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Effects of defocus incorporated multiple segments (DIMS) and highly aspherical lenslets (HAL) spectacle lenses on myopia management and choroidal thickness in pre-myopic children: a 1-year prospective clinical study

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Effects of defocus incorporated multiple segments (DIMS) and highly aspherical lenslets (HAL) spectacle lenses on myopia management and choroidal thickness in pre-myopic children: a 1-year prospective clinical study

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Abstract

Purpose: To evaluate the 1-year effects of defocus incorporated multiple segments (DIMS) and highly aspherical lenslets (HAL) spectacle lenses on myopia management and choroidal thickness (ChT) in pre-myopic children.

Methods: This prospective, real-world study recruited 114 children (114 eyes) aged between 6 and 12 years with pre-myopia (spherical equivalent [SE] ≤ +0.75 and > –0.50 D), who were assigned to three groups: wearing plano lenses with DIMS, HAL, or a control group receiving no intervention. The 1-year data were evaluated, including axial length (AL), SE, subfoveal (SF) ChT, and ChT in nine retinal regions.

Results: A total of 98 participants (35 in the DIMS group, 33 in the HAL group, and 30 in the control group) finished the 1-year follow-ups. At the 1-year visit, the DIMS and HAL groups had lower SE increase than the control group (-0.30±0.32D and -0.26±0.25D *vs.* -0.51±0.43 D, P=0.008); the DIMS and HAL groups had lower AL elongation than the control group (0.16±0.14 mm and 0.12±0.17 mm *vs.* 0.35±0.21 mm, P<0.001); the DIMS and HAL groups had greater ChT increases in T3, T6, S6 regions than the control group, and the HAL group had greater ChT increase in S3 region than the control group (all P<0.05). The 1-year change in SFChT and S6 region showed a significant negative correlation with 1-year AL change across DIMS and HAL groups, and significant negative correlations were also found in the S3 region of the HAL group and the N3 region of the control group (all P<0.05).

Conclusion: Both DIMS and HAL spectacle lenses can effectively slow SE progression and AL elongation in pre-myopic children, which might be related to the different levels of ChT increases in various regions.

KEYWORDS: DIMS, HAL, myopia, spectacle, pre-myopia, choroidal thickness

INTRODUCTION

Myopia that develops in childhood typically begins early and progresses rapidly, and such early onset substantially raises the lifelong risk of high myopia[1,2]. Severe ocular disease, visual disability, and irreversible loss of sight are frequently attributable to high myopia. It is therefore of considerable importance to develop and apply effective measures for preventing and managing myopia during the critical window of childhood ocular development. Over recent decades, research in this field has focused primarily on slowing progression in children who have already been diagnosed with myopia. Nevertheless, keeping high-risk children from ever becoming myopic represents a more fundamental and clinically valuable strategy, yet dedicated research on this approach remains relatively scarce. In children, pre-myopia refers to an ocular refractive state in which the spherical equivalent exceeds −0.50 D but does not surpass +0.75 D[3]; axial elongation proceeds rapidly during this phase, and the likelihood of advancing to overt myopia is considerable, making pre-myopia a critical period for early intervention. Epidemiological evidence accumulating from China indicates that pre-myopia is prevalent among children and that its prevalence is still rising[4,5]. Furthermore, interventions that prevent pre-myopic children from crossing the threshold into myopia appear to yield substantially greater benefits than treatments that merely slow further worsening in children who are already myopic[6]. According to an estimate by Hu and colleagues[7], postponing myopia onset from age 9 to age 10 could lower the total axial length (AL) gained up to adulthood by approximately 0.5 mm. For comparison, control interventions delivered to myopic children generally curtail AL elongation by less than 0.4 mm over two years relative to untreated controls[8]. Taken together, these observations underscore an urgent clinical need for prevention strategies aimed specifically at pre-myopic children.

To date, three candidate approaches—increased outdoor exposure, low-dose atropine eye drops, and repeated low-level red light therapy—have been tested for their ability to prevent the onset of myopia in pre-myopic children. Newer-generation spectacle lenses for myopia control offer a low-risk, non-surgical, and generally well-tolerated approach that lends itself to large-scale use in children; however, prospective clinical evidence supporting their use for pre-myopia prevention remains sparse. Among such spectacle designs, two have attracted particular interest: lenses built on defocus incorporated multiple segments (DIMS) and lenses equipped with highly aspherical lenslets (HAL). In a recent trial, Zhang et al.[9] examined HAL lenses in children with low hyperopia (0.00 to +2.00 D). Chen et al.[10] retrospectively compared the two lens designs in pre-myopic children and observed findings suggestive of protective effects in this population.

Although the precise mechanisms by which these lenses prevent or slow myopia remain incompletely understood, a growing body of evidence identifies the choroid as a key mediator[11,12]. Because choroidal thickness (ChT) influences the position of the retinal focal plane, fluctuations in ChT can initiate downstream signaling that travels from the retina toward the sclera. In turn, these signals ease hypoxia within the sclera, drive restructuring of the scleral extracellular matrix,

and help regulate ocular growth during emmetropization[13,14]. To date, most studies of choroidal responses have involved children with established myopia. Only a few investigations have documented how ChT changes in pre-myopic children after they begin wearing myopia-control spectacle lenses. Furthermore, the choroid does not respond uniformly to imposed myopic defocus: the magnitude of thickness change can vary by retinal region. Such regional variation suggests that the spatial distribution of defocus and site-dependent choroidal responses may influence treatment outcomes[15,16]. Determining precisely how DIMS and HAL lenses modulate ChT across distinct retinal zones would deepen the mechanistic understanding of spectacle-based myopia control and inform clinicians' decisions on refining management plans.

