Received: 28 December 2024 | Accepted: 3 April 2025 | Published online: 12 April 2025

DOI: 10.1111/opo.13515

ORIGINAL ARTICLE

OPO THE COLLEGE OF OPTOMETRISTS

Optical influence of myopia control spectacles at the retinal level: Effect of local light modulation

Hakan Kaymak[1,2] | **Ann-Isabel Mattern**[1] | **Birte Graff**[1,3] | **Machteld Devenijn**[1] | **Berthold Seitz**[4] | **Hartmut Schwahn**[1]

[1]Internationale Innovative Ophthalmochirurgie, Breyer Kaymak Klabe Augenchirurgie, Dusseldorf, Germany

[2]Gottfried O.H. Naumann-Institute of Epidemiology and Prevention of Myopia, Saarland University, Homburg, Germany

[3]Institute of Experimental Ophthalmology, Saarland University, Homburg, Germany

[4]Department of Ophthalmology, Saarland University Medical Center, Homburg, Germany

Correspondence
Hakan Kaymak, Internationale Innovative Ophthalmochirurgie, Breyer Kaymak Klabe Augenchirurgie, Dusseldorf, Germany.
Email: dr.h.kaymak@gmail.com

Abstract

Purpose: To investigate the influence of light modulation conferred by current designs of myopia control spectacles on retinal sensitivity.

Methods: Retinal sensitivity and scanning laser ophthalmoscopy (SLO) fundus images were obtained from nine healthy subjects using a Macular Integrity Assessment microperimeter with current myopia control spectacle lenses: MyoCare, Stellest, MiYOSMART and DOT. Respectively powered single vision lenses and a 0.8-grade Bangerter occlusion foil (BF) served as comparative controls.

Results: Using the SLO image, one can visualise the areas of light modulation of the various myopia control lens designs at the level of the retina. Clear zone sizes differ between lens designs, with the DOT lens having the smallest area. Retinal sensitivity in areas of local light modulation was not reduced for the Stellest and MyoCare lenses, but declined with the MiYOSMART lens, suggesting a more prominent local light modulation. The DOT lenses produced a significant reduction in overall retinal sensitivity, although the reduction with the BF was greater. In all instances, retinal sensitivity remained well above the range considered normal for a healthy retina.

Conclusions: None of the lenses tested produced a clinically relevant reduction in retinal sensitivity and all scored significantly better than the lowest (that is, 0.8) grade BF. Given that current myopia control spectacles do not show consistent treatment effects as required to slow progression effectively over extended periods, there appears to be a subtle, yet crucial difference in spatial light modulation among these myopia control spectacle lenses. Seemingly similar lens designs cannot be assumed to have equivalent treatment effects; a thorough assessment of these nuances is essential to ensure accurate claims regarding their long-term efficacy.

KEYWORDS
contrast, microperimetry, myopia, myopia control spectacle lenses, retinal sensitivity

INTRODUCTION

In most instances, myopia develops during childhood[1,2] when eye elongation exceeds the physiological eye growth that would normally result in emmetropia in adulthood. Myopia is not just a cosmetic problem that can be compensated by refractive correction. As the degree of myopia increases, there is a greater risk of developing ocular diseases in adulthood,[3–5] including glaucoma,[6] early cataract,[7] retinal detachment,[8] choroidal neovascularisation,[9] myopic retinopathy and myopic maculopathy.[10,11] Accordingly, slowing excessive axial eye growth by appropriate means not only lowers the degree of myopia but also meliorates the risk of vision loss.[12] Once myopia has progressed, it is irreversible when it

becomes manifest in an eye, with all the risks associated with excessive axial length.[13,14] Even if the patient undergoes refractive surgery in adulthood, the threat to vision from the established excessive axial length remains present.[15]

Several 'myopia control' treatments exist that aim to reduce myopia progression and/or delay myopia onset,[16–18] including purely optical means for myopia control, such as bifocal contact lenses[19–22] and spectacle lenses with specific optical lens designs.[23–26] The design of myopia control spectacles generally comprises a 'clear central zone', that is, a single vision (SV) zone for primary refractive correction. This clear zone is surrounded by a 'peripheral treatment zone' with a specific design to reduce myopia progression by acting mainly in the paracentral regions of the retina. This region, using evidence from electrophysiological and psychophysical measurements, is expected to include a defocus sensing retinal circuit believed to control axial eye growth during emmetropisation.[27–29] Myopia control spectacles have been shown to be a safe,[30] non-invasive option and can easily be implemented for most children. Spectacles include both the central refractive correction and a more peripheral myopia control zone, and treatment compliance is reported to be excellent. We previously found a slight, but not clinically relevant, reduction in visual acuity and contrast sensitivity in young subjects when looking through the peripheral treatment zone of defocus incorporated multiple segments (DIMS) spectacles,[30] which is in line with the findings of other authors.[31] Further results indicate that such spectacle lenses are generally well tolerated, do not impair the everyday tasks of children and all day traffic safety is maintained using most of the lens designs.[26,32–36]

Despite the apparent similarity in the optical designs of current myopia control spectacles, clinical trials to date have yielded disparate results with respect to acute treatment effects and long-term treatment efficacy[23–26,37] (see the Discussion section). This pilot study investigated the optical effects of the 'treatment zone' at the level of the sensory retina by employing scanning laser ophthalmoscopy (SLO) fundus imaging and functional microperimetry. Recently, de Tomas et al.[38] used infra-red imaging within optical coherence tomography (OCT) to visualise what they termed 'shadows' produced by various designs of myopia control spectacles. Such visualisation helps users to understand which areas of the retina are affected by the optical design of a myopia control spectacle lens. This provides a starting point for further investigations and the development of more refined lens designs.

