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Retinal shadows produced by myopia control spectacles

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Running head: Retinal shadows by defocus spectacles

Conflict of interest: Martin de Tomás works for International Optics in relation to DOMS spectacles. Abel Szeps and Rafael Iribarren are consultants of Novar and International Optics. Gabriel Martin works for Novar and Opulens. Jos Rozema is consultant for Morrow Optics and Azalea Optics. There are no conflicts of interest for the other authors.

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Authors' contributions: Martin de Tomás and Juan Manuel Suárez were responsible for the concept and design of the study. Jos Rozema and Rafael Iribarren performed the data analysis. Martin de Tomas, Abel Szeps, Jos Rozema and Rafael Iribarren have verified the data. Martin de Tomás, Abel Szeps, Gabriel Martín, Jos Rozema, David Atchison, and Rafael Iribarren drafted the manuscript. All authors read and approved the final manuscript.

Key Points

- It is not well known where on the retina the peripheral defocused images produced by myopia control spectacles fall
- Fundus photographs with OCT can help locate the shadows cast by the spectacles' treatment zone at the retinal plane
- This analysis can help improve the design of such spectacle lenses to optimize their therapeutic effect.

Abstract

Purpose: To analyse OCT images of the retinal shadows caused by defocus and diffusion optics spectacles.

Methods: One right eye was fitted successively with the Hoya Defocus Incorporated Multiple Segments (DIMS) spectacle, two variations of the *+3.50D* peripheral add spectacle (DEFOCUS), and the low-contrast dot lens (Diffusion Optics Multiple Segments, DOMS), each at a vertex distance of *12 mm*. Simultaneously a retinal image of the macular region with central fixation was obtained using infrared optical coherence tomography (OCT). The corneal power and intraocular distances were determined using an optical biometer.

Results: The retinal images for the DIMS and DOMS lenses showed patterns of obvious retinal shadows in the periphery, while the central $10 - 11°$ remained clear. The DEFOCUS lens produced a darkened peripheral area. Dividing the size of the retinal pattern, measured with the calliper of the OCT software, by actual size on the spectacle lens gave a magnification of -0.57 times. This is consistent with the incoming OCT beam being imaged to a position approximately 31 mm beyond the front of the eye.

Conclusion: With device-specific correction, retinal OCT images can help visualize the regions affected by the defocus or lowered contrast induced by myopia control spectacles. This is of potential value for improving myopia therapies.

Key Words. Myopia control spectacles, retinal shadows, OCT images

Introduction

In neonatal chicks, normal eye growth at the posterior pole may be accelerated by imposing hyperopic defocus using negative lenses and slowed by imposing myopic defocus using positive lenses.[1] The origins of this process lies in the retina, which detects the defocus locally at the posterior pole[2] and independently from either the foveal focus[3] or the central nervous system.[4] Many papers have described how diffusers (form deprivation) or lenses imposed on various animal species lead to myopia,[5] and experiments with central holes of different sizes in the diffusers have derived the extent of the perifoveal macula and surrounding extramacular regions involved in ocular growth.[6]

Observations with chicks showed that short periods of myopic defocus can arrest myopia produced by long periods of hyperopic defocus[7] probably to bring protection from excessive axial growth that would put the eye out of focus permanently. These observations triggered interest in the use of optical interventions for myopia control in humans. Anstice & Phillips designed contact lenses with two annular zones to induce peripheral myopic defocus to arrest myopia progression and presented good results in a randomized controlled trial.[8] Other multifocal contact lens designs with peripheral positive additions have been similarly effective, e.g.[9] Similar success has been accomplished with spectacle lenses, one having a hexagonal arrangement of *1 mm*-diameter lenslets with an addition of approximately *+3.50D*[10] and another having a ring arrangement of aspherical lenslets.[11]

There is much to learn about how these contact and spectacle lenses affect the retinal image and where treatment takes place at the posterior pole. Although this can be addressed theoretically through eye models and ray tracing, these calculations have yet to be supported by experimental data. Hence, this work presents a novel way to use the shadows in retinal optical coherence tomography (OCT) images, cast by the peripheral lenslets, peripheral adds, or low contrast dots in myopia treatment spectacle lenses, as a means to determine the treatment area.