Accordingly, this one-year prospective study was designed to evaluate the clinical performance of DIMS and HAL lenses for myopia management and to characterize regional ChT changes in pre-myopic children.

METHODS

Study design

This prospective, non-randomized cohort study was conducted from November 2022 to January 2026. This study adhered to the guidelines of the Helsinki Declaration and obtained approval from the Institutional Review Board of the First Affiliated Hospital of Chengdu Medical College (2022CYFYIRB-BA-Nov08). This study has been registered at Chinese clinical trial registry (number ChiCTR2300072872). The parents or legal guardians of all participants received full information regarding the study protocol, potential benefits, and associated risks, and provided written informed consent prior to enrollment.

Subjects

This study consecutively recruited 114 participants at the First Affiliated Hospital of Chengdu Medical College between November 2022 and December 2024. All participants were enrolled based on the following criteria (Table 1).

Table 1 Inclusion & Exclusion Criteria.

Inclusion criteria	Exclusion criteria
6 to 12 years old (inclusive)	Previous history of myopia control in the past 6 months
Cycloplegic spherical equivalent (SE): ≤ +0.75 and > –0.50 D	Ocular or systemic disease
Uncorrected visual acuity (UCVA) of 0.10 LogMAR or better in both eyes	Binocular vision problems
Anisometropia: ≤1.00 D	Poor compliance
Astigmatism: ≤1.00 D	

Allocations and Treatments

Based on the preferences of patients and their guardians, eligible participants were assigned to three groups: wearing plano DIMS lenses (Hoya Miyosmart, Tokyo, Japan), wearing plano HAL lenses (Essilor Stellest, Paris, France), or receiving no clinical intervention (control group). The DIMS spectacle lens incorporates a central zone (9.4 mm diameter) for clear distance vision surrounded by a honeycomb treatment zone (33mm diameter) including 396 tiny lenslets with a myopic defocus power of +3.50D[17]. The HAL lens has a 9 mm diameter central zone and achieves myopic defocus via 11 peripheral concentric rings formed by 1021 continuous aspherical lenslets, creating a myopic defocus power of +3.0-5.5D[18]. Children in the DIMS and HAL groups were all instructed to wear the spectacles full-time (except during sleeping and taking shower) for no less than 10 hours per day, and the time of lens wear was assessed through a questionnaire on the daily average hours of lens wear at each follow-up.

Measurements

All participants attended follow-up visits at baseline, 3 months, 6 months, and 1 year, and all study visits were scheduled between 08:00 am and 10:00 am to minimise diurnal variation.

Axial length (AL) and cycloplegic spherical equivalent (SE) were measured using the IOLMaster 500 (Carl Zeiss, Germany) and RM8900 autorefractor (Topcon, Japan), respectively, in accordance with the manufacturer's instructions. Cycloplegia was induced by three instillations of 0.5% tropicamide eye drops (Zhuobi'an, Shenyang Sinqi Pharmaceutical Co., Ltd., China),

administered at 5-minute intervals. Measurements were acquired no less than 30 minutes after the final instillation.

Choroidal thickness (ChT) was measured three times for all participants using the enhanced depth imaging (EDI) mode of the Spectralis OCT instrument (Heidelberg Engineering, Heidelberg, Germany). Macular scanning was centered on the fovea with 12 radial-line B-scans covering a 6 × 6 mm area, and scans were acquired with the automatic real-time (ART) averaging function set to 32 frames. Acquired under high-speed mode, each B-scan contained 128 A-scans, and only scans with a quality index ≥25 dB were included. Measurements were conducted under the 1:1 micron calibration setting. The built-in Early Treatment Diabetic Retinopathy Study (ETDRS) grid[19] was automatically overlaid on the macular area (Fig. 1). Full details regarding OCT acquisition and the ETDRS grid have been reported elsewhere in our prior work[20].

Initial choroidal layer segmentation was generated by the instrument's built-in algorithm. Two experienced ophthalmic graders, masked to participant information, independently reviewed the segmentation boundaries on all B-scans and manually rectified segmentation artifacts to achieve reliable choroidal delineation. Following manual correction, the software automatically computed mean ChT across the nine ETDRS macular subfields for each eye. Measurements from the two graders were averaged for subsequent statistical analysis.

As previously reported[21], ocular magnification correction is not required for central macular ChT measurements. For the N6 subfield and other macular regions in eyes with an AL < 22.8 mm or > 26.0 mm, magnification correction was performed using the Littmann formula, with individual participant AL incorporated into the calculation[22,23].

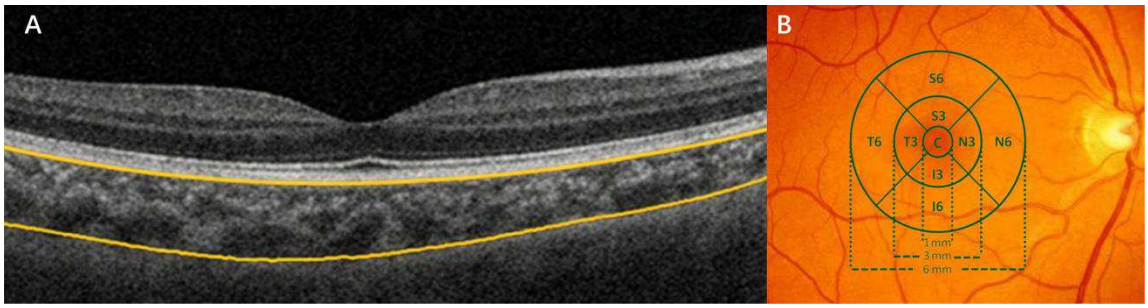

Fig. 1 Schematic diagram of choroidal layer segmentation and ETDRS regions. A. The choroid boundary (yellow lines). B. The ETDRS region diagram. C, central; N, nasal; T, temporal; S, superior; I, inferior.