Key points

- A novel method was used to visualise the areas of spatial light modulation created by myopia control spectacle lenses at the level of the retina.
- Some myopia control spectacle designs reduced retinal sensitivity, as assessed by functional microperimetry.
- In comparison, a 0.8-grade Bangerter-type occlusion foil produced a greater reduction in retinal sensitivity than any of the myopia control spectacle designs tested here; neither a clinically relevant reduction in vision nor a greater risk of amblyopia is anticipated.

MATERIALS AND METHODS

Subjects

Retinal sensitivity was measured using functional microperimetry in the presence of a test lens, that is, either a myopia control spectacle lens or an SV lens, in the right eyes of nine healthy volunteers (six females and three males). All of the eyes were healthy, as assessed by ophthalmologic examination and OCT scan, and underwent autorefraction and biometry. Table 1 shows the patient and ocular characteristics.

Spectacle lenses

For each subject ($n = 9$), each of the following spectacle designs was tested: (1) Zeiss Vision spherical ($n = 1.5$) single vision (SV) lenses (Zeiss.com), which served as a control; (2) Zeiss MyoCare (Zeiss.com); (3) Essilor Stellest (Essilor.com); (4) Hoya MiYOSMART (hoyavision.com) and (5) SightGlass Vision's Diffusion Optics Technology (DOT) lenses (sightglassvision.com).

The MyoCare, Stellest and MiYOSMART designs are based on a similar approach, namely, generating numerous local myopic defocus zones superimposed on the in-focus image generated by the SV central region by way of multiple refractive elements embedded within a SV lens. In more detail, the MyoCare design comprises cylindrical annular refractive elements, which form alternating defocus and correction zones in a ring-like pattern around a central clear zone. This design is available in two slightly different designs, which vary in the power of the defocusing elements (+4.6 and +3.8 D in the MyoCare and MyoCare S, respectively) and the diameter of the central clear zone (7 and 9 mm in the MyoCare and MyoCare S, respectively); the MyoCare lens was tested

TABLE 1 Characteristics of the subjects and their right eyes ($N = 9$).

	Age (years)	SER (D)	AL (mm)
Mean ± SD	29.4 ± 3.9	−1.6 ± 2.8	23.9 ± 1.4
Median	28.5	−1.1	24.1
Range (min; max)	23.3; 34.8	−7.0; +1.6	21.7; 25.9

Abbreviations: AL, axial length; SER, spherical equivalent refraction.

here. The Stellest design comprises numerous 'highly aspherical lenslet targets' (HALT) embedded in a SV lens, which is claimed to create a 'volume of defocus' in front of the retina.[35] The HALT lenslets are 1.1 mm in diameter and include 11 concentric rings around a central 'clear' zone of 10 mm diameter with the underlying SV power. The power of the lenslets varies from +6.0 to +3.50 D depending upon their eccentricity.[39,40] The MiYOSMART design comprises multiple DIMS, that is, about 400 single segments with add power of +3.5 D and a diameter of 1.03 mm arranged in a honeycomb-like pattern around a central 9 mm diameter 'clear' zone containing the underlying refractive correction.[24,39–42] Each segment produces a local myopic defocus zone at the retina.

SightGlass Vision's DOT design takes a different approach based on light diffusion using tiny (<0.5 mm) pseudo-randomly distributed 'diffusor' elements produced by laser engraving the front surface of an SV spectacle lens around a 4 mm diameter central clear zone. The DOT design aims to reduce retinal contrast,[26] and unlike the multiple lenslet designs, does not produce any (local) defocus at the retina.

Scanning laser ophthalmoscopy

Fundus imaging was performed with a microperimeter as described below, which incorporated a confocal SLO to capture images of the fundus at a wavelength of 850 nm. The SLO is normally used for eye tracking during functional microperimetry to compensate for eye movements in patients with poor fixation. Here, the SLO was used to visualise any spatial light modulation or contrast reduction at the retina, as it was created by the 'treatment zones' of the spectacle lenses.

Microperimetry and retinal sensitivity

Retinal sensitivity was assessed by functional microperimetry using the Macular Integrity Assessment (MAIA) instrument (CenterVue SpA; icare-world.com). A custom grid (see below) and a 4-2 staircase threshold strategy[43] was incorporated, that is, automatically adjusting the intensity of the target in ±4 decibel (db) forward steps followed by a ±2 db reverse step, based on the subject's response of 'seen' or 'not seen'. All myopia control lenses were fitted into trial frames and mounted to the eye piece of the microperimetry device. All lenses had a spherical power of −0.25 D; any remaining refractive errors were compensated for by the internal focus of the device. One measurement was performed per day, on consecutive days, to account for any lack of attention and fatigue. Measurements were obtained by trained ophthalmic assistants in the retinal clinic. First, subjects adjusted to the indoor lighting level for 10–15 min, followed by a 2–3-min adaptation period in a fully darkened examination room. Testing took between 6 and 10 min per eye. The MAIA 'Average Threshold' reading (dB) was taken as the value for 'retinal sensitivity'.

A custom test grid was created (Figure 1) to assess sensitivity in those retinal areas potentially affected by the spectacle lens optical 'treatment zones'. A close spacing of the targets inside each testing grid (<1 degree) was adopted. For example, the custom test grid overlaid with the SLO fundus image of one subject with the Stellest lens is shown in Figure 2. For analysis, the targets were summarised into two distinct fields: (Field A): the central five targets located in the retinal region corresponding to the central clear zones of each lens and (Field B): the peripheral band of 36 targets within the temporal retinal region corresponding to the treatment zone. For additional analyses of apparent spatial light modulation, the targets for field B were differentiated between locations that lay directly within the light modulated zones, evidenced by a darker spot in the SLO fundus image (blue dots in Figure 1) and targets lying between such modulated zones (orange dots in Figure 1). This distinction was performed manually for each of the 36 peripheral targets in field B and for each subject based on the individual fundus images for the MyoCare, Stellest and MiYOSMART lenses. For the DOT lens and a 0.8-grade Bangerter occlusion foil (BF), see below; this distinction was considered unreasonable due to the higher granularity of the lens designs.