Materials and Methods

This study involved four spectacle lenses, the *+3.50D* Hoya Defocus Incorporated Multiple Segments (DIMS),[10] the *+3.50D* peripheral add spectacles (designed by NOVAR, "DEFOCUS"),[12] and two versions of the low contrast dot design (Diffusion Optics Multiple Segments, "DOMS", International Optics).[12] The DIMS and DEFOCUS spectacles have *9 mm* wide central zones for distance vision. One version of the DOMS spectacle has a *9 mm* wide central distance vision zone surrounded by *1 mm* dots spaced *0.75 mm* apart (DOMS 0.75 mm), and the second version has an *8 mm* central distance zone surrounded by *1 mm* dots spaced *0.50 mm* apart (DOMS 0.50 mm). The DEFOCUS and DOMS lenses had no distance power, while the DIMS lens had a distance power of –2 D. These characteristics are shown in Table 1.

This study was conducted in accordance with the tenets of the Declaration of Helsinki. The Ethics Committee of the Argentinian Society of Ophthalmology stated that no approval was needed as there were no patients involved in the study. The volunteer was a *45*-year-old emmetropic male with *logMAR* visual acuity of *0.0* (Snellen *20/20*) and a normal biomicroscopic evaluation in both eyes. The biometry of the subject's right eye was determined with the Lenstar (Haag-Streit, Köniz, Switzerland); details are provided in Table 2. From these data the crystalline lens power and whole eye power were calculated using Bennett's method.[13] These were used to estimate the retinal magnification for an object at the spectacle plane by considering the ratio of the image distance to the object distance when these were determined with respect to the principal planes of the eye.

The volunteer was fitted with each lens in a spectacle at *12 ± 1 mm* vertex distance as determined with a millimetre rule. The volunteer sat in front of the *780 nm* infrared Xephilio OCT (Canon, Singapore) OCT device looking at the fixation target set at infinity. An operator focused the OCT camera at the fundus of the right eye and recorded the images without pupil dilation and with the room lights on. The best focused images obtained after several tries are presented here for each lens type.

Table 1: Characteristics of the four tested spectacle designs

	HOYA DIMS	NOVAR DEFOCUS	DOMS 0.75mm	DOMS 0.50 mm
Central distance area	*9 mm*	*9 mm*	*9 mm*	*8 mm*
Peripheral add	*+3.50 D*	*+3.50 D*	-	-
Diameter of the dots	*1.03 mm*	-	*1 mm*	*1 mm*
Spacing of the dots	*0.3 mm*	-	*0.75 mm*	*0.50 mm*

Table 2: Biometry of the right eye

Spherical equivalent	*0.00 D*	Axial length	*24.15 mm*
Corneal power*	*42.19 D*	Crystalline lens power	*21.72 D*
Ant. corneal radius of curvature	*8.00 mm*	Whole eye power	*59.87 D*
Anterior chamber depth	*3.43 mm*	1^{st} principal point of the eye	*1.57 mm*
Lens thickness	*3.98 mm*	2^{nd} principal point of the eye	*1.86 mm*
Vitreous depth	*16.74 mm*		

*Determined as 0.3375/Ant. corneal radius of curvature

Results

Retinal shadows

All myopia control lenses cast obvious shadows on the peripheral retina while keeping the central area around the fovea clear (Figure 1). For the lenslets of the Hoya DIMS lens, the shadow pattern was fuzzy and hexagonal, while the low contrast dots of the DOMS lenses cast dark rectangular patterns. The DEFOCUS lens showed a sharp central retinal image, while the periphery was much darker due to the addition (Table 3). Increasing the image brightness in this dark region revealed the retinal vessels (Figure 2).

Table 3: Overview of the retinal spot patterns

Type	Pattern description
HOYA DIMS	Fuzzy dots in hexagonal grid
NOVAR DEFOCUS	Bright sharp center and dark periphery with transition zone
DOMS 0.75mm	Neat dots in rectangular grid
DOMS 0.50 mm	Neat dots in rectangular grid

Magnification

The size of the retinal shadows was determined using the calliper of the OCT software for the DOMS with *0.50 mm* spacing (Figure 3). Comparing this distance with the corresponding distance on the lens surface gave a magnification of *−5.46 mm/9.6 mm = −0.57 times*. The negative sign appears because of inversion of the retinal image relative to the lens surface, as was made clear using the reading segment on an Executive bifocal producing a superior retinal shadow. This magnification and the eye biometry can be used to estimate the shape of the incoming beam. Applying Bennett's equations,[13] the whole eye power was estimated at *59.87D*, with principal points of the eye *1.57 mm* and *1.86 mm* behind the corneal apex. The spectacle lenses were a vertex distance of *12 mm* from the corneal apex, or *13.57 mm* from the first principal point of the eye. The sharp image of the spectacle pattern was *74 mm* beyond the retina, but this is not relevant in this instance. One can use paraxial transfer and refraction equations and vary the object distance until the experimental magnification is obtained. This is satisfied by a converging beam with an object position about 31 mm beyond the corneal apex.

