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Axial length shortening in a myopic child with anisometropic amblyopia after wearing violet light-transmitting eyeglasses for 2 years

Yoshiko Ofuji [a,1], Hidemasa Torii [a,b,1], Erisa Yotsukura [a,b], Kiwako Mori [a,b], Toshihide Kurihara [a,b], Kazuno Negishi [a], Kazuo Tsubota [a,c,*]

[a] Department of Ophthalmology, Keio University School of Medicine, 35 Shinanomachi, Shinjuku-ku, Tokyo, 160-8582, Japan
[b] Laboratory of Photobiology, Keio University School of Medicine, 35 Shinanomachi, Shinjuku-ku, Tokyo, 160-8582, Japan
[c] Tsubota Laboratory, Inc., 304 Toshin Shinanomachi-ekimae Bldg., 34 Shinanomachi Shinjuku-ku, Tokyo, 160-0016, Japan

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ABSTRACT

Purpose: To report a case in which the axial length (AL) shortened and the choroid thickened due to the use of violet light-transmitting eyeglasses.

Observations: A 4-year-old boy with high myopia was referred to Keio University Hospital. He was prescribed standard eyeglasses. Six months after the first visit, his best-corrected visual acuities were 1.2 and 0.4 in the right and left eyes, respectively, with the standard eyeglasses, and he was diagnosed with anisometropic amblyopia. The right eye then was patched for 6 hours daily during the daytime. Because of the availability of violet light-transmitting eyeglasses, we changed the eyeglasses and instructed his parents to have him engage in outdoor activities for over 2 hours daily to be exposed to sufficient violet light. As a result, the violet light entered his left eye and minimal violet light entered his right eye. The changes in the ALs, choroidal thicknesses, and cycloplegic objective refractions in the right and left eyes during 2 years of wearing violet light-transmitting eyeglasses were +0.85 and −0.20 mm, +4.9 and + 115.7 µm, and −1.02 and + 1.88 D, respectively.

Conclusions and importance: We successfully described a case in which the myopia improved, the AL shortened, and the choroid thickened after using violet light-transmitting eyeglasses.

1. Introduction

The incidence of myopia has been increasing worldwide[1] including in Japan.[2] Many epidemiologic, experimental animals, and clinical intervention studies have reported that outdoor activities suppress myopia progression, but the protective mechanism of outdoor activities against myopia progression remains unclear. We have reported previously that violet light (360–400 nm wavelength) may have the potential to retard myopia progression.[3,4]

We performed phakic intraocular lens (pIOL) implantation, a refractive surgery, on adults with high myopia and compared the myopia progression between two groups implanted with different lenses for a 5-year period postoperatively. The results showed a significant difference in the axial length (AL) elongation between the two groups in the 5 postoperative years. We compared the differences between the two lenses against a variety of criteria including higher order aberrations, residual astigmatism, spectral transmittance of the pIOL, and off-axis aberration simulation using eye models. We found that there were no significant differences other than the spectral transmittance of the pIOL, suggesting that the difference in violet light transmittance may be responsible for the differences seen in adults with high myopia.[3] Thus, we focused on violet light, which is abundant in outdoor environments, and carried out research using a chick myopia model. In that model, myopic progression in chicks exposed to violet light was suppressed, and the *early growth response 1* (*EGR1* [ZENK, zif268]) gene, a gene that suppresses myopia progression, was up-regulated in chicks exposed to violet light.[4] This clarified that the *EGR1* gene may be involved in the violet light suppression of myopia. We also reported that in students wearing contact lenses that transmit violet light, myopia progression was suppressed more than in those wearing contact lenses that did not transmit violet light, suggesting that myopia progressed when wearing contact lenses that do not transmit violet light.[4] Based on the results of those previous studies,[3–5] violet light can be used to suppress AL elongation and myopia progression not only in young people but also adults

* Corresponding author. Department of Ophthalmology, Keio University School of Medicine, 35 Shinanomachi, Shinjuku-ku, Tokyo, 160-8582, Japan.
E-mail address: tsubota@z3.keio.jp (K. Tsubota).

[1] Drs. Ofuji and Torii contributed equally to this work and request dual first authorship

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with high myopia.