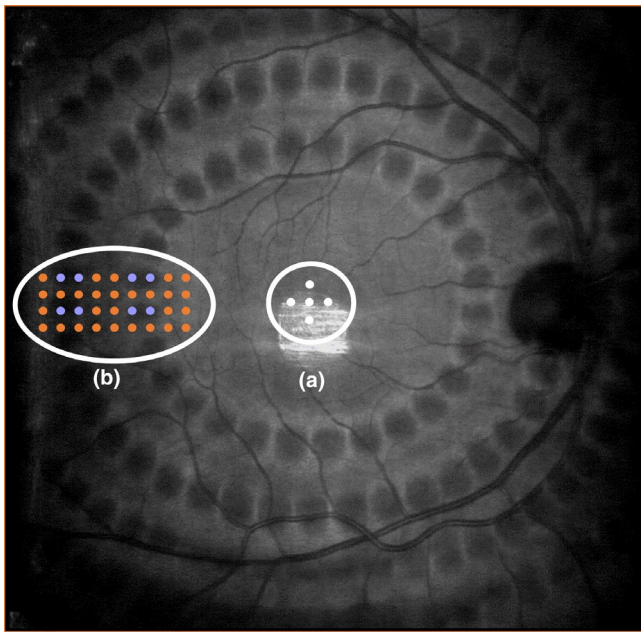

FIGURE 1 Custom grids for automated microperimetry (Macular Integrity Assessment) overlaid on the retinal image. The circled areas indicate the regions of analysis. (a) Central perimetry targets (corresponding to the lens' central 'clear zone'). (b) Temporal, peripheral perimetry targets (corresponding to lens' 'treatment zone'); *blue dots* indicate the perimetry targets located within the darker areas of spatial light modulation by the multiple lenslet design of the Stellest myopia control lens and *orange dots* indicate the perimetry targets located outside of these areas. The white patch at the image centre is an unavoidable artefact caused by light reflection.

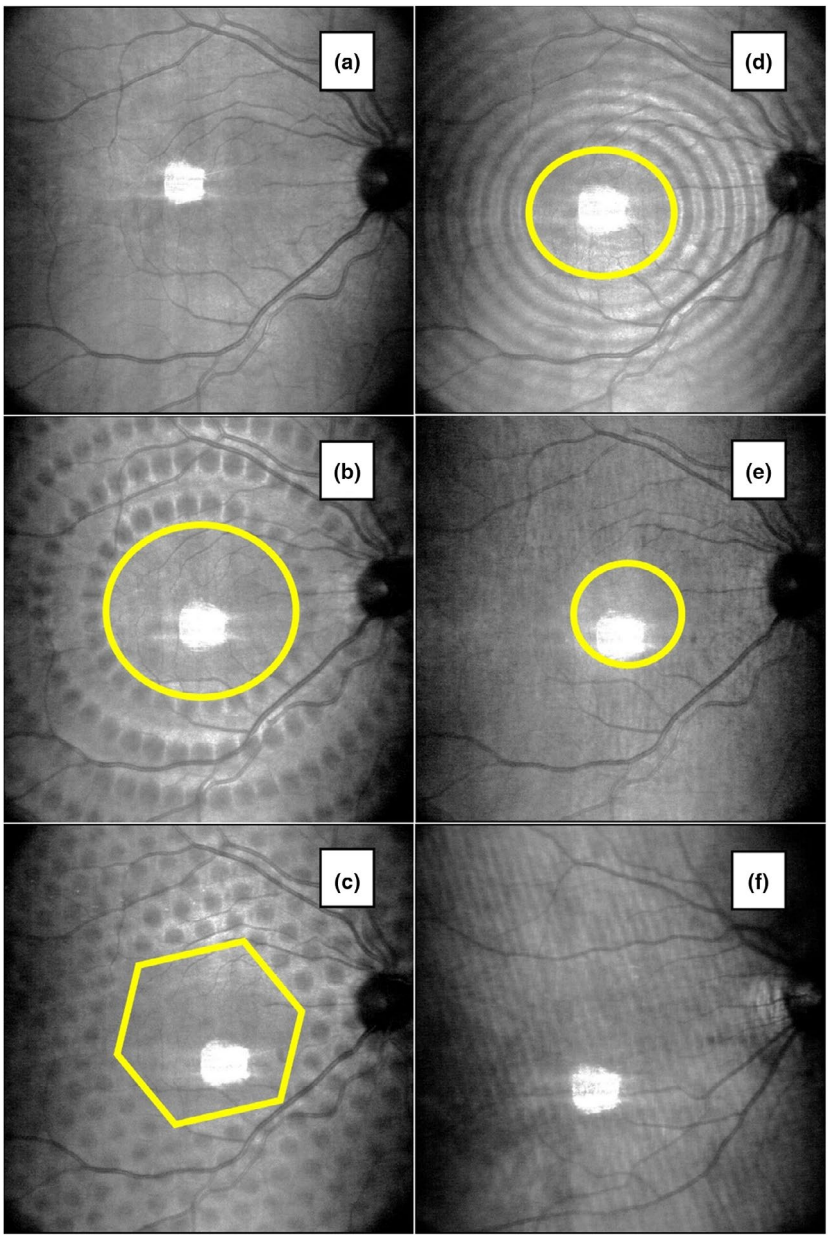

FIGURE 2 Patterns of local light modulation at the retina with myopia control lenses, visualised using the scanning laser ophthalmoscope of the Macular Integrity Assessment microperimeter. (a) Single vision lens, (b) Stellest, (c) MiYOSMART, (d) MyoCare, (e) Diffusion Optics Technology and (f) 0.8-grade Bangerter foil. The yellow shapes demarcate the boundaries between the central 'clear zone' and the optically structured 'treatment zone' of each lens (where applicable). The white patch in the image centre is an unavoidable artefact caused by light reflection.

