Am J Transl Res 2026;18(8):7141-7162
www.ajtr.org /ISSN:1943-8141/AJTR0174201

Original Article

Repeated low-intensity red light combined with defocus-incorporated multiple segments (DIMS) spectacles for controlling myopia progression in children

Wubo Cheng[1,2], Xianglong Yi[1,2]

[1]*Department of Ophthalmology, The First Affiliated Hospital of Xinjiang Medical University, Urumqi 830054, Xinjiang Uygur Autonomous Region, China;* [2]*First Clinical Medical College, Xinjiang Medical University, Urumqi 830054, Xinjiang Uygur Autonomous Region, China*

Received May 21, 2026; Accepted July 23, 2026; Epub August 15, 2026; Published August 30, 2026

Abstract: Objective: To investigate the efficacy and safety of repeated low-intensity red light (RLRL) therapy combined with defocus incorporated multiple segments (DIMS) spectacles for controlling myopia progression in children. Methods: In this retrospective cohort study, medical records of 100 children with persistent myopia progression despite DIMS spectacle wear were reviewed. Patients were divided into two groups based on their treatment history: a DIMS-only control group (n=50) and an RLRL+DIMS combination group (n=50). Axial length (AL), spherical equivalent refraction (SER), uncorrected visual acuity (UCVA), central retinal thickness (CRT), subfoveal choroidal thickness (SFChT), corneal curvature (CC), fundus autofluorescence, adverse events were assessed at baseline and 1, 3, 6, 9 and 12 months. Results: Of the 100 enrolled children, 92 completed the 12-month follow-up. Baseline characteristics were comparable between groups (all P>0.05). At 12 months, the combination group showed significantly less axial elongation than the control group (mean change: 0.060±0.237 mm vs. 0.386±0.183 mm, P<0.001), with 37.8% of children showing axial shortening. SER progression was also significantly slower in the combination group (change: +0.038±0.435 D vs. -0.720±0.295 D; P<0.001). SFChT increased significantly in the combination group (+13.2±27.4 μm) but decreased in controls (-3.3±12.4 μm, P<0.001). No significant changes in CRT or CC were observed. Transient glare occurred in nine children; one child withdrew due to an 8-minute afterimage. No abnormal fundus autofluorescence was detected. Conclusion: RLRL combined with DIMS spectacles effectively increased choroidal thickness, delayed axial elongation, and slowed SER progression in myopic children over 12 months, with a favorable short-term safety profile. Longer-term studies are warranted to confirm sustained efficacy and safety.

Keywords: Repeated low-intensity red light, defocus spectacles, myopia control, choroidal thickness

Introduction

The prevalence of myopia among children and adolescents in China ranks among the highest in the world, and controlling myopia has become a national strategic priority, representing an urgent public health issue [1]. Common methods for controlling myopia progression in children mainly include repeated low-intensity red light (RLRL), orthokeratology, defocus spectacles, and low-concentration atropine eye drops [2]. Currently, defocus spectacles are widely used in China, designed based on the theory of peripheral retinal defocus to delay myopia progression. Although different manufacturers have minor differences in the microstructure design of the microlenses, no studies have demonstrated significant differences in the efficacy of myopia control among these designs [3]. These spectacles offer advantages such as easy fitting, comfortable wear, and simple care, while avoiding the ocular surface risks associated with orthokeratology and the potential drug allergies or side effects of low-concentration atropine, making them widely adopted [4]. Studies have confirmed that defocus spectacles are superior to single-vision spectacles in controlling myopic degree and delaying axial elongation [5]. However, a considerable proportion of patients wearing defocus spectacles still experience uncontrolled myopia progression, necessitating consideration of combined inter-

https://doi.org/10.62347/JGQF1692

ventions [6]. The core rationale of combined intervention is to superimpose the comprehensive effects of different mechanisms of action, maximizing overall benefits while maintaining acceptable safety and compliance [7]. RLRL, as an emerging myopia control approach, has evolved from the scientific hypothesis that light influences ocular growth [8]. Previous studies, through multiple randomized controlled trials, have demonstrated the efficacy of repeated low-intensity red light therapy for myopia control. Most of these studies have focused on comparisons of single interventions, such as RLRL vs. single-vision spectacles, RLRL vs. sham devices, RLRL vs. 0.01% atropine. Apart from studies on RLRL combined with orthokeratology, evidence for other combined interventions involving RLRL remains very limited [9-12].

For children who continue to experience myopia progression despite wearing defocus spectacles, this study aimed to investigate the efficacy of combining DIMS spectacles with RLRL therapy, thereby providing stronger scientific evidence and clinical reference value for this combined intervention strategy.

Research content and methods

This study adopted a single-center, retrospective cohort study design. The research process strictly followed the ethical principles for human subjects stipulated in the Declaration of Helsinki. The study protocol, which included a waiver of informed consent, was approved by the Ethics Committee of The First Affiliated Hospital of Xinjiang Medical University. The requirement for written informed consent was waived because this study involved no more than minimal risk and the retrospective review of medical records could not be practicably carried out without the waiver. Patient data were de-identified prior to analysis to protect privacy. The study was supervised throughout by the hospital's Human Subject Protection Committee.

Study participants

We reviewed the medical records of children aged 8-12 years from the Department of Ophthalmology, The First Affiliated Hospital of Xinjiang Medical University, who had been wearing defocus spectacles and had documented myopia progression in the past year. Two ophthalmologists screened the records to identify potentially eligible participants based on the pre-defined inclusion and exclusion criteria. Eligible patients were divided into two groups according to their treatment history: those who had received only DIMS spectacles were assigned to the control group, and those who had used DIMS spectacles in combination with RLRL therapy were assigned to the combination group. Baseline data were collected from the medical records at the initiation of the respective treatment. Outcome measures recorded during routine follow-up at 3, 6, 9, and 12 months were extracted for analysis. The study site was the ophthalmology outpatient clinic.

Inclusion criteria

(1) Age: 8 to 12 years at the time of data collection, consistent with the approved indications for the RLRL device. (2) Diagnosed with myopia and having worn DIMS spectacles for at least 1 year. Eligible patients had to demonstrate inadequate control of myopia progression, defined as axial elongation ≥0.3 mm/year or spherical equivalent refraction (SER) progression ≥0.5 D/year. (3) Best-corrected visual acuity (BCVA): 20/20 or better. (4) Refractive range (spherical equivalent): SER >-6.00 D and ≤-1.0 D. (5) Anisometropia <1.00 D, astigmatism <1.50 D. (6) Availability of complete medical records, including baseline and follow-up data at 3, 6, 9, and 12 months.