Sample Size

Sample size calculation was performed using PASS 11.0 for one-way analysis of variance (ANOVA), based on data from a prior study[24]. A minimum of 26 participants per group was required to detect a between-group difference of 0.14 mm, assuming a standard deviation of 0.16 mm, 90% statistical power, and an α level of 0.05. After accounting for an anticipated 30% dropout rate, the required total sample size was 114 participants (38 per group).

Statistical Analysis

Data from the right eyes were included in the analyses. Statistical analyses were performed using SPSS version 26.0 (IBM-SPSS Inc., USA). Categorical variables were compared using the chi-squared test. The Kolmogorov–Smirnov test was used to examine the normality of data distribution; normally distributed data were presented as mean ± standard deviation (SD). Levene's test was applied to assess homogeneity of variances. One-way ANOVA was adopted for between-group comparisons across the three groups, followed by Bonferroni post-hoc testing. Repeated-measures ANOVA was performed to evaluate the effect of time (four study visits) on ChT. Associations between changes in AL and changes in ChT were explored using Pearson correlation analysis. A P value < 0.05 was considered statistically significant.

RESULTS

Participants

A total of 98 participants (35 in the DIMS group, 33 in the HAL group, and 30 in the control group) finished the 1-year follow-ups (Fig. 2). There were no statistical differences in baseline data between the three groups (all $P>0.05$, Table 2).

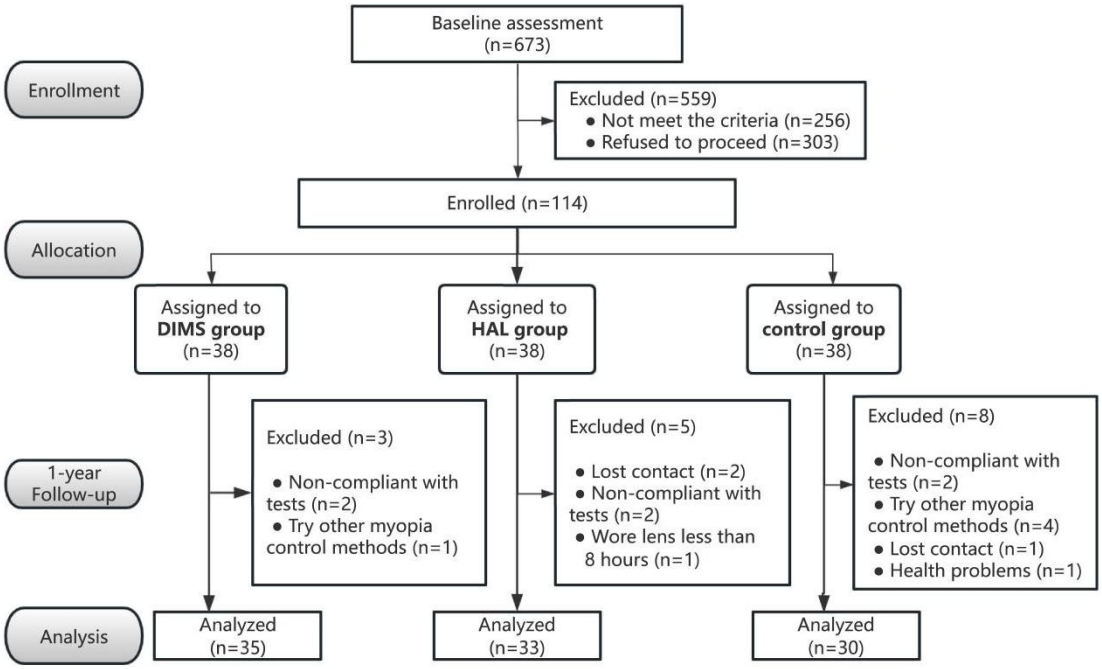

Fig. 2 Study flowchart. DIMS, defocus incorporated multiple segments; HAL, highly aspherical lenslets.

Table 2 Baseline data.

	DIMS (n=35)	HAL (n=33)	control (n=30)	F/χ^2	P
Age (y)	7.91±1.48	8.06±1.69	8.27±1.62	0.394	0.675
Male/female	21/14	18/15	12/18	2.714	0.257
SE (D)	0.10±0.40	-0.01±0.35	0.23±0.41	3.050	0.052
AL (mm)	23.17±0.65	23.29±0.87	23.34±0.99	0.379	0.686
SFChT (μm)	305.89±43.19	297.18±40.44	307.03±45.38	0.511	0.602
parental myopia (none/1/both)	5/17/13	7/14/12	7/13/10	1.006	0.909

DIMS, defocus incorporated multiple segments; HAL, highly aspherical lenslets; SE, spherical equivalent; AL, axial length; SFChT, subfoveal choroidal thickness.

Changes in AL and SE

The increase of SE in the DIMS group was lower than that in the control group by post-hoc analysis (6-month: P=0.036, 12-month: P=0.033). The increase of SE in the HAL group was lower than that in the control group by post-hoc analysis (12-month: P=0.011). The AL elongation in the DIMS group was lower than that in the control group by post-hoc analysis (6-month: P=0.010, 12-month: P<0.001). The AL elongation in the HAL group was lower than that in the

control group by post-hoc analysis (3-month: P=0.007, 6-month: P=0.003, 12-month: P<0.001) (Table 3).

Table 3 Changes in AL and SE from baseline in each group (mean ± SD).