Comparative testing with a Bangerter foil

A 0.8-grade BF (Ryser Optik AG; ryseroptik.ch), placed on a −0.25 D spherical trial lens, was employed for comparative assessment of retinal sensitivity with the SV and DOT lenses.

Statistics

Multiple measures analysis of variance and Bonferroni post-hoc tests, correcting for alpha error inflation, were employed with R Studio (Version number: 2023.12; posit.co/products/open-source/rstudio). p-Values <0.05 were considered significant.

RESULTS

Structure of the zones of spatial light modulation at the level of the retina

Figure 2 shows the patterns of light modulation created by each of the spectacle lenses. SLO fundus imaging allows visualisation of the optical effects of the 'treatment

zones' at the level of the retina. Each lens design creates a characteristic distribution of light, visible as patterns of darker and brighter areas in the fundus image. These patterns reflect the physical optical design of the spectacle lens. For the fundus images from the Stellest, MiYOSMART and MyoCare lenses, darker zones were surrounded by or embedded within lighter zones, reflecting the distinct ridges or multitude of lenslets of positive defocus imposed by the lens design. The DOT lens design does not reveal such distinct regions but rather a diffusion effect of the lens in the 'treatment zone'. The 0.8-grade BF, which served as a comparative control, showed an apparently similar diffusion effect within the SLO fundus image.

The size of the 'clear zone' differs significantly for each lens. The approximate dimensions at the level of the retina, expressed in relative optic disc diameter units (PD), are shown in Table 2. The DOT clear zone is approximately half the size of the clear zone for the Stellest and MiYOSMART lenses.

Retinal sensitivity in the central area

For the central targets (Figure 1a), corresponding to the central zone of the lens, no significant impact on retinal sensitivity was found (Table 3). All retinal sensitivities fell in the 'normal' range for a healthy retina, that is from 36 to 24 dB.[43]

TABLE 2 The mean dimensions of the 'clear zone' of each lens presented in relative units of optic disc diameter.

Diameter [PD]	Stellest	MiYOSMART	MyoCare	DOT
Mean ± SD	3.2 ± 0.4	3.0 ± 0.3	2.2 ± 0.2	1.7 ± 0.2

Note: PD is the ratio of the horizontal optic disc diameter to the diameter of the clear zone.

Abbreviation: DOT, diffusion optics technology.

Retinal sensitivity in the perifoveal regions

For the peripheral targets (Figure 1b), corresponding to the treatment zone of the lens, no significant impact on retinal sensitivity was found, apart from the DOT lens (Table 4), which showed significantly reduced retinal sensitivity in the treatment zone.

Effect of spatial light modulation at the level of the retina

Specific analysis across the targets in the peripheral visual field (Figure 1b) revealed a difference in retinal sensitivity between loci with and without evident light modulation, but this was only significant for the MiYOSMART lens, which also showed the largest difference in retinal sensitivity between the target spots (29.1 ± 1.5 vs. 28.5 ± 1.3 dB; $p < 0.02$).

Comparison of the DOT lens with a Bangerter occlusion foil

The peripheral retinal sensitivity through the 0.8-grade BF was significantly less (26.1 ± 1.9 dB) than that through either the DOT lens (27.2 ± 1.8 dB; $p < 0.001$) or the SV lens (27.9 ± 1.9 dB; $p < 0.001$).

DISCUSSION

The study utilised SLO imaging to visualise the effects of various designs of myopia control lenses at the retinal level, permitting insight into the quality, that is, appearance of the image spatial light modulation created by the lens treatment zones. It becomes evident that none of the designs tested here merely induced a simple myopic shift in

TABLE 3 Retinal sensitivity in the central clear zone of each lens.

Retinal sensitivity (dB)	SV	MyoCare	MiYOSMART	Stellest	DOT
Mean ± SD	29.2 ± 2.4	29.3 ± 2.8	29.1 ± 2.7	28.5 ± 2.4	28.8 ± 2.6
p-Value ($n = 9$)	–	>0.99	>0.99	0.39	>0.99

Note: *p*-Values reflect the comparison of each myopia control lens with the single vision (SV) lens.

Abbreviation: dB, decibels; DOT, diffusion optics technology.

TABLE 4 Retinal sensitivity as measured in the peripheral treatment zone of each lens.

Retinal sensitivity (dB)	SV	MyoCare	MiYOSMART	Stellest	DOT
Mean ± SD	28.1 ± 2.0	27.9 ± 2.4	28.0 ± 2.2	27.9 ± 2.2	27.3 ± 2.0
p-Value ($n = 9$)	–	0.38	>0.99	>0.99	**<0.001**

Note: *p*-Values reflect the comparison of each myopia control lens with the single vision (SV) lens. Bold letters emphasize the fact that this number is statistically significant (*p*-value), other *p*-values are not significant ("n.s.").

Abbreviation: dB, decibels; DOT, diffusion optics technology.

the peripheral retina, that is, the generation of a focused image in front of, rather than directly on, the retina. The minimal hypothesis that an image with positive myopic defocus will act as a signal to the eye to slow (excessive) axial growth might not be correct.[44] From the SLO fundus images observed here, the darker zones were surrounded by lighter zones, suggesting that structures within the 'treatment zone' of the lens create a large number of local areas of light modulation at the retina. This effect was most evident for the MiYOSMART and Stellest lenses, but also visible with the MyoCare design. In contrast, DOT lenses, with a pattern of laser embossed spots, showed an overall contrast reduction in the treatment zone. Evidently, the DOT design, both in terms of physical appearance and with regard to the SLO fundus images, resembles the design of a Bangerter-type occlusion patch/foil, which is intended for use in the treatment of amblyopia.[45] From this similarity in structure, it is apparent that the effects of the DOT lens and Bangerter foil at the retina are very similar.