Exclusion criteria

(1) Incomplete refractive records, incomplete follow-up, or lack of parental cooperation. (2) Ocular diseases other than refractive error, any history of ocular surgery, including but not limited to strabismus, binocular vision abnormalities, and peripheral retinal lesions. (3) Any systemic diseases or conditions that may affect visual function and development (including diabetes and chromosomal abnormalities). (4) Previous use of orthokeratology, atropine eye drops, or RLRL therapy alone or in combination. (5) Presence of contraindications explicitly stated in the device instructions: photosensitivity, halos, cured ADHD, or psoriasis. (6) Missing key outcome data (e.g., axial length or spherical equivalent refraction) at the 12-month follow-

up, preventing the assessment of the primary outcome.

Interventions

DIMS+RLRL treatment group: Children in this group had used DIMS spectacles in combination with RLRL therapy. The RLRL therapy was administered at home twice daily, 3 minutes per session, with an interval of at least 4 hours between sessions. Before initial use, an ophthalmologist had explained the correct operation procedures to the children and parents, provided detailed instructions, and supplied an instructional video. A WeChat group was established to promptly answer any operational questions and report adverse events. During the intervention period, each child received two sessions of treatment per day under parental supervision (e.g., morning + afternoon, morning + evening, or afternoon + evening), with each session lasting three minutes, after which the device automatically stopped. Each participant was assigned a unique personal account and password. The device could only be activated after logging into the system for verification. Researchers monitored and reminded participants about device usage via the online backend data.

DIMS control group: Children in this group had used DIMS spectacles only, without receiving RLRL irradiation during the same observation period. They only engaged in routine study and daily life activities. No additional myopia control medications or training measures were used. When a child's refractive error progressed by more than 0.50 D or when corrected visual acuity could no longer meet their daily learning and living needs, the defocus spectacles (DIMS lenses) were promptly replaced with appropriate power.

Outcome measures and data collection

Primary outcome: the change in axial length (AL) at 12 months. Based on the distribution of AL changes, participants were categorized into three groups: axial shortening (<0 mm), minimal progression (0-0.3 mm), and rapid progression (>0.3 mm). The proportion of children in each category was compared between the two groups. Secondary outcomes: Best-corrected visual acuity at 12 months, uncorrected visual acuity, changes in SFChT, self-reported adverse events, and optical coherence tomography (OCT) findings.

An optical biometer (Carl Zeiss IOL-Master 500) was used for non-contact measurement of ocular refractive components, including AL and corneal curvature (CC). An automated computerized refractor (RM-1, Topcon, Japan) was used in automatic mode to measure central corneal refraction three times per eye, and the average value was recorded. The spherical equivalent was calculated as SER = sphere + 1/2 × cylinder. Subjective refraction was then performed using a phoropter (CV-5000, Topcon, Japan) to obtain the maximum plus to maximum visual acuity (MPMVA) result, which was recorded. Visual acuity was measured using an ETDRS chart. Optical coherence tomography (BM-400K, Topcon, China) was used to measure subfoveal retinal thickness and choroidal thickness in myopic children. The built-in measurement system automatically measured subfoveal retinal thickness and choroidal thickness. Retinal thickness was defined as the vertical distance between the internal limiting membrane and the retinal pigment epithelium. Choroidal thickness was defined as the vertical distance between Bruch's membrane and the choroid-sclera junction. Fundus autofluorescence images were captured by the same experienced examiner using a Daytona 200 panoramic scanning laser ophthalmoscope (Optos) in autofluorescence mode.

At each follow-up visit, an ophthalmologist interviewed the participating child or their guardian and asked them to complete an adverse reaction questionnaire covering flash blindness, afterimages, scotoma, glare, sudden vision loss ≥2 lines, and others. Two experienced retinal specialists performed OCT examinations and independently reviewed the OCT results to promptly detect possible structural damage. If a participant experienced a serious adverse reaction, such as sudden vision loss ≥2 lines, central scotoma, or structural changes on retinal/choroidal OCT, treatment was immediately terminated, the adverse reaction was reported by the researchers, and the case was reviewed by the executive committee. All adverse reactions were recorded in the case report form.

The RLRL device used in this study had an automatic compliance monitoring function via inter-

net connectivity, recording the date and time of each treatment session. The device-controlled treatment frequency according to the prescribed schedule (3 minutes per session, twice daily, with a minimum interval of 4 hours). Researchers could access usage records and compliance via the device backend.

Data collection, management, and monitoring

The study principal investigator convened a researcher meeting to train all study personnel on the study protocol, data extraction procedures, and case report form completion. A standardized data extraction form was used to collect data from the electronic and paper medical records. When instruments had printed results (e.g., IOL-Master printouts), these were directly attached to the data extraction form. For data that could not be directly printed, two investigators independently verified the extracted data before entry into the electronic database. After data collection was completed, all study documents were stored in a secure cabinet to protect participant privacy and ensure accessibility for data review and auditing. Participant medical records were accessible only to researchers and monitors. Participant data and information could not be used for any other non-research purposes, ensuring privacy protection. Adverse events that had been documented in the medical records during the treatment period were extracted and recorded.

Sample size calculation and statistical methods

A post-hoc power analysis was performed based on the final sample size. Based on a previous study of RLRL therapy combined with optical interventions [13], we anticipated that approximately 35% of children in the combination group would achieve axial shortening or minimal progression (≤0.3 mm) at 12 months, compared to approximately 10% in the control group. Using a two-sided chi-square test for comparison of proportions, with a significance level (α) of 0.05 and a statistical power (1-β) of 80%, the calculated sample size was approximately 42 participants per group. To account for an anticipated dropout rate of 15%, we enrolled 50 participants per group, resulting in a total sample size of 100 participants. This sample size ensures adequate power to detect a clinically meaningful difference in the primary categorical outcome between the two groups.