	DIMS (n=35)	HAL (n=33)	control (n=30)	F	P
Change in SE (D)					
3-month	-0.05±0.27	-0.03±0.24	-0.11±0.31	0.711	0.494
6-month	-0.13±0.23	-0.14±0.27	-0.31±0.36*	3.913	**0.023**
12-month	-0.30±0.32	-0.26±0.25	-0.51±0.43*#	5.122	**0.008**
Change in AL (mm)					
3-month	0.01±0.12	-0.02±0.14	0.09±0.14#	5.201	**0.007**
6-month	0.06±0.13	0.05±0.19	0.19±0.19*#	6.885	**0.002**
12-month	0.16±0.14	0.12±0.17	0.35±0.21*#	15.630	**<0.001**

Post-hoc test, *P<0.05 *vs*. DIMS group. #P<0.05 *vs*. HAL group. DIMS, defocus incorporated multiple segments; HAL, highly aspherical lenslets; SE, spherical equivalent; AL, axial length.

Percentage of Myopia Progression and Myopia Incidence

After 1 year, the percentage of myopia progression, categorized by annual change in SE and AL, showed a statistical difference between the three groups (SE: χ^2=15.290, P<0.001; AL: χ^2=8.573, P=0.014). The proportion of children with rapid myopia progression (SE progression > 0.50 D) was significantly lower in the HAL group than in the control group (Fig. 3A). Similarly, the proportion of children with rapid axial elongation (>0.2 mm) was significantly lower in the HAL group than in the control group (Fig. 3B). However, there was no statistical difference in myopia incidence between the three groups (DIMS: 34.29%; HAL: 27.27%; control: 36.67%; χ^2=0.697, P=0.706).

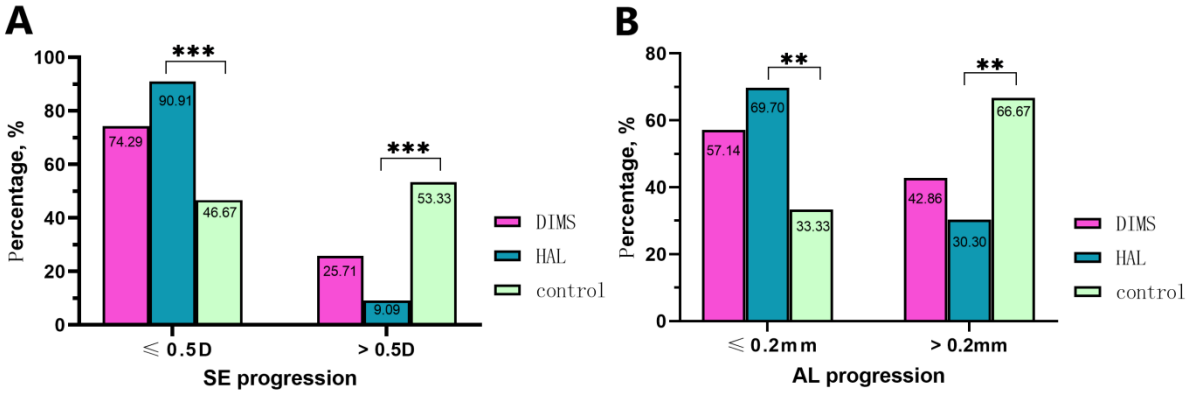

Fig. 3 Distribution of myopia progression based on annual changes of SE (A) and AL (B) between the three groups. Post-hoc test, **P<0.01, ***P<0.001. DIMS, defocus incorporated multiple segments; HAL, highly aspherical lenslets; SE, spherical equivalent; AL, axial length.

Changes in ChT

Fig. 4 summarizes the localized ChT across nine retinal regions for three groups over time. After 1 year, ChT decreased in most regions. The control group showed a significant reduction in ChT in the N3, T3, S3, and S6 regions (all P < 0.05). In contrast, a significant reduction in ChT was

observed only in the N6 region in the DIMS group ($P < 0.05$), while no significant changes were observed in the HAL group.

At the 1-year visit, the DIMS and HAL groups had greater ChT increases in the T3, T6, S6 regions than the control group, and the HAL group had greater ChT increases in the S3 region than the control group (all $P<0.05$, Fig. 5).