Scanning laser ophthalmoscopy fundus imaging reliably estimates both the treatment zone and central zone dimensions of the myopia control lenses relative to the observer's fundus. This study focused on the dimensional analysis of the clear zone, with the DOT design having a clear zone about half the diameter of that for the Stellest or MiYOSMART lenses. To standardise the measurements, a relative measure was applied, with the dimensions of the clear zones in the respective fundus images being expressed as a multiple of the optic disc diameter (PD). It should also be noted that minus spectacle lenses used to correct myopia, including myopia control lenses, will minify the retinal image. This effect is influenced by factors such as vertex distance, lens refractive index, base curve, the axial length of the eye and the power of the correcting lens. While myopia control spectacles are generally fixed in terms of their physical dimensions, the axial length, refractive power and other ocular parameters may vary significantly across wearers. This leads to differences in the absolute dimensions of the light modulating structures at the retina. On average, the treatment zones are located, on a retinal level, at an eccentricity that aligns with the perifoveal region found most responsive to defocus. Notably, Panorgias et al., using electroretinography, identified a perifoveal region of 6°–12° eccentricity as highly sensitive to blur,[46] while Swiatczak and colleagues recently highlighted the near-peripheral retina, 6°–10° away from the fovea, as a 'sweet spot' for detecting positive defocus. They suggested that this region alone could influence eye growth control and perhaps long-term refractive development.[47]

The subtle yet crucial impact of local light modulation—and eventually retinal image contrast reduction—which is required to slow progression effectively over time, demands further evaluation. Before lenses of a similar optical design can be assumed to have equivalent treatment effects, a thorough assessment is essential to ensure accurate claims regarding their long-term efficacy. For instance, in Figure 3, the treatment effect of the myopia control spectacles was evaluated using the data available from existing clinical trials for the MyoCare,[48] MiYOSMART,[23] Stellest[25] and DOT[49] lenses. An additional evaluation of treatment efficiency was based primarily on the Age-Matched Myopia Control system by assessing the annual axial length growth rate with respect to an age-matched average physiological growth rate.[50] MiYOSMART lenses exhibited a sufficient treatment effect by reducing mean axial length growth to physiological levels (Figure 3 'green zone') over 5 years of treatment. While the DOT and Stellest lenses provided sufficient inhibition of growth in the first year, they appear to allow excessive axial growth in the subsequent years of treatment (Figure 3 'red zone'). On average, treatment with the MyoCare lens did not show a physiological axial length growth rate in the first year. However, long-term data are not yet available.

It remains unclear how the reduction in retinal sensitivity is related to the effect of myopia inhibition by the myopia control spectacles. The DOT lens showed the strongest reduction in retinal sensitivity in this study, while the MiYOSMART lens, which delivered the strongest myopia control effect according to the presented analysis (Figure 3), did not reduce overall retinal sensitivity. However, the MiYOSMART lens was the only design that exhibited significant modulation of retinal sensitivity in the 'treatment zone'.

In the retinal sensitivity measurements, the intended 'diffusion' approach of the DOT lens becomes apparent. This lens showed significantly lower retinal sensitivity in the periphery than any of the other lenses tested here. Notably, a 0.8-grade BF reduced retinal sensitivity significantly more than the DOT lens. Therefore, there is no reason to anticipate any risk of amblyopia with DOT lens use or with any of the other lens designs tested here.

The reduced long-term treatment effect with DOT lenses may be due to local contrast adaptation, where the retina adjusts to the continuous and uniform low-contrast environment created by these lenses. Initially, contrast reduction slowed axial growth, but over time, the retina's response to uniform contrast reduction may decrease, resulting in a reduced inhibitory effect on eye growth. This is in line with Schaeffel and Swiatczak's broader observations on the role of retinal image quality and spatial frequency on eye growth regulation.[51] The low spatial frequencies crucial for defocus detection may no longer be detected effectively during prolonged contrast reduction, further diminishing the DOT lens's inhibitory effect on axial elongation.

It is noteworthy that none of the lens designs tested here showed a reduction in retinal sensitivity of clinical relevance. All peripheral retinal sensitivities were found to be within the 'normal' range for a healthy retina, that is, from 36 to 24 dB.[43,52,53] This finding coincides with previous observations of a non-clinically significant reduction in contrast sensitivity during short-term wear of DIMS lenses.[30]

Finally, both defocus and diffusion-based lenses ultimately reduced image contrast at the peripheral retina,