Because violet light does not penetrate standard eyeglasses,[4] we developed violet light-transmitting eyeglasses in collaboration with JINS, Inc. (Tokyo, Japan). There are several types of commercially available eyeglasses, ranging from non-ultraviolet (UV) cut lens to UV cut lens. The non-UV cut lenses have been sold for decades, and almost all lenses are now UV cut lenses.[4] The JINS violet light-transmitting eyeglasses, which do not penetrate under 350 nm and allow violet light to penetrate, are positioned between the non-UV cut and UV cut lenses, which means that the violet light-transmitting eyeglasses also are classified as normal eyeglasses. The JINS violet light-transmitting eyeglasses have been commercially available in eyeglass shops operated by the manufacturer throughout Japan and approved by the Japanese Ministry of Health, Labor and Welfare for their safety. Furthermore, this is a case report. For these reasons, the institutional review board approval of the current case was waived in Japan.

A number of treatments have been used to retard myopia progression including outdoor activities,[6] orthokeratology,[7] low-dose atropine eye drops,[8] and dietary supplementation;[9] however, myopia currently cannot be stopped or improved by a non-surgical method.

We describe the unique case of a child with high myopia (spherical equivalent [SE], −5.00 diopters [D] or less)[1] bilaterally and anisometropic amblyopia for which we prescribed violet light-transmitting eyeglasses after the availability of this technology. We prescribed patching of his right eye for 6 hours daily during the daytime. As a result, violet light entered his left eye and most violet light was prevented from entering his patched right eye. We successfully showed a case in which the myopia improved, the AL shortened, and the choroid thickened in association with the use of violet light-transmitting eyeglasses.

2. Case report

A 4-year-old boy was referred to the Keio University Hospital in Tokyo with high myopia. He had no medical history except myopia and his mother had high myopia. No remarkable findings were evidence on slit-lamp and fundus examinations. The best-corrected visual acuities (BCVA, decimal) in the right and left eyes were 0.5 and 0.3, respectively. The respective cycloplegic objective refractions (SE) were −5.75 and −9.75 D, corneal keratometric values of 45.25 and 45.75 D, and ALs of 24.00 and 25.67 mm measured using the IOLMaster® 500 (Carl Zeiss Meditec AG, Jena, Germany). The choroidal thickness was measured using spectral-domain optical coherence tomography (SD-OCT) (RS-3000, Nidek, Aichi, Japan) using ImageJ software (National Institutes of Health, Bethesda, MD) as reported previously.[9–12] The intraocular pressures were 13 mmHg bilaterally. We diagnosed ametropic amblyopia and prescribed non-violet light-transmitting eyeglasses.

Six months after the first visit, the BCVA in his right eye improved to 1.2 by wearing the eyeglasses, and the BCVA in his left eye remained 0.4. Because of development of anisometropic amblyopia, we prescribed patching of his right eye for 6 hours daily during the daytime. We also prescribed violet light-transmitting eyeglasses (Fig. 1), which may have the potential to retard progression of myopia, after we obtained informed assent and consent from the patient and his parents,. We recommended to his parents that he engage in outdoor activities for over 2 hours daily to be exposed to sufficient violet light. Since that time, we can measure the ALs using a swept-source optical coherence tomography biometer, IOLMaster® 700 (Carl Zeiss Meditec AG), which has a measurement accuracy of ± 5 μm, because the technology became available. We also recorded the AL 10 times and averaged the data.

Four months after the patient started wearing the violet light-transmitting eyeglasses and patching his right eye, the choroidal thicknesses were 307.6 and 167.9 μm in the right and left eyes, respectively (Fig. 2A). In addition, the BCVA improved to 0.9 with shortening of the AL, and the myopia improved in his left eye simultaneously with the AL lengthening and the myopia progression in his right eye with patching (Fig. 3). The corneal refractions did not change bilaterally during the observation period.

After 24 months of wearing violet light-transmitting eyeglasses with patching to treat amblyopia in his right eye for 6 hours daily, the BCVAs, SEs, ALs, and choroidal thicknesses in the right and left eyes were, 1.0 and 0.9, −6.74 and −8.30 D, 25.03 and 25.47 mm, and 312.5 and 283.6 μm, respectively (Fig. 2B).

The patient arrived at our hospital around 3 p.m. for every appointment, so the times at which the measurements were performed were almost the same and there were no diurnal variations to consider.