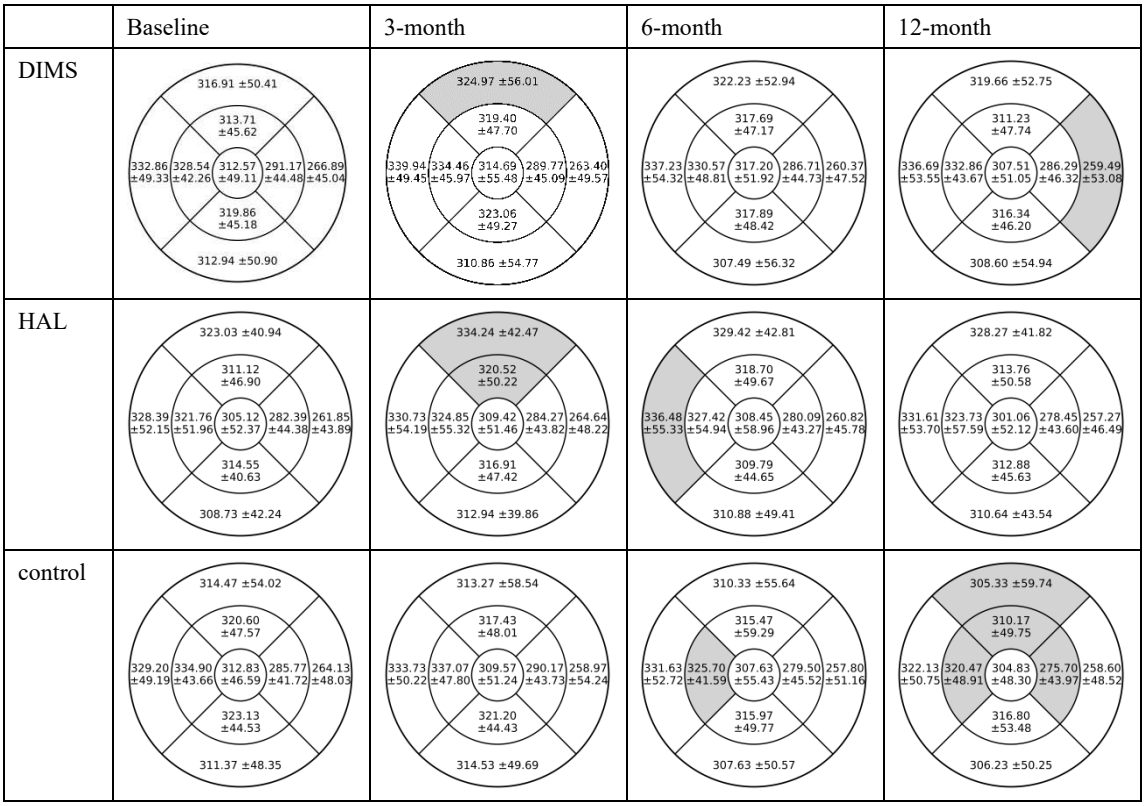

Fig. 4 Overview of choroidal thickness across nine regions for DIMS, HAL, and control groups measured at each visit. Regions highlighted in grey indicate a significant difference between the current measurement and baseline after multiple comparisons. DIMS, defocus incorporated multiple segments; HAL, highly aspherical lenslets.

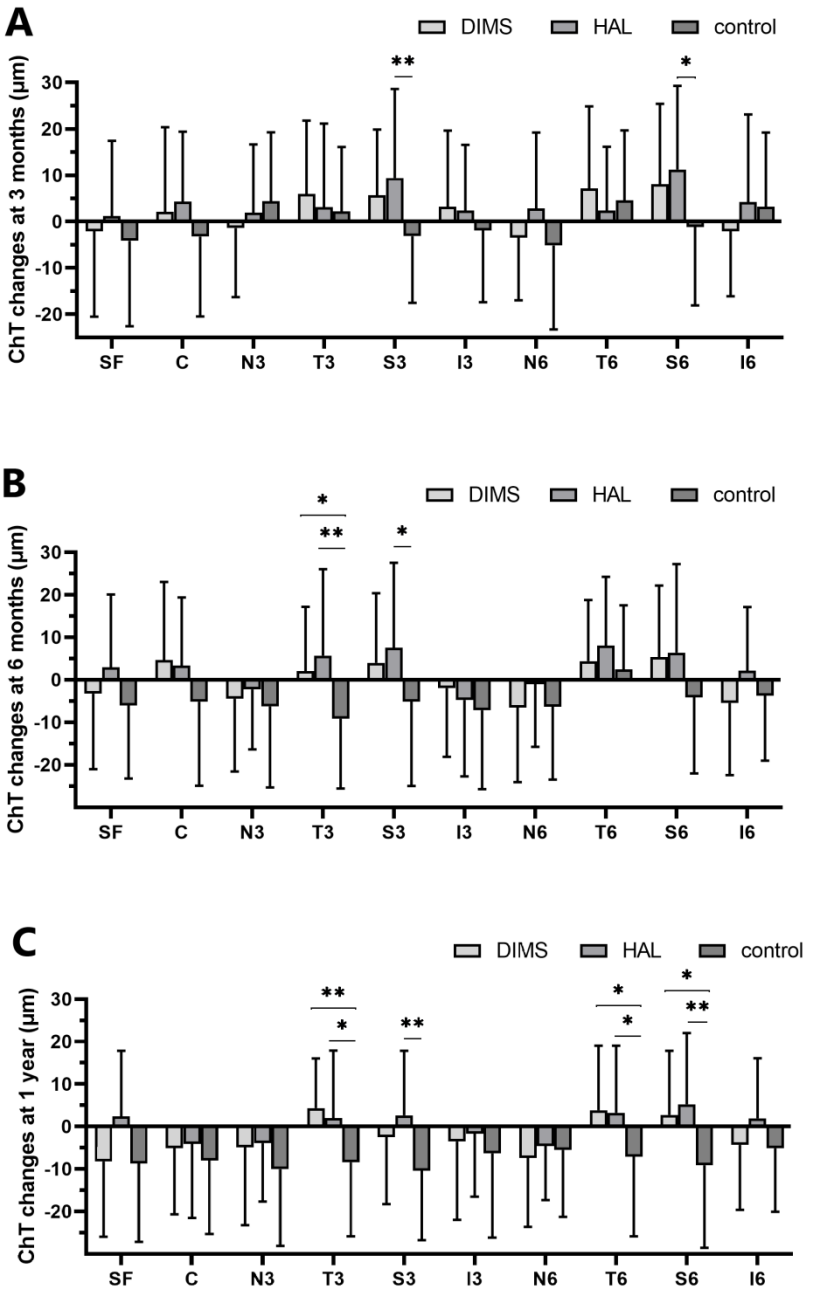

Fig. 5 Comparison of changes in ChT at 3 months (A), 6 months (B), and 1 year (C) from baseline between the three groups. Post-hoc test, **P*<0.05, ***P*<0.01. Error bars represent standard deviation. DIMS, defocus incorporated multiple segments; HAL, highly aspherical lenslets; ChT, choroidal thickness; SF, subfoveal; C, central; N, nasal; T, temporal; S, superior; I, inferior.