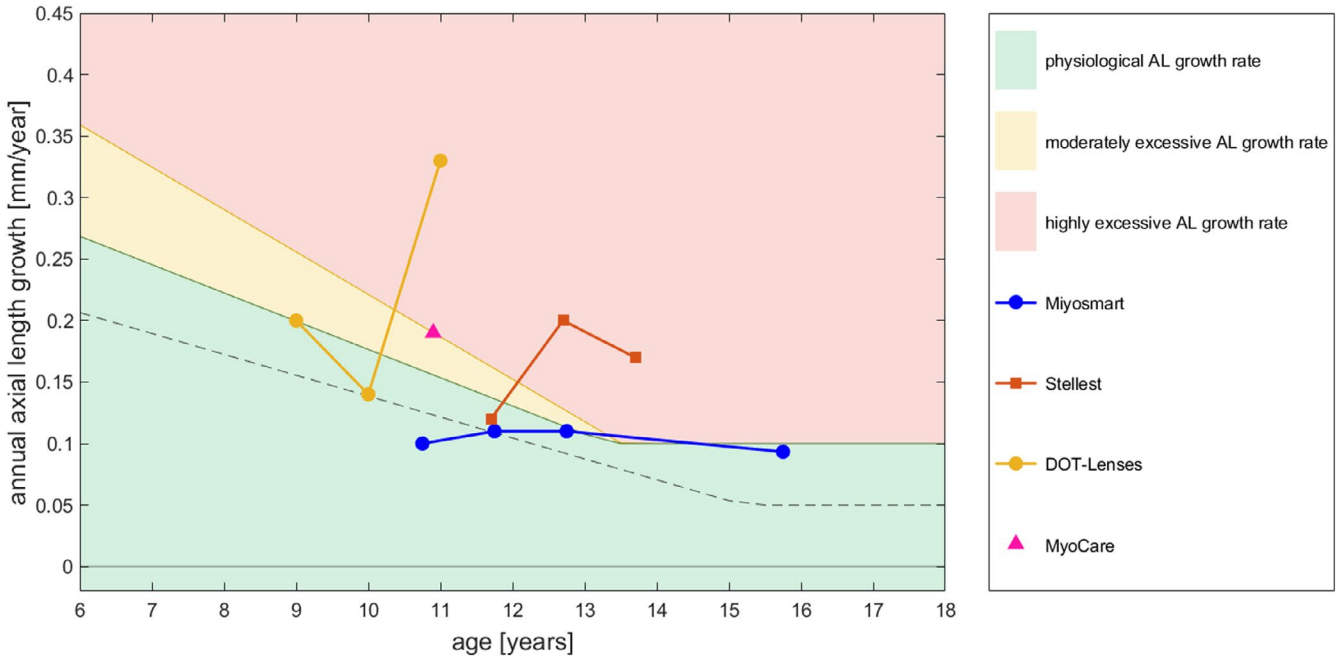

FIGURE 3 Evaluation of the myopia control effect of MyoCare, MiYOSMART, Stellest and DOT lenses based on the Age-Matched Myopia Control system. The MiYOSMART lens achieved the most stable myopia control effect, maintaining a physiological axial length growth rate over several years. However, while showing efficient myopia control in the first year of treatment (first data point), the DOT and Stellest lenses exhibited diminished efficacy or even a reversed effect in the following year of treatment (subsequent data points). AL, axial length; DOT, Diffusion Optics Technology.

which aligns with the insights of Schaeffel and Swiatczak[51] as to how peripheral visual input may influence axial growth. However, the retina's ability to adapt to sustained low-contrast conditions, as seen with DOT lenses, suggests that future lens designs may need to consider such adaptive mechanisms or incorporate variable contrast designs to maintain long-term efficacy.

It should be kept in mind that this study incorporated a static measurement using a paraxial light beam, in which the shadow spots of the treatment zone largely fell onto the same retinal loci. In reality, the eye moves behind the lens and light comes from all directions, so it can be assumed that the individual shadow spots of the defocusing components merge into a kind of diffuse shadow, similar to the overall diffusion by the DOT lenses. Theoretically, defocus and diffusion alter the retinal image in a slightly different manner; that is, despite a similar effect on the modular transfer function, there is a difference in phase shift.[54] However, it is unclear what aspects of vision should be targeted in the context of myopia treatment. Future lens designs should consider strategies to mitigate contrast adaptation and ensure sustained long-term myopia control, perhaps through dynamic lens designs that prevent the retina from adapting fully to low-contrast conditions.

CONCLUSION

This pilot study aimed to evaluate local retinal sensitivity and fundus light distribution through different myopia control spectacle lenses, in order to explore the factors behind the variations in myopia control effectivity. All of the current lens designs comprised a central 'SV' area for the refractive correction, surrounded by a more peripheral 'treatment area' of a particular optical design. This treatment zone was considered to slow myopia progression. All of the myopia control spectacles evaluated in this study were deemed tolerable in their impact on image contrast. Regarding the effect on retinal sensitivity, only subtle differences were observed between the lens designs and none produced a clinically relevant reduction in retinal sensitivity. Further, all lens designs produced significantly less reduction than a 0.8-grade occlusion foil.

AUTHOR CONTRIBUTIONS

Hakan Kaymak: Conceptualization (equal); investigation (equal); methodology (equal); project administration (equal); resources (equal); supervision (equal); writing – original draft (equal); writing – review and editing (equal). **Hartmut Schwahn:** Supervision (equal); validation (equal); writing – original draft (lead); writing – review and editing (lead). **Machteld Devenijn:** Data curation (equal); investigation (equal). **Ann-Isabel Mattern:** Conceptualization (equal); data curation (equal); formal analysis (equal); investigation (equal); methodology (equal); validation (equal); visualization (equal); writing – original draft (equal); writing – review and editing (equal). **Birte Neller:** Conceptualization (equal); data curation (equal); funding acquisition (equal); investigation (equal); methodology (equal); project administration (equal); validation (equal); visualization (equal); writing – original draft (equal). **Berthold Seitz:** Writing – review and editing (equal).

FUNDING INFORMATION

This research was privately funded; no external funding sources were used.

CONFLICT OF INTEREST STATEMENT

There are no relevant conflicts of interest for any of the authors.

ORCID

Hakan Kaymak https://orcid.org/0000-0001-5006-7420
Ann-Isabel Mattern https://orcid.org/0000-0002-0585-7818
Birte Graff https://orcid.org/0000-0002-9005-172X
Machteld Devenijn https://orcid.org/0009-0001-0698-7163
Berthold Seitz https://orcid.org/0000-0001-9701-8204
Hartmut Schwahn https://orcid.org/0000-0001-7791-532X