Statistical analysis was performed using IBM SPSS 27.0. To avoid bias from inter-eye correlation, data from the right eye of each participant were used for analysis. When right-eye data were unavailable, left-eye data were substituted. This approach follows established methods in myopia research, where analyzing one randomly selected or designated eye is a widely accepted strategy to eliminate inter-eye dependence [5, 14, 15]. For missing data due to dropouts, complete-case analysis was adopted, as the overall dropout rate was low (8%, 8/100) and the reasons were primarily related to early treatment discomfort, compliance issues, or parental concerns rather than to treatment outcomes. No imputation methods, including last observation carried forward or multiple imputation, were applied. Given the low dropout rate and the balanced distribution of dropout reasons between groups, complete case analysis was considered appropriate for the primary efficacy evaluation. All continuous variables were tested for normality and presented as mean ± standard deviation (SD). Categorical data between groups were compared using the chi-square test, and continuous variables were compared using the t-test. Generalized estimating equations (GEE) were used to compare AL, SER, UCVA, CRT, CC, and SFChT between the treatment and control groups at different time points. Differences in the above parameters between the two groups at the same time point were compared using the independent-samples t-test. Paired-samples t-tests were used to compare AL, SER, UCVA, CRT, CC, and SFChT before and after 12 months of RLRL treatment. In addition, GEE was used to analyze the effects of sex, baseline age, baseline ocular parameters, treatment modality, follow-up time, the interaction between treatment modality and follow-up time, and changes in choroidal thickness on AL.

Results

Follow-up and baseline characteristics

Follow-up diagram: See **Figure 1**.

Follow-up status of participants: A total of 100 patients were initially identified from the medical records, all had used the same DIMS spectacle lens (MyoSmart, HOYA, Japan). After applying the inclusion and exclusion criteria, 92 patients with complete 12-month follow-up data were included in the final analysis: 45 in

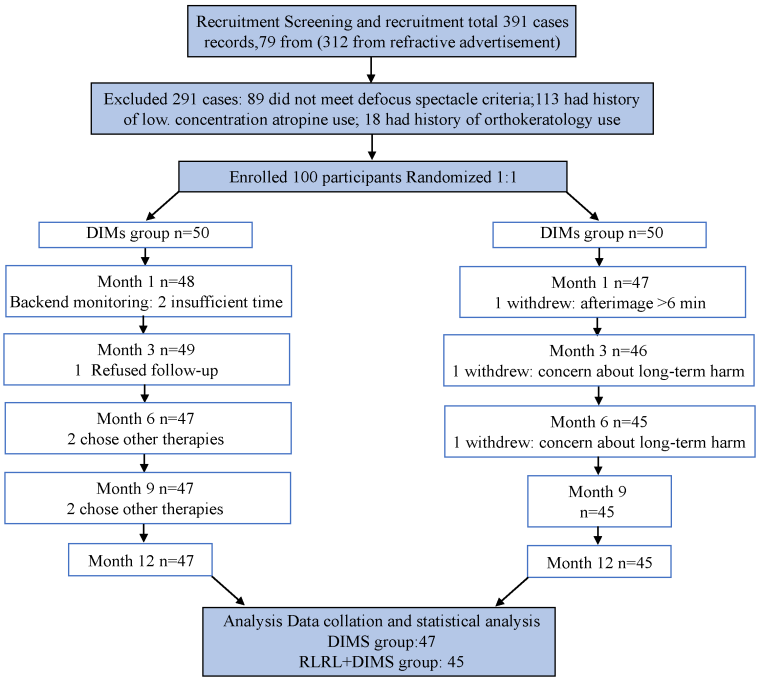

Figure 1. Patient disposition flowchart.

the DIMS+RLRL combination group and 47 in the DIMS control group.

Exclusions: A total of 8 patients were excluded from the analysis. In the RLRL+DIMS group, 5 were excluded, mainly due to incomplete medical records (n=2, 2%), missing compliance data (n=2, 2%), and missing follow-up data after the adverse event of prolonged afterimage (n=1, 1%). In the DIMS control group, 3 were excluded due to incomplete 12-month follow-up data (n=3, 3%).

Baseline characteristics of participants: A total of 92 participants were included in the statistical analysis, aged 8-12 years, with SER ranging from -5.75 D to -1.50 D. In the DIMS+RLRL combination group (n=45), there were 14 males (31.1%) and 31 females (68.9%), with mean age 9.94±0.83 years, AL 25.03±0.83 mm, and SER -3.38±1.00 D. In the DIMS control group (n=47), there were 23 males (48.9%) and 24 females (51.1%), with mean age 10.07±0.93 years, AL 24.92±0.75 mm, and SER -3.69±0.91 D. No statistically significant differences were found between the two groups in terms of sex distribution, age, AL, UCVA, IOP, SER, SFChT, CRT, CC, or other parameters (all P>0.05). Furthermore, the standardized differences for all baseline characteristics were below 0.1, confirming good baseline comparability between the groups. Detailed baseline characteristics are shown in **Table 1**.

Effect of RLRL therapy on axial length in children wearing defocus spectacles

To investigate the effect of RLRL and time on AL in children wearing DIMS spectacles, AL data from the DIMS+RLRL combination group and the DIMS control group were statistically analyzed. There was a statistically significant difference in AL across time points among all participants (F_time = 144.858, P_time < 0.001), indicating that AL changed significantly over time. Moreover, the interaction effect between time and treatment modality on AL was significant (F_time × treatment = 68.329, P_time × treatment <0.001), indicating that the AL change trends over time differed significantly between the two groups. The primary outcome - the categorical distribution of 12-month AL changes (shortening, minimal progression, and rapid progression) - is presented in **Table 2**. The intergroup comparison showed a statistically significant difference in the proportion of children achieving axial control between the two groups (χ^2=38.096, P<0.001). Specifically, axial shortening was observed in 37.8% (17/45) of children in the combination group, whereas no axial shortening was observed in the control group (0%). In the control group, 74.5% (35/47) of children showed rapid progression (>0.3 mm), compared to only 15.6% (7/45) in the combination group. Following this primary analysis, the mean changes in AL and other continuous variables are reported below as secondary outcomes.