Discussion

In this paper we present OCT images of the retinal shadow patterns cast by myopia control spectacles. The lenslets of DIMS and the low contrast dots of DOMS produced similar spotted patterns, albeit with differences in contrast, but the addition of the DEFOCUS lens darkened the entire periphery.

With appropriate, device specific corrections, these shadows may form an easy-to-use tool to delineate the retinal areas affected by the peripheral lens corrections. Note that the contrast between the shadows and their surroundings is likely exaggerated in these images as the light is out of focus for the DIMS lenslets and the addition of the DEFOCUS, or scattered by the image acquisition, causing less light to reach the confocal detector of the OCT than the retina would observe on that location.

These OCT images are especially interesting since the retinal zone thought most sensitive to defocus signals lies between $6 – 12°$ from the fovea,[14] while the optical calculations suggest that for this volunteer the internal edge of the shadow patterns was at $10.2 – 11.4°$ depending on the lens being considered. Other authors have reported that posterior pole growth may be controlled by the entire central $30°$ of the retina during myopia development,[15] a large part of which is covered by the patterns.

Bearing in mind the issue of magnification, both due to the OCT and the spectacles themselves, the images presented here may help improve myopia control methods by identifying the retinal regions receiving treatment. Since the way in which the retina detects defocus is increasingly well understood[16, 17] and that the retinal area most sensitive to defocus has been identified,[14] this OCT method could help optimize contact lens and spectacle designs to bring the treatment zone where it will be most effective. This should be tested and optimised for the eyes of children and young adults, which will experience different amounts of magnification due to differences in ocular biometry.

References

1. Schaeffel F, Glasser A, Howland HC. Accommodation, refractive error and eye growth in chickens. *Vision Res*. 1988;28(5):639-57.
2. McFadden S. Partial occlusion produces local form deprivation myopia in the guinea pig eye. *Invest Ophthalmol Vis Sci*. 2002;43(13):189.
3. Smith EL, Ramamirtham R, Qiao-Grider Y, Hung L-F, Huang J, Kee C-s, et al. Effects of foveal ablation on emmetropization and form-deprivation myopia. *Invest Ophthalmol Vis Sci*. 2007;48(9):3914-22.
4. Wildsoet C, Schmid K. Optical correction of form deprivation myopia inhibits refractive recovery in chick eyes with intact or sectioned optic nerves. *Vision Res.* 2000;40(23):3273-82.
5. Troilo D, Smith EL, Nickla DL, Ashby R, Tkatchenko AV, Ostrin LA, et al. IMI–Report on experimental models of emmetropization and myopia. *Invest Ophthalmol Vis Sci.* 2019;60(3):M31-M88.
6. Smith EL, 3rd, Hung LF, Arumugam B. Visual regulation of refractive development: insights from animal studies. *Eye* (Lond). 2014;28(2):180-8.

7. Winawer J, Wallman J. Temporal constraints on lens compensation in chicks. *Vision Res*. 2002;42(24):2651-68.
8. Anstice NS, Phillips JR. Effect of dual-focus soft contact lens wear on axial myopia progression in children. *Ophthalmology*. 2011;118(6):1152-61.
9. Walline JJ, Greiner KL, McVey ME, Jones-Jordan LA. Multifocal contact lens myopia control. *Optom Vis Sci*. 2013;90(11):1207-14.
10. Lam CSY, Tang WC, Tse DY, Lee RPK, Chun RKM, Hasegawa K, et al. Defocus Incorporated Multiple Segments (DIMS) spectacle lenses slow myopia progression: a 2-year randomised clinical trial. *Brit J Ophthalmol*. 2020;104(3):363-8.
11. Bao J, Yang A, Huang Y, Li X, Pan Y, Ding C, et al. One-year myopia control efficacy of spectacle lenses with aspherical lenslets. *Brit J Ophthalmol*. 2022;106(8):1171-6.
12. Martín De Tomas CK, Abel Szeps, Ricardo Impagliazzo, Rafael Iribarren. New spectacles for myopia control. *Oftalmol Clin Exp.* 2022;15(2):240-247.
13. Bennett A. A method of determining the equivalent powers of the eye and its crystalline lens without resort to phakometry. *Ophthal Physiol Opt.* 1988;8(1):53-9.
14. Panorgias A, Aigbe S, Jeong E, Otero C, Bex PJ, Vera-Diaz FA. Retinal responses to simulated optical blur using a novel dead leaves ERG Stimulus. *Invest Ophthalmol Vis Sci.* 2021;62(10):1.
15. Gilmartin B, Nagra M, Logan NS. Shape of the posterior vitreous chamber in human emmetropia and myopia. *Invest Ophthalmol Vis Sci.* 2013;54(12):7240-51.
16. Schaeffel F. Functional changes in the myopic retina interfere with emmetropization. In: Optometry TOSUCo, editor. Richard and Leonora Hill Lecture Series; Tuesday March 21. https://optometry.osu.edu/richard-and-leonora-hill-lecture-series2023.
17. Swiatczak B, Schaeffel F. Myopia: why the retina stops inhibiting eye growth. *Sci Rep.* 2022;12(1):21704.