As a result, the respective changes in the left eye in the SE, AL, and choroidal thickness during 2 years were +1.88 D (improved myopia), −0.20 mm (shortened), and +115.7 μm (thickened). In the right eye, the respective changes in the SE, AL, and choroidal thickness during 2 years were −1.02 D (myopia progression), +0.85 mm (lengthened), and +4.9 μm (thickened). No adverse effects were observed.

3. Discussion

It has been reported that the AL has increased and myopia has progressed bilaterally in patients with myopic anisometropia[13,14] during refractive correction with what we assume were standard eyeglasses and not violet light-transmitting eyeglasses. The current case is unique in that different changes in the AL, choroidal thickness, and SE in each eye were seen.

There are several ways to retard myopia progression, i.e., outdoor activities,[6] orthokeratology,[7] and low-dose atropine.[8] According to a recent prospective randomized study of low-dose (0.01%) atropine eye drops,[8] there was no statistically significant difference in the AL

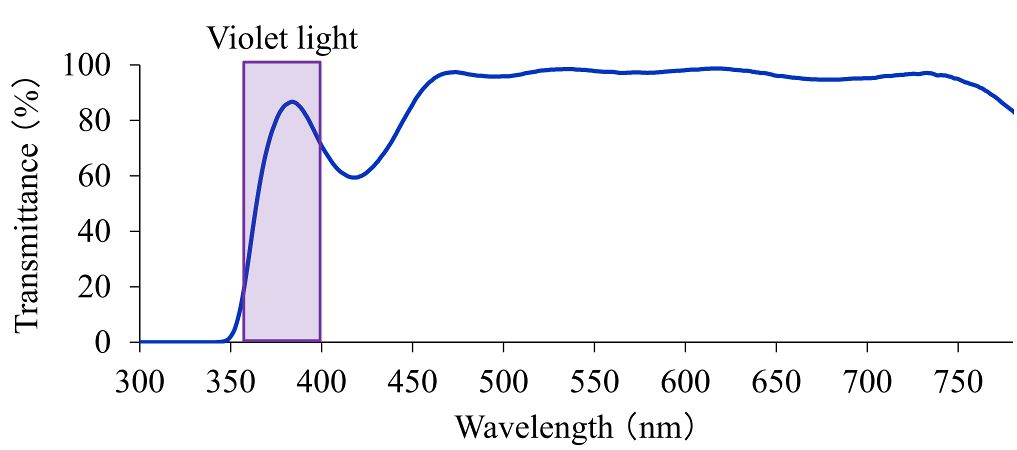

Fig. 1. The spectral transmission of the violet light-transmitting eyeglasses. This eyeglass permits transmission of violet light (360–400 nm wavelength).