In the DIMS+RLRL group, baseline AL was 25.03±0.83 mm. After RLRL therapy, AL showed an initial decrease to 24.98±0.85 mm at 3 months, followed by a gradual increase at 6 and 12 months. At 12 months, AL was 25.08±0.84 mm, representing a change of 0.060±0.237 mm from baseline. The AL changes in the DIMS+RLRL treatment group at 3, 6,

Table 1. Comparison of baseline characteristics between the two groups

Characteristic	DIMS group (n=47)	DIMS+RLRL group (n=45)	Statistic	*P* value
Sex			χ^2=2.342	0.126
Male	23 (48.9%)	14 (31.1%)		
Female	24 (51.1%)	31 (68.9%)		
Age (years)	10.07±0.93	9.94±0.83	t=0.729	0.468
Age at myopia onset (years)	8.22±1.15	8.06±1.16	t=0.652	0.516
Annual axial length change (mm)	0.59±0.13	0.60±0.13	t=-0.533	0.595
Baseline UCVA	0.26±0.12	0.27±0.12	t=-0.707	0.481
Baseline AL (mm)	24.92±0.75	25.03±0.83	t=-0.644	0.521
Baseline IOP (mmHg)	14.63±2.84	14.14±2.84	t=0.815	0.417
Baseline SER (D)	-3.69±0.91	-3.38±1.00	t=-1.556	0.123
Baseline SFChT (μm)	275.37±43.85	265.19±44.98	t=1.099	0.275
Baseline CRT (μm)	250.72±26.67	253.54±20.01	t=-0.571	0.569
Baseline CC (D)	43.35±1.35	43.07±1.27	t=1.038	0.302

Abbreviations: UCVA, uncorrected visual acuity; AL, axial length; IOP, intraocular pressure; SER, spherical equivalent refraction; SFChT, subfoveal choroidal thickness; CRT, central retinal thickness; CC, corneal curvature.

Table 2. Absolute values and changes in AL at different time points

Characteristic	DIMS group (n=47)	DIMS+RLRL group (n=45)	Statistic	*P* value
AL (mm)				
Baseline (M0)	24.92±0.75	25.03±0.83	0.107	0.521
Month 3 (M3)	25.00±0.75	24.98±0.85	-0.019	0.908
Month 6 (M6)	25.10±0.78	25.01±0.86	-0.090	0.600
Month 9 (M9)	25.19±0.76	25.11±0.85	-0.082	0.628
Month 12 (M12)	25.30±0.77	25.08±0.84	-0.219	0.196
F value (time)	144.858			<0.001
F value (time × treatment)	68.329			<0.001
AL change (mm)				
Month 3 (M3-M0)	0.081±0.087	-0.045±0.163	-0.126	<0.001
Month 6 (M6-M0)	0.178±0.134	-0.018±0.178	-0.196	<0.001
Month 9 (M9-M0)	0.275±0.125	0.087±0.169	-0.188	<0.001
Month 12 (M12-M0)	0.386±0.183	0.060±0.237	-0.326	<0.001
Distribution of 12-month AL change			χ^2=38.096	<0.001
>0.3 mm	35 (74.5%)	7 (15.6%)		
0-0.3 mm	12 (25.5%)	21 (46.7%)		
<0 mm	0 (0.0%)	17 (37.8%)		

Abbreviation: AL, axial length.

9, and 12 months were: -0.045±0.163 mm, -0.018±0.178 mm, 0.087±0.169 mm, and 0.060±0.237 mm, respectively (**Table 2**).

In the DIMS control group, the baseline AL was 24.92±0.75 mm. AL then gradually and continuously increased over time. At 12 months of treatment, AL reached 25.30±0.77 mm, representing a change of 0.386±0.183 mm from baseline, with a statistically significant difference (P<0.001). The AL changes in the DIMS control group at 3, 6, 9, and 12 months were: 0.081±0.087 mm, 0.178±0.134 mm, 0.275±0.125 mm, and 0.386±0.183 mm, respectively (see **Figure 2**).

Comparing the DIMS+RLRL group with the DIMS group, there was no significant difference in baseline AL (P=0.521). However, at 3, 6, 9, and 12 months, the differences in AL change between the two groups were statistically significant (all P<0.001), and the AL change in the

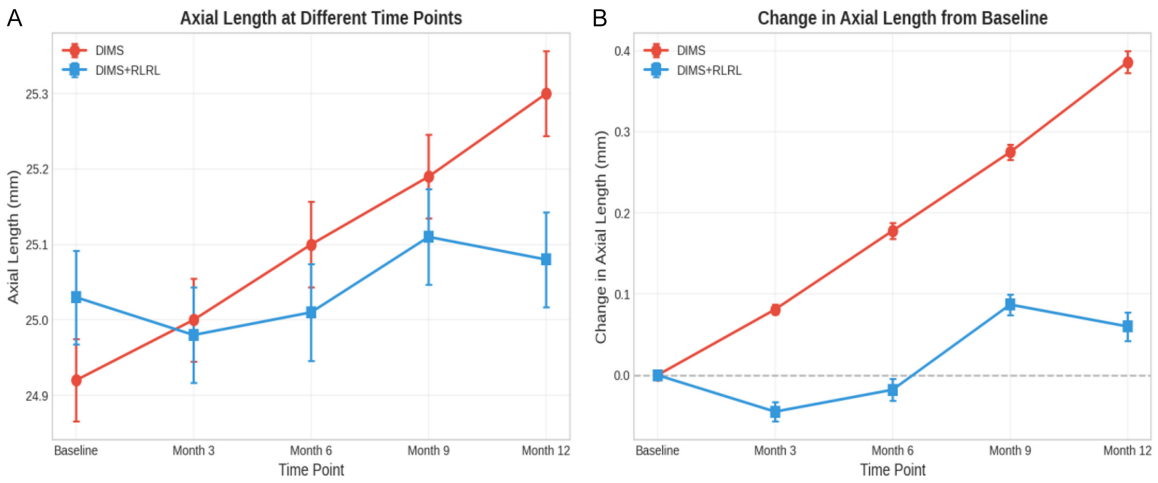

Figure 2. AL at different time points in the two groups (Inter-group Comparison) and changes. A. Absolute axial length (AL) at Baseline, Month 3, 6, 9, and 12 in the DIMS control and DIMS+RLRL combination groups. B. Change in AL from baseline at Month 3, 6, 9, and 12 in the two groups. Abbreviation: AL, axial length.