REFERENCES

1. Zadnik K, Sinnott LT, Cotter SA, Jones-Jordan LA, Kleinstein RN, Manny RE, et al. Prediction of juvenile-onset myopia. *JAMA Ophthalmol*. 2015;133:683–9.
2. Mutti DO, Hayes JR, Mitchell GL, Jones LA, Moeschberger ML, Cotter SA, et al. Refractive error, axial length, and relative peripheral refractive error before and after the onset of myopia. *Invest Ophthalmol Vis Sci*. 2007;48:2510–9.
3. Haarman AEG, Enthoven CA, Tideman JWL, Tedja MS, Verhoeven VJM, Klaver CCW. The complications of myopia: a review and meta-analysis. *Invest Ophthalmol Vis Sci*. 2020;61:49. https://doi.org/10.1167/iovs.61.4.49
4. Saw S-M, Gazzard G, Shih-Yen EC, Chua W-H. Myopia and associated pathological complications. *Ophthalmic Physiol Opt*. 2005;25:381–91.
5. Flitcroft DI. The complex interactions of retinal, optical and environmental factors in myopia aetiology. *Prog Retin Eye Res*. 2012;31:622–60.
6. Marcus MW, de Vries MM, Junoy Montolio FG, Jansonius NM. Myopia as a risk factor for open-angle glaucoma: a systematic review and meta-analysis. *Ophthalmology*. 2011;118:1989–94.
7. Chang MA, Congdon NG, Bykhovskaya I, Munoz B, West SK. The association between myopia and various subtypes of lens opacity: SEE (Salisbury Eye Evaluation) Project. *Ophthalmology*. 2005;112:1395–401.
8. van Leeuwen R, Haarman AEG, van de Put MAJ, Klaver CCW, Los LI. Association of rhegmatogenous retinal detachment incidence with myopia prevalence in the Netherlands. *JAMA Ophthalmol*. 2021;139:85–92.
9. Wong TY, Ferreira A, Hughes R, Carter G, Mitchell P. Epidemiology and disease burden of pathologic myopia and myopic choroidal neovascularization: an evidence-based systematic review. *Am J Ophthalmol*. 2014;157:9–25.
10. Vongphanit J, Mitchell P, Wang JJ. Prevalence and progression of myopic retinopathy in an older population. *Ophthalmology*. 2002;109:704–11.
11. Liu HH, Xu L, Wang YX, Wang S, You QS, Jonas JB. Prevalence and progression of myopic retinopathy in Chinese adults: the Beijing Eye Study. *Ophthalmology*. 2010;117:1763–8.
12. Bullimore MA, Brennan NA. Myopia control: why each diopter matters. *Optom Vis Sci*. 2019;96:463–5.
13. Chua SYL, Sabanayagam C, Cheung Y-B, Chia A, Valenzuela RK, Tan D, et al. Age of onset of myopia predicts risk of high myopia in later childhood in myopic Singapore children. *Ophthalmic Physiol Opt*. 2016;36:388–94.
14. Pärssinen O, Kauppinen M. Risk factors for high myopia: a 22-year follow-up study from childhood to adulthood. *Acta Ophthalmol*. 2019;97:510–8.
15. Kaymak H, Devenijn M, Neller K, Cosma C, Sickenberger W, Seitz B, et al. Post-SMILE—Was myope über ihre sekundär emmetropen Augen wissen. *Fortschr Ophthalmol*. 2023;120:400–5.
16. Ang M, Wong TY, editors. Updates on myopia: a clinical perspective. Singapore: Springer; 2020.
17. Walline JJ, Lindsley KB, Vedula SS, Cotter SA, Mutti DO, Ng SM, et al. Interventions to slow progression of myopia in children. *Cochrane Database Syst Rev*. 2020;1:CD004916. https://doi.org/10.1002/14651858.CD004916.pub4
18. Russo A, Boldini A, Romano D, Mazza G, Bignotti S, Morescalchi F, et al. Myopia: mechanisms and strategies to slow down its progression. *J Ophthalmol*. 2022;2022:1004977. https://doi.org/10.1155/2022/1004977
19. Walline JJ, Walker MK, Mutti DO, Jones-Jordan LA, Sinnott LT, Giannoni AG, et al. Effect of high add power, medium add power, or single-vision contact lenses on myopia progression in children: the BLINK randomized clinical trial. *JAMA*. 2020;324:571–80.
20. Chamberlain P, Bradley A, Arumugam B, Hammond D, McNally J, Logan NS, et al. Long-term effect of dual-focus contact lenses on myopia progression in children: a 6-year multicenter clinical trial. *Optom Vis Sci*. 2022;99:204–12.
21. Yu Z, Zhong A, Zhao X, Li D, Duan J. Efficacy and safety of different add power soft contact lenses on myopia progression in children: a systematic review and meta-analysis. *Ophthalmic Res*. 2022;65:398–416.
22. Sankaridurg P. Contact lenses to slow progression of myopia. *Clin Exp Optom*. 2017;100:432–7.
23. Lam CSY, Tang WC, Zhang HY, Lee PH, Tse DYY, Qi H, et al. Long-term myopia control effect and safety in children wearing DIMS spectacle lenses for 6 years. *Sci Rep*. 2023;13:5475. https://doi.org/10.1038/s41598-023-32700-7
24. 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. *Br J Ophthalmol*. 2020;104:363–8.
25. Li X, Huang Y, Yin Z, Liu C, Zhang S, Yang A, et al. Myopia control efficacy of spectacle lenses with aspherical lenslets: results of a 3-year follow-up study. *Am J Ophthalmol*. 2023;253:160–8.
26. Rappon J, Chung C, Young G, Hunt C, Neitz J, Neitz M, et al. Control of myopia using diffusion optics spectacle lenses: 12-month results of a randomised controlled, efficacy and safety study (CYPRESS). *Br J Ophthalmol*. 2023;107:1709–15.
27. Ho W-C, Wong O-Y, Chan Y-C, Wong S-W, Kee C-S, Chan HH-L. Sign-dependent changes in retinal electrical activity with positive and negative defocus in the human eye. *Vision Res*. 2012;52:47–53.
28. Wagner S, Strasser T. Impact of text contrast polarity on the retinal activity in myopes and emmetropes using modified pattern ERG. *Sci Rep*. 2023;13:11101. https://doi.org/10.1038/s41598-023-38192-9
29. Xu Z, Zhuang Y, Chen Z, Hou F, Chan LYL, Feng L, et al. Assessing the contrast sensitivity function in myopic parafovea: a quick contrast sensitivity functions study. *Front Neurosci*. 2022;16:971009. https://doi.org/10.3389/fnins.2022.971009
30. Kaymak H, Neller K, Schütz S, Graff B, Sickenberger W, Langenbucher A, et al. Vision tests on spectacle lenses and contact lenses for optical myopia correction: a pilot study. *BMJ Open Ophthalmol*. 2022;7:e000971. https://doi.org/10.1136/bmjophth-2022-000971
31. Li X, Ding C, Li Y, Lim EW, Gao Y, Fermigier B, et al. Influence of lenslet configuration on short-term visual performance in myopia control spectacle lenses. *Front Neurosci*. 2021;15:667329. https://doi.org/10.3389/fnins.2021.667329
32. Lu Y, Lin Z, Wen L, Gao W, Pan L, Li X, et al. The adaptation and acceptance of defocus incorporated multiple segment lens for Chinese children. *Am J Ophthalmol*. 2020;211:207–16.
33. Lam CSY, Tang WC, Qi H, Radhakrishnan H, Hasegawa K, To CH, et al. Effect of defocus incorporated multiple segments spectacle lens