Correlations between AL change and ChT change

The Pearson correlation analysis indicated that the 1-year change in AL was not statistically correlated with the 1-year ChT change in central, temporal, and inferior regions (all $P>0.05$). However, the 1-year change in SFChT and S6 region showed a significant negative correlation with AL change across DIMS and HAL groups. Additionally, significant negative correlations were also found in the S3 region of the HAL group and the N3 region of the control group (all $P<0.05$, Fig. 6).

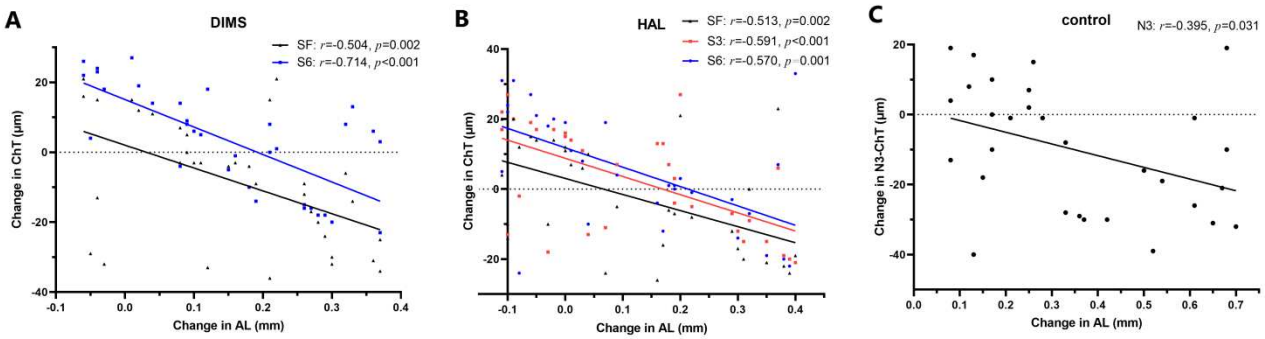

Fig. 6 Scatterplots exhibit the correlation between the change in AL and ChT over 1 year. A. DIMS group. B. HAL group. C. control group. DIMS, defocus incorporated multiple segments; HAL, highly aspherical lenslets; AL, axial length; ChT, choroidal thickness; SF, subfoveal; N, nasal; S, superior.

DISCUSSION

This prospective, one-year clinical study provides real-world evidence that DIMS and HAL spectacle lenses effectively manage myopia progression in pre-myopic children. Our findings demonstrate that these lenses significantly slow the increases in SE and AL compared to no intervention, while also inducing region-specific thickening of the choroid. Critically, for the DIMS and HAL groups, our results observed significant negative correlations between choroidal thickening (in the subfoveal and superior regions) and axial elongation, suggesting that the choroidal response, particularly in specific retinal regions, may be a potential mediator of the observed treatment efficacy.

The present study demonstrated that DIMS and HAL lenses slowed SE progression by 0.21D and 0.25D, and also slowed AL elongation by 0.19mm (54%) and 0.23mm (66%) after 1 year compared with the control group, indicating that both interventions were effective. This was basically consistent with conclusions drawn by Rao *et al.*[25]. Besides, Sun *et al.*[24] *and* Wang *et al.*[26] also found that HAL lenses were effective in slowing axial elongation and SE progression among pre-myopic children. However, Zhang *et al*.[27] observed no significant differences between HAL and single-vision spectacles in AL change. Their participants were low hyperopia (+0.00 to +2.00D). The present study showed no significant differences between DIMS and HAL spectacles for slowing the increases in SE and AL in pre-myopic children. To date, there was only one retrospective study[10] that has compared myopia control efficacy of the two lens designs in pre-myopic children. They found HAL lenses demonstrated superior myopia control efficacy versus DIMS. The retrospective study that did not observe the wearing time and did not include a control group may partly explain the discrepancy. Whereas we found no mean differences, our categorical analysis revealed that the HAL group showed a significantly lower proportion of children with rapid SE progression (> 0.50 D/year) and axial elongation (>0.2 mm/year), suggesting that this lens design may be particularly effective in controlling the more aggressive myopia progression often seen in the pre-myopic phase. The superior performance of HAL in the rapid progression subgroup analyses might be attributed to its optical design, which features a continuous, highly aspherical lenslet array that may provide a smoother, more coherent gradient of defocus signal across the retina compared to the segmented design of DIMS[28]. This more coherent defocus signal could be more effective in overriding the pro-myopic signals during the critical pre-myopia window.

As the first study, to our knowledge, to report the impact of DIMS and HAL lenses on choroidal response in children with pre-myopia, our investigation reveals a complex and region-specific pattern of change that appears to be associated with the inhibition of axial elongation. A central finding of our study is that both DIMS and HAL lenses not only prevented the physiological choroidal thinning observed in the control group over one year but also induced a statistically significant thickening in specific retinal regions, most notably the superior (S6) and temporal (T3, T6) areas. This observation is consistent with a growing body of evidence suggesting that the

choroid is an active participant in the eye's response to optical defocus [12,14]. It is hypothesized that peripheral myopic defocus, as generated by these spectacle lenses, triggers a signaling cascade from the retina that modulates choroidal thickness [15,16]. This response is thought to be a potential mediator of eye growth, possibly through mechanisms involving altered choroidal blood flow, changes in scleral oxygen tension, or the release of growth factors [29]. However, it is important to note that our study is observational and does not establish causality; the observed choroidal thickening could be a correlated phenomenon rather than the direct cause of reduced axial elongation.