DIMS+RLRL treatment group at 12 months was significantly lower than that in the DIMS control group (difference = -0.326 mm, P<0.001). At 12 months, the AL change in the DIMS+RLRL combination group was 0.326 mm less than that in the DIMS control group, indicating that the DIMS+RLRL combination group had a significantly smaller axial elongation compared to the DIMS control group, with an inter-group difference of 0.326 mm at 12 months. Axial shortening was observed in 37.8% (17/45) of children in the combination group, whereas no axial shortening was observed in the control group (0%).

Effect of RLRL therapy on spherical equivalent refraction in children wearing defocus spectacles

To investigate the effect of RLRL and time on SER, we analyzed SER data from the two groups. There was a statistically significant difference in SER among all participants at different time points (F_time = 98.542, P_time < 0.001), indicating that SER changed significantly over time. Moreover, the interaction effect between time and treatment modality on SER was significant (F_time × treatment = 72.156, P_time × treatment < 0.001), meaning that the trend of SER change over time differed significantly depending on the treatment modality.

In the DIMS+RLRL combination group, the baseline SER was -3.38±1.00 D. After combination therapy, SER showed a gradual hyperopic shift, peaking at -3.33±1.08 D at 9 months. At 12 months, SER was -3.34±1.00 D, representing a change of 0.038±0.435 D from baseline. The SER changes in the DIMS+RLRL treatment group at 3, 6, 9, and 12 months were: 0.046±0.259 D, 0.009±0.322 D, 0.048±0.327 D, and 0.038±0.435 D, respectively (**Table 3**).

In the DIMS control group, the baseline SER was -3.69±0.91 D. SER then gradually and continuously decreased over time (myopic progression). At 12 months, SER reached -4.41±0.95 D, representing a change of -0.720±0.295 D from baseline, with a statistically significant difference (P<0.001). The SER changes in the DIMS control group at 3, 6, 9, and 12 months were: -0.233±0.207 D, -0.393±0.233 D, -0.520±0.238 D, and -0.720±0.295 D, respectively (see **Figure 3**).

Comparing the DIMS+RLRL group with the DIMS group, there was no significant difference in baseline SER (P=0.123). However, at 3, 6, 9, and 12 months, the differences in SER between the two groups were statistically significant (all P<0.001), and the SER change in the DIMS+RLRL treatment group at 12 months was significantly better than that in the DIMS control group (difference = 0.758 D, P<0.001). At 12 months, the SER change in the DIMS+RLRL combination group was 0.758 D less than that in the DIMS control group, indicating a substantial treatment effect with an inter-group difference of 0.758 D in favor of the combination group. Notably, the combination group exhibit-

Table 3. Absolute values and changes in SER at different time points

Characteristic	DIMS group (n=47)	DIMS+RLRL group (n=45)	Statistic	*P* value
SER (D)				
Baseline (M0)	-3.69±0.91	-3.38±1.00	0.31	0.123
Month 3 (M3)	-3.92±0.88	-3.34±1.00	0.59	0.003
Month 6 (M6)	-4.09±0.96	-3.37±1.14	0.71	0.002
Month 9 (M9)	-4.21±0.97	-3.33±1.08	0.88	<0.001
Month 12 (M12)	-4.41±0.95	-3.34±1.00	1.07	<0.001
F value (time)	98.542			<0.001
F value (time × treatment)	72.156			<0.001
SER change (D)				
Month 3 (M3-M0)	-0.233±0.207	0.046±0.259	0.279	<0.001
Month 6 (M6-M0)	-0.393±0.233	0.009±0.322	0.402	<0.001
Month 9 (M9-M0)	-0.520±0.238	0.048±0.327	0.568	<0.001
Month 12 (M12-M0)	-0.720±0.295	0.038±0.435	0.758	<0.001

Abbreviation: SER, spherical equivalent refraction.

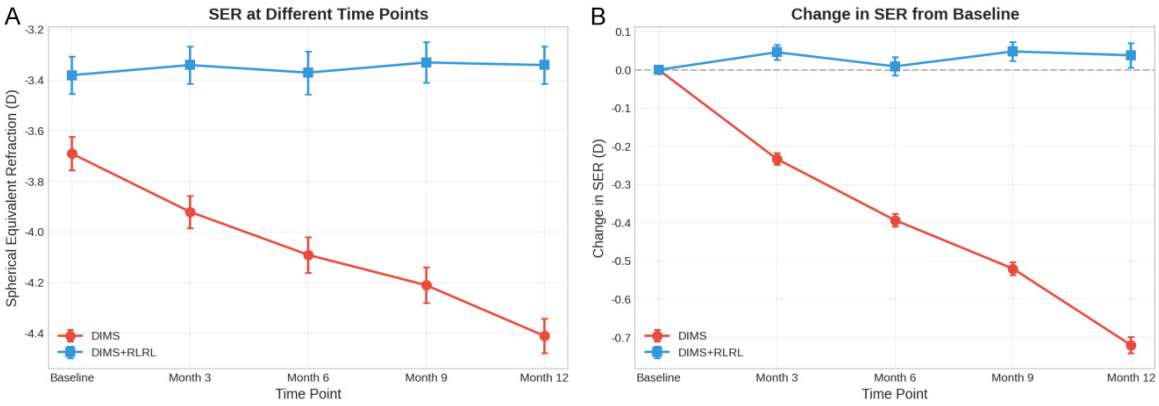

Figure 3. SER at different time points in the two groups and changes. A. Absolute spherical equivalent refraction (SER) at Baseline, Month 3, 6, 9, and 12 in the DIMS control and DIMS+RLRL combination groups. B. Change in SER from baseline at Month 3, 6, 9, and 12 in the two groups. Abbreviation: SER, spherical equivalent refraction.

ed a mean hyperopic shift (+0.038 D) compared to the myopic progression in the control group (-0.720 D).

Effect of RLRL therapy on uncorrected visual acuity in children wearing defocus spectacles

To investigate the effects of RLRL and time on UCVA, we analyzed UCVA data from the two groups. There was a statistically significant difference in UCVA among all participants at different time points (F_time = 15.234, P_time < 0.001), indicating that UCVA changed significantly over time. Moreover, the interaction effect between time and treatment modality on UCVA was significant (F_time × treatment = 28.456, P_time × treatment < 0.001), meaning that the trend of UCVA change over time differed significantly depending on the treatment modality.

