axial elongation (Kee et al., 2002b; Napper et al., 1997; Schmid & Wildsoet, 1996; Winawer & Wallman, 2002). Consequently, blur due to aberrations could potentially influence ocular growth and refractive development.

Early in life, during the rapid infantile phase of ocular growth, there are substantial changes in the eye's optical and axial components that could influence the pattern and degree of high-order aberrations. In particular, changes in the curvature of the cornea and lens and in the refractive index and thickness of the lens not only influence the eye's refractive status, but may also change the magnitude and the pattern of aberrations. In addition to being a potential stimulus for anomalous growth, such aberration changes may potentially alter the accuracy or the end point of the emmetropization process. Conversely, it is also possible that the optimum combination of certain types of aberrations may provide signals that guide emmetropization (Wallman & Winawer, 2004; Wilson, Decker, & Roorda, 2002). Thus, it is important to understand the developmental changes in high-order aberrations because they directly affect retinal image quality and may potentially influence the efficiency of the emmetropization process.

Recent population studies of both human children and adults have found large amounts of inter-individual variability both in the pattern and magnitude of high-order aberrations (Carkeet, Luo, Tong, Saw, & Tan, 2002; Castejon-Mochon, Lopez-Gil, Benito, & Artal, 2002; De Brabander et al., 2004; He, Burns, & Marcos, 2000; He et al., 2002; Porter, Guirao, Cox, & Williams, 2001; Thibos, Hong, Bradley, & Cheng, 2002c). Among the few studies that compared aberrations between adults and children, one study reported that the magnitude of high-order aberrations during childhood (5–20 years of age) was 40–50% higher in comparison to adults (Brunette, Bueno, Parent, Hamam, & Simonet, 2003) while a second study of 5- to 7-week-old infants found that infants had only 20% higher total RMS errors and that they exhibited similar patterns of aberrations as young adults (Wang & Candy, 2005). Although the differences in the results between these two studies can be explained partly by differences in the way aberrations were compared between infant and adult eyes (constant pupil size, Brunette et al., 2003, vs. constant numerical aperture, Wang & Candy, 2005), longitudinal data are needed to properly characterize the maturational changes in high-order aberrations, particularly the changes

that take place during the early growth period when emmetropization normally takes place.

Animal models provide a unique opportunity to study normal longitudinal changes in high-order aberrations and the changes that occur during the development of abnormal refractive errors. Recent studies in both the chick and marmoset have shown that wavefront aberrations decrease with age (Campbell, Hunter, Ksilak, Irving, & Huang, 2003; Coletta, Triolo, Moskowitz, Nickla, & Marcos, 2004; Garcia de la Cera, Rodriguez, & Marcos, 2006; Thibos, Cheng, Phillips, & Collins, 2002b). However, the pattern and, in some studies, the magnitude of high-order aberrations in these species appear to be different from those found in humans. For example, infant marmosets exhibit negative spherical aberration whereas humans typically show positive spherical aberration (Coletta et al., 2004) and one study reported that the magnitude of high-order aberrations in chick eyes was about 6–10 times higher than that in human eyes (Thibos et al., 2002b). Consequently, qualitative differences in the shape, size, and organization between the eyes of humans and those of chicks and marmosets may confound direct comparison between these animals and humans.

The structural and developmental aspects of the rhesus monkey eye closely resemble those of human eyes thus making macaque monkeys good animal models for investigations of emmetropization and refractive development (Bradley, Fernandes, Lynn, Tigges, & Boothe, 1999; Smith, 1998). Studying wave aberrations in macaques could provide insights into the role of aberrations in emmetropization and refractive development. The goals of our study were to characterize the high-order aberrations and retinal image quality in infant rhesus monkeys and to compare them to those in adolescent monkeys. In addition, we determined the longitudinal changes in ocular monochromatic wavefront aberrations that took place during the course of emmetropization in a subgroup of infant monkeys. Some of the data from this study have been presented in abstract form elsewhere (Ramamirtham et al., 2002).

2. Methods

2.1. Subjects

Our subjects were 50 normal infant monkeys and 6 normal adolescent monkeys (*Macaca mulatta*). Cross-sectional biometric data on refractive state, monochromatic wavefront aberrations, and axial dimensions were obtained from both eyes of all 56 animals. Longitudinal biometric data were obtained from both eyes of five infants and four adolescent monkeys. All of the rearing and experimental procedures, many of which have been described previously (Hung et al., 1995; Smith & Hung, 1999), were approved by the University of Houston's Institutional Animal Care and Use Committee and were in compliance with the National Institutes of Health Guide for the Care and Use of Laboratory Animals.

Cross-sectional data were collected in the infants at about 3 weeks of age (mean = 21 ± 3 days) and in the adolescents at 4–5 years of age (4.8 ± 0.6 years). Longitudinal data were obtained from five infants at 2- to 4-week intervals beginning at 3 weeks of age until the monkeys were about 200 days of age. This period encompasses the rapid infantile phase of ocular growth and the bulk of the emmetropization process, which in

Download English Version:

<https://daneshyari.com/en/article/4036585>

Download Persian Version:

<https://daneshyari.com/article/4036585>

[Daneshyari.com](https://daneshyari.com)