wear on visual function in myopic Chinese children. *Transl Vis Sci Technol*. 2020;9:11. https://doi.org/10.1167/tvst.9.9.11
34. Ryu H, Ju U, Wallraven C. Myopia-correcting lenses decrease eye fatigue in a visual search task for both adolescents and adults. *PLoS One*. 2021;16:e0258441. https://doi.org/10.1371/journal.pone.0258441
35. 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. *Br J Ophthalmol*. 2022;106:1171–6.
36. Gao Y, Lim EW, Yang A, Drobe B, Bullimore MA. The impact of spectacle lenses for myopia control on visual functions. *Ophthalmic Physiol Opt*. 2021;41:1320–31.
37. Kaymak H, Neller B, Mattern A-I, Devenijn M, Neller K. Influence of retinal 'shadows' produced by myopia control spectacle lenses on retinal sensitivity—preliminary results: Abstract Book IMC 2024, Sanya, China.
38. de Tomas M, Szeps A, Martín G, Suárez JM, Atchison DA, Rozema JJ, et al. Retinal shadows produced by myopia control spectacles. *Ophthalmic Physiol Opt*. 2024;44:214–8.
39. Gantes-Nuñez J, Jaskulski M, López-Gil N, Kollbaum PS. Optical characterisation of two novel myopia control spectacle lenses. *Ophthalmic Physiol Opt*. 2023;43:388–401.
40. Radhakrishnan H, Lam CSY, Charman WN. Multiple segment spectacle lenses for myopia control. Part 1: optics. *Ophthalmic Physiol Opt*. 2023;43:1125–36.
41. Jaskulski M, Singh NK, Bradley A, Kollbaum PS. Optical and imaging properties of a novel multi-segment spectacle lens designed to slow myopia progression. *Ophthalmic Physiol Opt*. 2020;40:549–56.
42. Carlà MM, Boselli F, Giannuzzi F, Gambini G, Caporossi T, de VU, et al. Overview on defocus incorporated multiple segments lenses: a novel perspective in myopia progression management. *Vision*. 2022;6:20. https://doi.org/10.3390/vision6020020
43. CenterVue. MAIA macular integrity assessment operating manual. 2019 [cited 2024 Nov 10]. Available from: https://materialbank.icare-world.com/wp-content/uploads/2023/03/2.6-MAIA2-Operating-Manual-EN.pdf
44. Benavente-Pérez A, Nour A, Troilo D. Axial eye growth and refractive error development can be modified by exposing the peripheral retina to relative myopic or hyperopic defocus. *Invest Ophthalmol Vis Sci*. 2014;55:6765–73.
45. Bangerter A. Treatment of amblyopia: part 1. *Strabismus*. 2017;25:222–30.
46. 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;62:1. https://doi.org/10.1167/iovs.62.10.1
47. Swiatczak B, Scholl HPN, Schaeffel F. Retinal 'sweet spot' for myopia treatment. *Sci Rep*. 2024;14:26773. https://doi.org/10.1038/s41598-024-78300-x
48. Chen X, Wu M, Yu C, Ohlendorf A, Padmaja S, Rifai K, et al. Slowing myopia progression with Cylindrical Annular Refractive Elements (CARE)—12-month interim results from a 2-year prospective multicenter trial. *IOVS*. 2024;65:ARVO E-Abstract 2736. https://doi.org/10.1111/aos.16795
49. Chalberg T, Laughton D, Hill J, Tasso V, Young G, Hunt C, et al. Control of myopia using diffusion optics spectacle lenses: efficacy and safety study (CYPRESS) 42-month results. *Invest Ophthalmol Vis Sci*. 2023;64:ARVO E-Abstract 5092. https://doi.org/10.1136/bjo-2021-321005
50. Graff B, Lam CSY, Vlasak N, Kaymak H. Age-matched analysis of axial length growth in myopic children wearing defocus incorporated multiple segments spectacle lenses. *Br J Ophthalmol*. 2023;108:1060–6.
51. Schaeffel F, Swiatczak B. Mechanisms of emmetropization and what might go wrong in myopia. *Vision Res*. 2024;220:108402. https://doi.org/10.1016/j.visres.2024.108402
52. Molina-Martín A, Piñero DP, Pérez-Cambrodí RJ. Normal values for microperimetry with the MAIA microperimeter: sensitivity and fixation analysis in healthy adults and children. *Eur J Ophthalmol*. 2017;27:607–13.
53. Charng J, Sanfilippo PG, Attia MS, Dolliver M, Arunachalam S, Chew AL, et al. Interpreting MAIA microperimetry using age- and retinal loci-specific reference thresholds. *Transl Vis Sci Technol*. 2020;9:19. https://doi.org/10.1167/tvst.9.7.19
54. Pérez GM, Archer SM, Artal P. Optical characterization of Bangerter foils. *Invest Ophthalmol Vis Sci*. 2010;51:609–13.

How to cite this article: Kaymak H, Mattern A-I, Graff B, Devenijn M, Seitz B, Schwahn H. Optical influence of myopia control spectacles at the retinal level: Effect of local light modulation. *Ophthalmic Physiol Opt*. 2025;45:995–1003. https://doi.org/10.1111/opo.13515