In the DIMS+RLRL group, baseline UCVA was 0.27±0.12. After combination therapy, UCVA gradually increased, peaking at (0.39±0.18) 9 months. At 12 months, UCVA was 0.38±0.18, representing a change of 0.111±0.144 from baseline. The UCVA changes in the DIMS+RLRL treatment group at 3, 6, 9, and 12 months were: 0.056±0.083, 0.063±0.090, 0.116±0.108, and 0.111±0.144, respectively (see **Table 4**).

In the DIMS control group, the baseline UCVA was 0.26±0.12. UCVA then gradually decreased over time, reaching 0.17±0.12 at 9 months and 0.21±0.14 at 12 months, representing a

Table 4. Absolute values and changes in UCVA at different time points

Characteristic	DIMS group (n=47)	DIMS+RLRL group (n=45)	Statistic	*P* value
UCVA				
Baseline (M0)	0.26±0.12	0.27±0.12	0.02	0.481
Month 3 (M3)	0.24±0.14	0.33±0.13	0.09	0.002
Month 6 (M6)	0.23±0.12	0.34±0.15	0.10	<0.001
Month 9 (M9)	0.17±0.12	0.39±0.18	0.22	<0.001
Month 12 (M12)	0.21±0.14	0.38±0.18	0.18	<0.001
F value (time)	15.234			<0.001
F value (time × treatment)	28.456			<0.001
UCVA change				
Month 3 (M3-M0)	-0.015±0.044	0.056±0.083	0.071	<0.001
Month 6 (M6-M0)	-0.025±0.063	0.063±0.090	0.087	<0.001
Month 9 (M9-M0)	-0.082±0.081	0.116±0.108	0.198	<0.001
Month 12 (M12-M0)	-0.050±0.102	0.111±0.144	0.161	<0.001

Abbreviation: UCVA, uncorrected visual acuity.

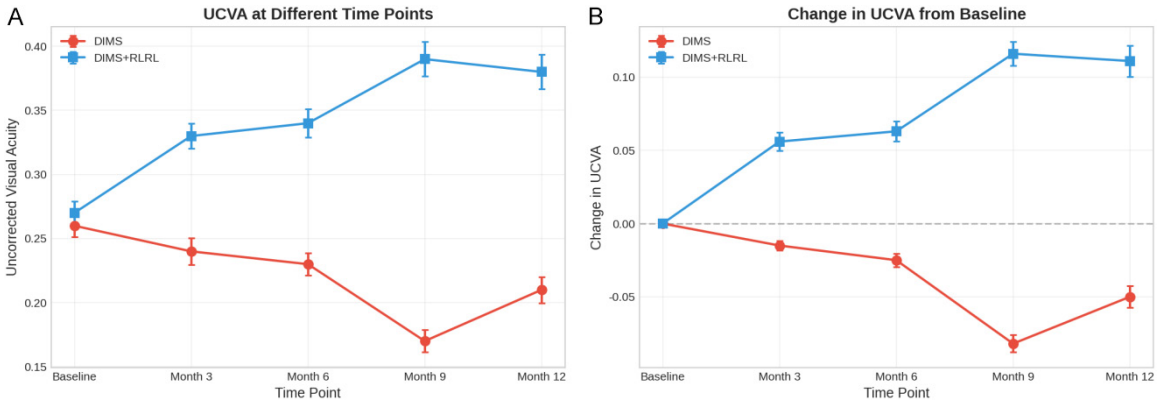

Figure 4. UCVA and changes at different time points in the two groups. A. Absolute uncorrected visual acuity (UCVA) at Baseline, Month 3, 6, 9, and 12 in the DIMS control and DIMS+RLRL combination groups. B. Change in UCVA from baseline at Month 3, 6, 9, and 12 in the two groups. Abbreviation: UCVA, uncorrected visual acuity.

change of -0.050±0.102 from baseline. The UCVA changes in the DIMS control group at 3, 6, 9, and 12 months were: -0.015±0.044, -0.025±0.063, -0.082±0.081, and -0.050±0.102, respectively (see **Table 4**).

Figure 4 shows that the differences in UCVA change between the two groups at 3, 6, 9, and 12 months were 0.071, 0.087, 0.198, and 0.161, respectively. The differences in UCVA change between the two groups at all time points were statistically significant (all P< 0.001).

Effect of RLRL therapy on subfoveal choroidal thickness in children wearing defocus spectacles

To investigate the effects of RLRL and time on choroidal thickness, we analyzed subfoveal choroidal thickness (SFChT) data from the two groups. There was a statistically significant difference in SFChT among all participants at different time points (F_time = 12.567, P_time < 0.001), indicating that SFChT changed significantly over time. Moreover, the interaction effect between time and treatment modality on SFChT was significant (F_time × treatment = 35.891, P_time × treatment < 0.001), meaning that the trend of SFChT change over time differed significantly depending on the treatment modality.

In the DIMS+RLRL combination group, baseline SFChT was 265.2±45.0 μm. After receiving combination therapy, SFChT increased significantly, peaking at 289.6±52.6 μm at 6 months (change +24.4±17.3 μm), then slightly decreased to 278.4±53.9 μm at 12 months (change

Table 5. Absolute values and changes in SFChT at different time points

Characteristic	DIMS group (n=47)	DIMS+RLRL group (n=45)	Statistic	*P* value
SFChT (μm)				
Baseline (M0)	275.4±43.8	265.2±45.0	-10.2	0.275
Month 3 (M3)	274.8±44.9	282.6±50.2	7.8	0.436
Month 6 (M6)	274.9±45.5	289.6±52.6	14.7	0.156
Month 9 (M9)	270.4±43.4	282.8±45.7	12.4	0.184
Month 12 (M12)	272.1±46.7	278.4±53.9	6.3	0.547
F value (time)	12.567			<0.001
F value (time × treatment)	35.891			<0.001
SFChT change (μm)				
Month 3 (M3-M0)	-0.6±9.1	17.4±20.1	18.0	<0.001
Month 6 (M6-M0)	-0.5±10.4	24.4±17.3	24.8	<0.001
Month 9 (M9-M0)	-5.0±10.0	17.6±20.5	22.6	<0.001
Month 12 (M12-M0)	-3.3±12.4	13.2±27.4	16.5	<0.001

Abbreviation: SFChT, subfoveal choroidal thickness.