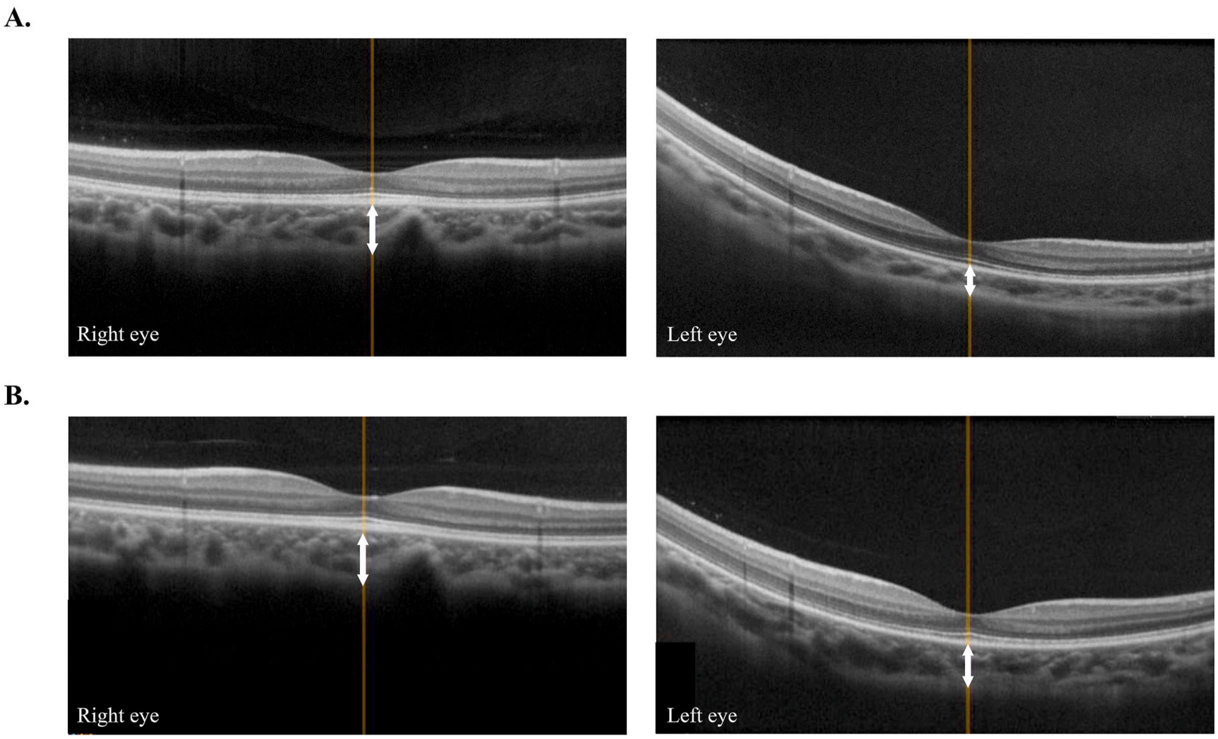

Fig. 2. The choroidal thicknesses of the right and left eyes. The choroidal thickness (arrows) was measured with spectral-domain optical coherence tomography. (A) The choroidal thicknesses were 307.6 (right eye) and 167.9 (left eye) μm 4 months after the patient started wearing violet light-transmitting eyeglasses and patching his right eye and (B) 312.5 (right eye) and 283.6 (left eye) μm 24 months after the patient started wearing violet light-transmitting eyeglasses and patching his right eye for 6 hours daily. The respective changes in the choroidal thicknesses during 20 months were +4.9 (right eye) and +115.7 (left eye) μm.

elongation for 1 year between the placebo and 0.01% atropine groups. Although the suppressive effect of myopia (SE) was 0.22 D annually in the atropine group, the myopia progressed even in the atropine group. Regarding outdoor activity, the suppressive effect of myopia was 0.30 D over 3 years in a meta-analysis.[15] Regarding orthokeratology, the suppressive effect of axial elongation was 0.26 mm over 2 years in a meta-analysis.[16] Although myopia generally cannot be stopped or improved by these non-surgical methods, the current case showed that myopia improved (+1.88 D/2 years) and the AL shortened (−0.20 mm/2 years).

Highly myopic eyes usually have a thinner choroid and longer AL.[17] The mean choroidal thickness among Japanese children (34 children; mean age, 4.4 years) even with a normal refraction (mean refractive error, 0.31 D) decreased from 301.8 μm to 286.6 μm over 1.5 years.[18] Further, the choroidal thickness among children (115 children aged 2–16 years) increased in non-myopic patients and decreased in myopic patients over 15 months.[19] In the current case, the choroidal thickness increased in both eyes, with a prominent change especially in his left unpatched eye. We speculated that the reason for the difference between the right and left eyes was the difference in the light environment created in each highly myopic eye, i.e., violet light entered his left eye and minimal violet light entered his right eye. While bright light has been reported to stimulate choroidal thickening in chickens[20] but not humans,[21,22] the reason for the difference in species is unknown. These results suggested that the light spectrum may be the important factor in the changes in the choroidal thickness. Further studies are needed to elucidate the relationship between the choroidal thickness and light spectrum.

Some unknown confounders may have affected the results in this case report. If increasing outdoor activities provides some additive effects against myopia progression, it will affect both eyes and the myopia should be suppressed bilaterally. However, the myopia progression was suppressed only in the left eye, which was not covered by an eye patch. Considering this, we think that the light environment to which the eye is exposed is important regarding suppression of myopia. Although it cannot be denied that the progression of myopia may have a saturating tendency in the left eye, we need to confirm it in a future study. The current case is unique because of the eye patching for 6 hours daily, the result of which was that a different light environment was created in both highly myopic eyes. Subsequently, the AL shortened, the choroid thickened, and the myopia in his unpatched left eye improved gradually after the use of violet light-transmitting eyeglasses with sufficient outdoor activity. A larger number of cases are needed to confirm our findings.