The regional specificity of the choroidal response in our study warrants particular attention. The most noticeable thickening effects occurred in the temporal and superior regions. This aligns with an earlier study [15], which reported that choroidal responses to myopic defocus are not uniform and differ across retinal areas. While our results are consistent with this pattern, the underlying cause of such regional variation remains unclear. One possible explanation relates to differences in the distribution of retinal neurons responsible for processing defocus signals. An alternative explanation is that the densities of photoreceptors and ganglion cells are known to vary across the retina [30,31]. These regional differences may arise from variations in the mechanical properties or vascular reactivity of the choroid itself, possibly linked to the distribution of its non-vascular smooth muscle cells [32]. The asymmetric distribution of the myopic defocus signal actually delivered to the retina may also contribute to the observed regional pattern. These hypotheses, however, require direct testing in future work.

The significant negative correlation between the 1-year change in regional choroidal thickness, particularly in the subfoveal and superior region across intervention groups and the N3 region of the control group, and the change in axial length (AL) provides correlational evidence linking choroidal thickening to slower eye growth. This observation is consistent with prior longitudinal studies. For example, Read *et al*. [33] reported that children with faster axial elongation exhibited less choroidal thickening, or even choroidal thinning, over time. Whether this relationship is causal, serves as a biomarker of an underlying process, or is merely an epiphenomenon remains unresolved. Interestingly, the correlation patterns differed between the DIMS and HAL groups: for instance, a correlation in the S3 region was observed only in the HAL group. This suggests that different optical designs may elicit distinct choroidal response profiles. Such variation may be related to the differing optical characteristics of the two lens types, such as the continuous aspherical lenslets in the HAL design versus the segmented DIMS design. However, this remains a conjecture that warrants further investigation.

The finding that choroidal thickening in the intervention groups coincided with a slowing of AL elongation is clinically relevant, raising the possibility that regional choroidal thickness could serve as a biomarker for monitoring treatment response. Nevertheless, our results should be interpreted with caution. Although statistically significant, the increases in choroidal thickness observed over one year were relatively modest—on the order of tens of micrometers. Furthermore,

Huang et al. [12] found that choroidal thickening induced by HAL lenses may diminish over longer follow-up periods, suggesting that the initial thickening may not be sustained indefinitely. This highlights the need for long-term studies to evaluate the durability of the choroidal response and its relationship to sustained myopia control.

Our study has several strengths. Its prospective design, the inclusion of a well-defined pre-myopic population, and the comprehensive imaging of choroidal thickness across multiple retinal regions together enabled a more detailed analysis than that afforded by previous studies restricted to the subfoveal area. Several limitations, however, warrant consideration. First, the non-randomized design may have introduced selection bias, even though baseline characteristics were balanced between groups. Second, the lack of a single-vision spectacle control group prevented us from separating the specific optical effect of the intervention from a placebo effect, although comparison with a no-intervention group offered useful real-world context. Third, the one-year follow-up was too short to evaluate long-term efficacy or the sustainability of the choroidal response. Fourth, the mechanisms underlying the region-specific choroidal response remain speculative and require further investigation.

Conclusions

This study provides evidence that the myopia control effect of DIMS and HAL spectacle lenses in pre-myopic children is statistically associated with a region-specific increase in choroidal thickness. These findings suggest that choroidal thickness may serve as a useful biomarker for monitoring treatment response. However, further research, particularly long-term, randomized controlled trials with objective monitoring of compliance and choroidal blood flow, is needed to confirm these findings and fully clarify the mechanistic role of the choroid in the efficacy of myopia control interventions.

Data availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

REFERENCES

1 Wang, J. *et al.* Progression of Myopia in School-Aged Children After COVID-19 Home Confinement. *J. JAMA Ophthalmol*. **139,** 293–300 (2021).

2 Jonas, J. B. *et al.* IMI Prevention of Myopia and Its Progression. *J. Invest Ophthalmol Vis Sci*. **62,** 6 (2021).

3 Flitcroft, D. I. *et al.* IMI - Defining and Classifying Myopia: A Proposed Set of Standards for Clinical and Epidemiologic Studies. *J. Invest Ophthalmol Vis Sci*. **60,** M20–M30 (2019).

4 Chen, Z. *et al.* Significant myopic shift over time: Sixteen-year trends in overall refraction and age of myopia onset among Chinese children, with a focus on ages 4-6 years. *J. J Glob Health*. **13,** 04144 (2023).

5 Wang, C. Y. *et al.* Premyopia at Preschool Age: Population-based Evidence of Prevalence and Risk Factors from a Serial Survey in Taiwan. *J. Ophthalmology*. **129,** 880–889 (2022).

6 Bullimore, M. A. & Brennan, N. A. Myopia: An ounce of prevention is worth a pound of cure. *J. Ophthalmic Physiol Opt*. **43,** 116–121 (2023).

7 Hu, Y. *et al.* Association of Age at Myopia Onset With Risk of High Myopia in Adulthood in a 12-Year Follow-up of a Chinese Cohort. *J. JAMA Ophthalmol*. **138,** 1129–1134 (2020).

8 Wildsoet, C. F. *et al.* IMI - Interventions Myopia Institute: Interventions for Controlling Myopia Onset and Progression Report. *J. Invest Ophthalmol Vis Sci*. **60,** M106–M131 (2019).

9 Zhang, Z. *et al.* Spectacle Lenses With Highly Aspherical Lenslets for Slowing Axial Elongation and Refractive Change in Low-Hyperopic Chinese Children: A Randomized Controlled Trial. *J. Am J Ophthalmol*. **269,** 60–68 (2025).

10 Chen, L. *et al.* Age Modifies the Comparative Effectiveness of DIMS Versus HAL Spectacle Lenses for Myopia Control: A Real-World Study. *J. Transl Vis Sci Technol*. **15,** 10 (2026).