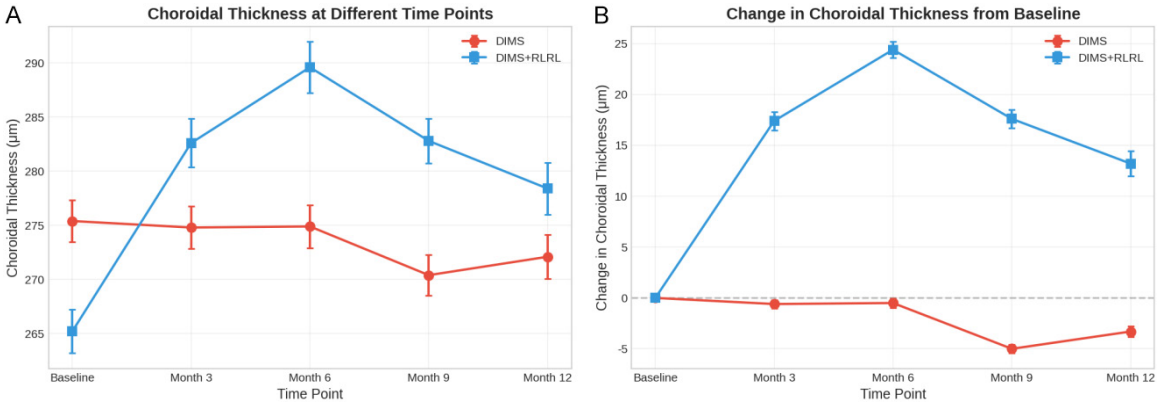

Figure 5. SFChT and changes at different time points in the two groups. A. Absolute subfoveal choroidal thickness (SFChT) at Baseline, Month 3, 6, 9, and 12 in the DIMS control and DIMS+RLRL combination groups. B. Change in SFChT from baseline at Month 3, 6, 9, and 12 in the two groups. Abbreviation: SFChT, subfoveal choroidal thickness.

+13.2±27.4 μm). The SFChT changes in the DIMS+RLRL treatment group at 3, 6, 9, and 12 months were: 17.4±20.1 μm, 24.4±17.3 μm, 17.6±20.5 μm, and 13.2±27.4 μm, respectively (see **Table 5**).

In the DIMS control group, the baseline SFChT was 275.4±43.8 μm. SFChT then gradually decreased over time, reaching 270.4±43.4 μm at 9 months and 272.1±46.7 μm at 12 months, representing a change of -3.3±12.4 μm from baseline. The SFChT changes in the DIMS control group at 3, 6, 9, and 12 months were: -0.6±9.1 μm, -0.5±10.4 μm, -5.0±10.0 μm, and -3.3±12.4 μm, respectively (see **Table 5**).

Figure 5 shows that the differences in SFChT change between the two groups at 3, 6, 9, and 12 months were 18.0 μm, 24.8 μm, 22.6 μm, and 16.5 μm, respectively. The differences in SFChT change between the two groups at all time points were statistically significant (all P<0.001).

Effect of RLRL therapy on central retinal thickness in children wearing defocus spectacles

To investigate the effects of RLRL and time on central retinal thickness (CRT), we analyzed CRT data from the two groups. There was no significant difference in CRT among all participants at different time points (F_time = 1.234, P_time = 0.298), indicating that CRT did not change significantly over time. Moreover, the interaction effect between time and treatment modality on CRT was not significant (F_time × treatment = 0.856, P_time × treatment =

Table 6. Absolute values and changes in CRT at different time points

Characteristic	DIMS group (n=47)	DIMS+RLRL group (n=45)	Statistic	*P* value
CRT (μm)				
Baseline (M0)	250.7±26.7	253.5±20.0	2.8	0.569
Month 3 (M3)	250.2±25.4	253.7±20.3	3.5	0.475
Month 6 (M6)	250.4±26.6	253.0±21.1	2.7	0.598
Month 9 (M9)	250.7±26.6	254.9±20.9	4.2	0.402
Month 12 (M12)	250.4±27.1	254.2±21.4	3.8	0.463
F value (time)	1.234			0.298
F value (time × treatment)	0.856			0.492
CRT change (μm)				
Month 3 (M3-M0)	-0.5±6.4	0.1±5.2	0.6	0.603
Month 6 (M6-M0)	-0.4±5.3	-0.5±6.5	-0.2	0.898
Month 9 (M9-M0)	0.0±5.6	1.4±5.8	1.4	0.244
Month 12 (M12-M0)	-0.3±6.2	0.6±5.2	0.9	0.431

Abbreviation: CRT, central retinal thickness.

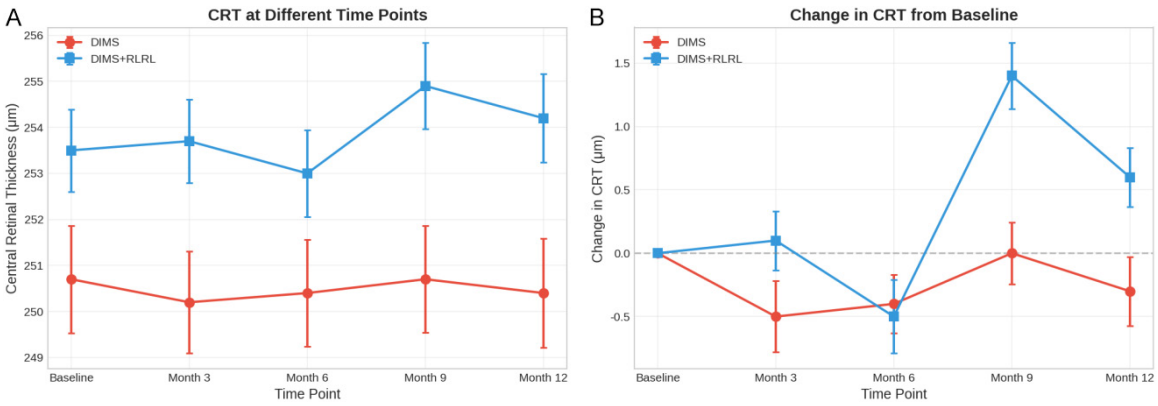

Figure 6. CRT and changes at different time points in the two groups. A. Absolute central retinal thickness (CRT) at Baseline, Month 3, 6, 9, and 12 in the DIMS control and DIMS+RLRL combination groups. B. Change in CRT from baseline at Month 3, 6, 9, and 12 in the two groups. Abbreviation: CRT, central retinal thickness.