4. Conclusion

We successfully described a case in which the myopia improved, the AL shortened, and the choroid thickened after using violet light-transmitting eyeglasses.

Patient consent

Not applicable. This report does not contain any personal information that could lead to the identification of the patient.

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Authorship

All authors attest that they meet the current ICMJE criteria for Authorship.

Declaration of competing interest

The international patent (WO 2015/186723) has been registered in

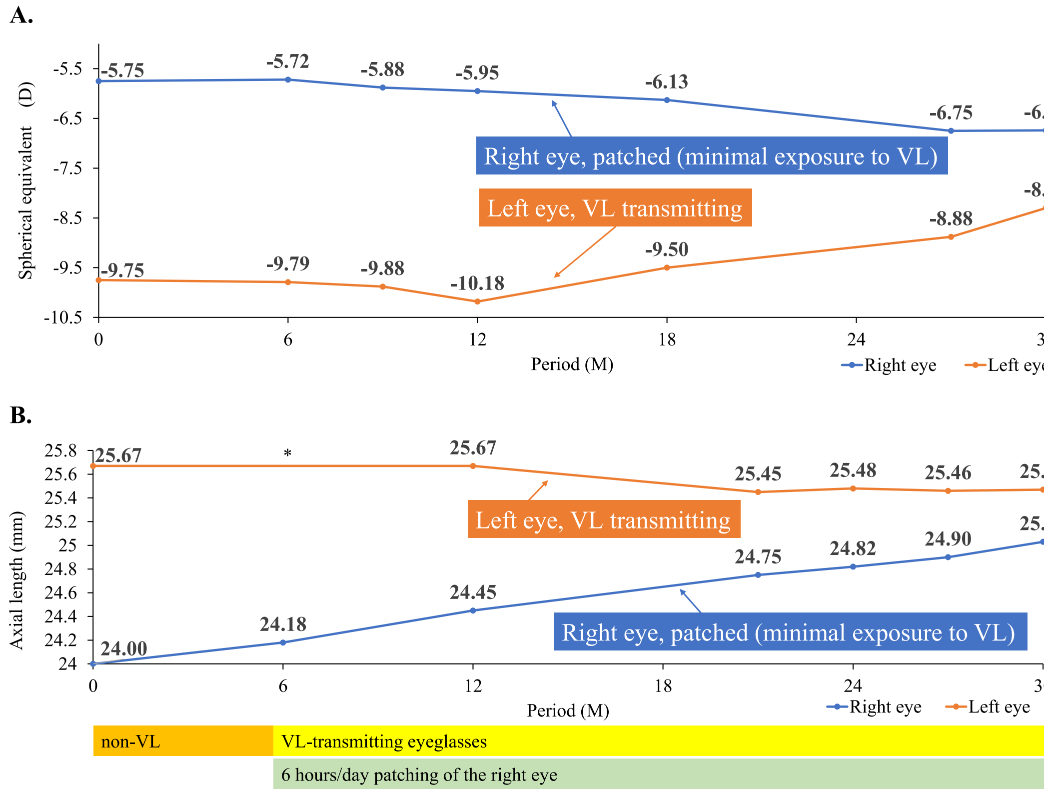

Fig. 3. The time course of (A) cycloplegic objective refraction and (B) axial length.* In the unpatched left eye, the myopia improved gradually, and the axial length (AL) shortened after the patient wore violet light-transmitting eyeglasses. It took 6 months for the myopia to improve after wearing violet light-transmitting eyeglasses. In the right eye, which was patched for 6 hours daily, the myopia progressed and the AL elongated. *The AL in the left eye at 6 months was omitted because of the low confidence value measured by the IOLMaster® 700. D: diopters; M: months; VL, violet light. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

Japan as JP 6085722 and in the US as US 10133092 for the violet light-transmitting eyeglasses. The authors H.T., T.K., K.N., and K.T. are the inventors listed on this patent. Outside the submitted work, K.T. reports research funding from JINS, Inc., and Tsubota Laboratory, Inc.

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