11 Huang, Y. *et al.* Effect of spectacle lenses with aspherical lenslets on choroidal thickness in myopic children: a 2-year randomised clinical trial. *J. Br J Ophthalmol*. **107,** 1806–1811 (2023).

12 Huang, Y. *et al.* Effect of spectacle lenses with aspherical lenslets on choroidal thickness in myopic children: a 3-year follow-up study. *J. Eye Vis (Lond)*. **11,** 16 (2024).

13 Nickla, D. L. & Wallman, J. The multifunctional choroid. *J. Prog Retin Eye Res*. **29,** 144–168 (2010).

14 Xiao, J., Pan, X., Hou, C. & Wang, Q. Changes in Subfoveal Choroidal Thickness after Orthokeratology in Myopic Children: A Systematic Review and Meta-Analysis. *J. Curr Eye Res*. **49,** 683–690 (2024).

15 Hoseini-Yazdi, H., Vincent, S. J., Collins, M. J. & Read, S. A. Regional alterations in human choroidal thickness in response to short-term monocular hemifield myopic defocus. *J. Ophthalmic Physiol Opt*. **39,** 172–182 (2019).

16 Huang, Y., Zhang, J., Li, X., Chen, H. & Bao, J. Effect of Myopic Defocus on the Retina and Choroid and Its Interaction with Defocus Regions, Diurnal Rhythm, and Accommodation. *J. Ophthalmol Sci*. **5,** 100773 (2025).

17 Carla, M. M. *et al.* Overview on Defocus Incorporated Multiple Segments Lenses: A Novel Perspective in Myopia Progression Management. *J. Vision (Basel)*. **6,** (2022).

18 Bao, J. *et al.* One-year myopia control efficacy of spectacle lenses with aspherical lenslets.

J. Br J Ophthalmol. **106,** 1171–1176 (2022).

19 Hwang, Y. H. & Kim, Y. Y. Macular thickness and volume of myopic eyes measured using spectral-domain optical coherence tomography. *J. Clin Exp Optom*. **95,** 492–498 (2012).

20 Tang, W. *et al.* Effects of orthokeratology versus cylindrical annular refractive elements spectacle lenses on myopia control and choroidal thickness in myopic children: A 1-year prospective clinical trial. *J. Cont Lens Anterior Eye*. **49,** 102833 (2026).

21 Deng, J. *et al.* Effect of Ocular Magnification on Macular Choroidal Thickness Measurements Made Using Optical Coherence Tomography in Children. *J. Curr Eye Res*. **47,** 1538–1546 (2022).

22 Ye, G. *et al.* Choroidal Features of Cynomolgus Macaques in Relation to Age and Axial Length. *J. Invest Ophthalmol Vis Sci*. **66,** 17 (2025).

23 Bennett, A. G., Rudnicka, A. R. & Edgar, D. F. Improvements on Littmann's method of determining the size of retinal features by fundus photography. *J. Graefes Arch Clin Exp Ophthalmol*. **232,** 361–367 (1994).

24 Sun, A., Li, X., Zhu, P., Xie, F. & Wu, Y. Real-world efficacy of plano lenses with highly aspherical lenslets in children with pre-myopia: A prospective cohort study. *J. Ophthalmic Physiol Opt*. **45,** 1468–1474 (2025).

25 Rao, J. *et al.* Efficacy of Multifocal Spectacles for Myopia Control in Pre-myopic Children: A Multicentre Real-world Study. *J. Ophthalmic Physiol Opt*. **46,** 654–660 (2026).

26 Wang, L., Wong, Y. L., Drobe, B. & Wang, X. Effectiveness of spectacle lenses with highly aspherical lenslets in slowing axial elongation among non-myopic children. *J. Clin Exp Optom*. **109,** 844–850 (2026).

27 Zhang, Z. *et al.* Effect of Duration of Spectacle Lenses With Highly Aspherical Lenslets Wear on Choroidal Thickness in Low-Hyperopic Chinese Children. *J. Transl Vis Sci Technol*. **15,** 15 (2026).

28 Gantes-Nunez, J., Jaskulski, M., Lopez-Gil, N. & Kollbaum, P. S. Optical characterisation of two novel myopia control spectacle lenses. *J. Ophthalmic Physiol Opt*. **43,** 388–401 (2023).

29 Zhou, X. *et al.* Increased Choroidal Blood Perfusion Can Inhibit Form Deprivation Myopia in Guinea Pigs. *J. Invest Ophthalmol Vis Sci*. **61,** 25 (2020).

30 Curcio, C. A., Sloan, K. R., Kalina, R. E. & Hendrickson, A. E. Human photoreceptor topography. *J. J Comp Neurol*. **292,** 497–523 (1990).

31 Curcio, C. A. & Allen, K. A. Topography of ganglion cells in human retina. *J. J Comp Neurol*. **300,** 5–25 (1990).

32 May, C. A. Non-vascular smooth muscle cells in the human choroid: distribution, development and further characterization. *J. J Anat*. **207,** 381–390 (2005).

33 Read, S. A., Alonso-Caneiro, D., Vincent, S. J. & Collins, M. J. Longitudinal changes in choroidal thickness and eye growth in childhood. *J. Invest Ophthalmol Vis Sci*. **56,** 3103–3112 (2015).

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Wenting Tang, Min Luo, Xiangning Luo, and Li Zhang. The first draft of the manuscript was written by Wenting Tang, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Ethics approval

This study adhered to the guidelines of the Helsinki Declaration and obtained approval from the Institutional Review Board of the First Affiliated Hospital of Chengdu Medical College (2022CYFYIRB-BA-Nov08).

Consent to participate

All participants' parents or guardians were fully informed of the study protocol, potential benefits, and complications, then signed a written consent before enrollment.