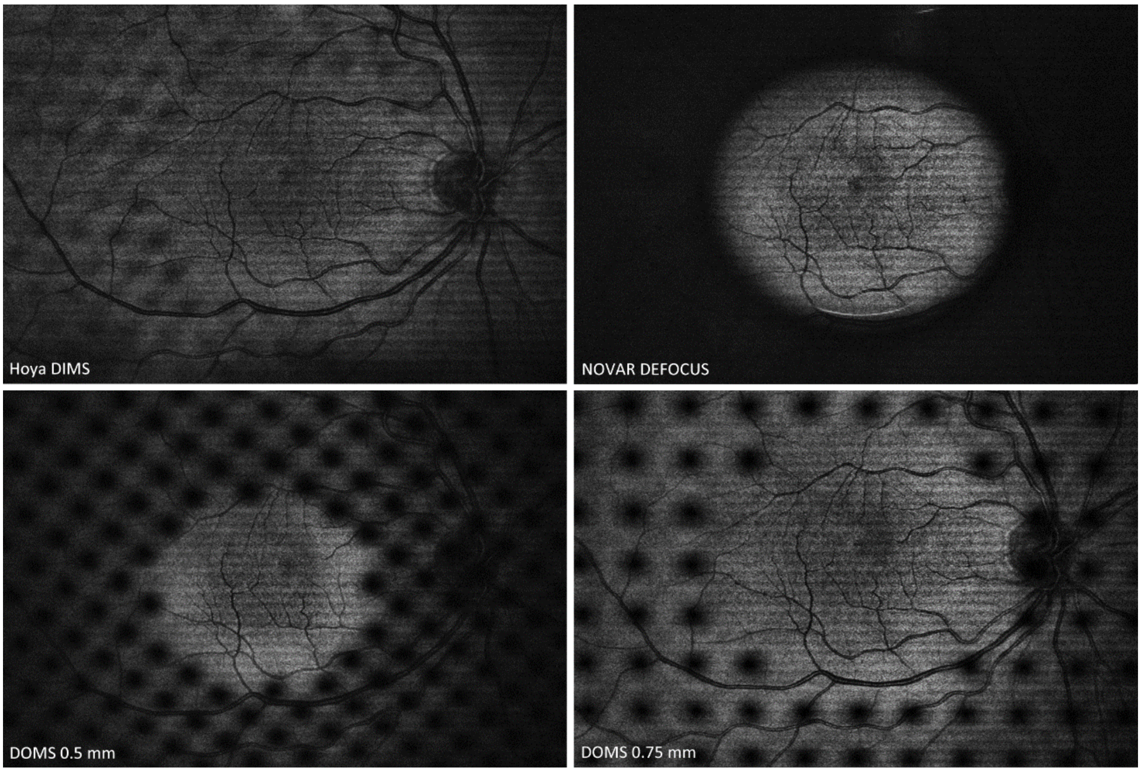

Figure 1: *OCT images of the retinal shadows cast by the myopia control lenses: Hoya DIMS (top left), Novar DEFOCUS (top right), DOMS with 0.5 mm spacing (bottom left) and 0.75 mm spacing (bottom right).*

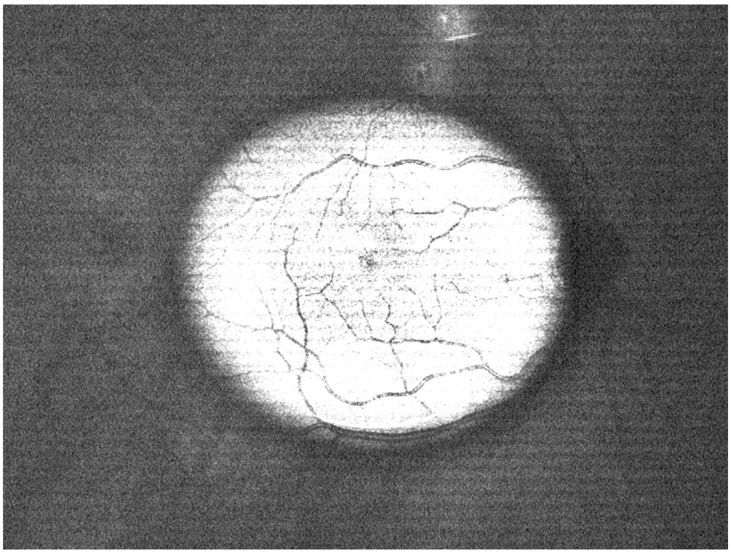

Figure 2: *OCT image of NOVAR DEFOCUS with increased brightness showing retinal vessels in the defocused peripheral area.*

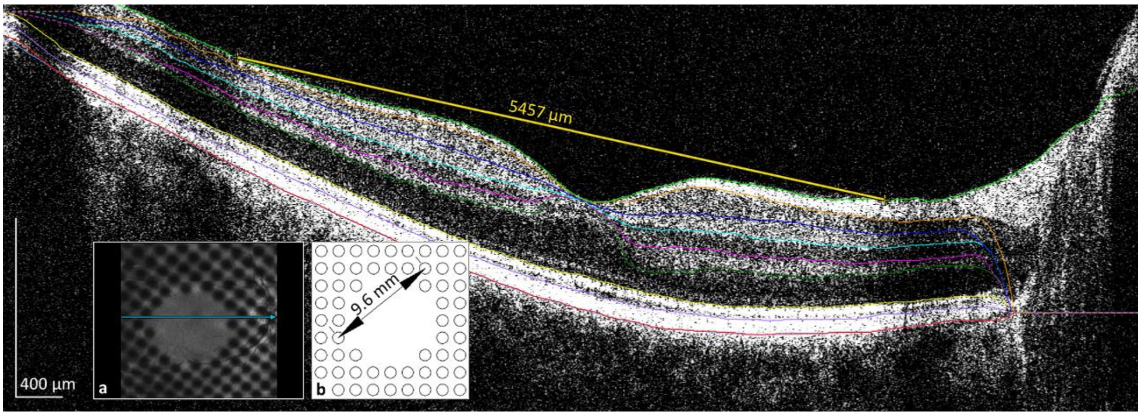

Figure 3: *Cross-section of the retina with a measurement between two shadows; a. en face image; b. corresponding distance on the DOMS lens with 0.5 mm spacing.*

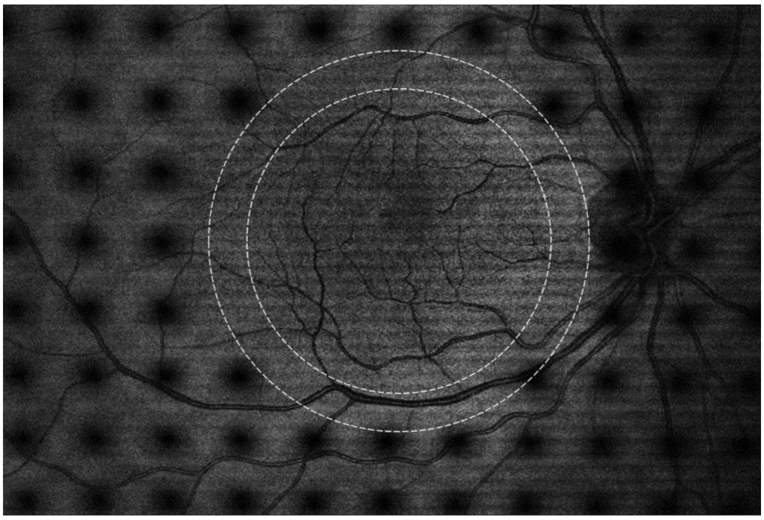

Figure 4: *Position of the clear zone on the OCT image (outer circle) versus the expected position (inner circle) for DOMS with 0.75mm spacing.*