0.492), meaning that the trend of CRT change over time did not differ significantly depending on the treatment modality.

In the DIMS+RLRL combination group, the baseline CRT was 253.5±20.0 μm. After receiving combination therapy, CRT remained relatively stable, with CRT at 12 months being 254.2±21.4 μm, a change of 0.6±5.2 μm from baseline. The CRT changes in the DIMS+RLRL treatment group at 3, 6, 9, and 12 months were: 0.1±5.2 μm, -0.5±6.5 μm, 1.4±5.8 μm, and 0.6±5.2 μm, respectively (**Table 6**).

In the DIMS control group, the baseline CRT was 250.7±26.7 μm. CRT remained relatively stable during follow-up, with CRT at 12 months being 250.4±27.1 μm, a change of -0.3±6.2 μm from baseline. The CRT changes in the DIMS control group at 3, 6, 9, and 12 months were: -0.5±6.4 μm, -0.4±5.3 μm, 0.0±5.6 μm, and -0.3±6.2 μm, respectively (see **Table 6**).

There was no significant difference in CRT change between the two groups during the 12-month follow-up period (P>0.05). At 12 months, CRT was 254.2±21.4 μm in the DIMS+RLRL combination group and 250.4±27.1 μm in the DIMS control group. These results indicate that RLRL therapy has no significant effect on central retinal thickness, suggesting its safety in this regard (**Figure 6**).

Effect of RLRL therapy on corneal curvature in children wearing defocus spectacles

To investigate the effects of treatment modality and time on CC, we analyzed CC data from the

Table 7. Absolute values and changes in CC at different time points

Characteristic	DIMS group (n=47)	DIMS+RLRL group (n=45)	Statistic	*P* value
CC (D)				
Baseline (M0)	43.35±1.35	43.07±1.27	-0.28	0.302
Month 3 (M3)	43.31±1.35	43.07±1.26	-0.24	0.380
Month 6 (M6)	43.38±1.38	43.05±1.35	-0.33	0.248
Month 9 (M9)	43.39±1.43	43.11±1.40	-0.28	0.349
Month 12 (M12)	43.37±1.37	42.99±1.23	-0.38	0.163
F value (time)	2.145			0.078
F value (time × treatment)	1.023			0.398
CC change (D)				
Month 3 (M3-M0)	-0.034±0.473	0.009±0.318	0.043	0.610
Month 6 (M6-M0)	0.027±0.362	-0.020±0.340	-0.047	0.523
Month 9 (M9-M0)	0.040±0.348	0.044±0.392	0.005	0.950
Month 12 (M12-M0)	0.026±0.408	-0.073±0.335	-0.099	0.209

Abbreviation: CC, corneal curvature.

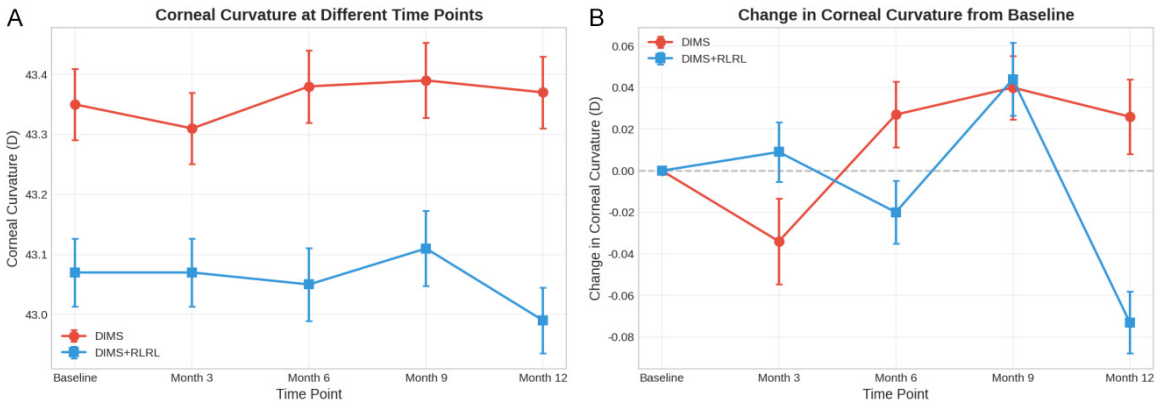

Figure 7. CC and changes at different time points in the two groups. A. Absolute corneal curvature (CC) at Baseline, Month 3, 6, 9, and 12 in the DIMS control and DIMS+RLRL combination groups. B. Change in CC from baseline at Month 3, 6, 9, and 12 in the two groups. Abbreviation: CC, corneal curvature.

two groups. There was no significant difference in CC among all participants at different time points (F_time = 2.145, P_time = 0.078), indicating that CC did not change significantly over time. Moreover, the interaction effect between time and treatment modality on CC was not significant (F_time × treatment = 1.023, P_time × treatment = 0.398), meaning that the trend of CC change over time did not differ significantly depending on the treatment modality.

In the DIMS+RLRL combination group, the baseline CC was 43.07±1.27 D. After receiving combination therapy, CC remained relatively stable, with CC at 12 months being 42.99±1.23 D, a change of -0.073±0.335 D from baseline. The CC changes in the DIMS+RLRL treatment group at 3, 6, 9, and 12 months were: 0.009±0.318 D, -0.020±0.340 D, 0.044±0.392 D, and -0.073±0.335 D, respectively (**Table 7**).

In the DIMS control group, the baseline CC was 43.35±1.35 D. CC remained relatively stable during follow-up, with CC at 12 months being 43.37±1.37 D, a change of 0.026±0.408 D from baseline. The CC changes in the DIMS control group at 3, 6, 9, and 12 months were: -0.034±0.473 D, 0.027±0.362 D, 0.040±0.348 D, and 0.026±0.408 D, respectively (**Table 7**).

There was no significant difference in CC change between the two groups during the 12-month follow-up period (P>0.05). These results indicate that low-intensity red light therapy has no significant effect on CC and does not alter corneal morphology (**Figure 7**).

Effect of RLRL therapy on fundus autofluorescence in children wearing defocus spectacles

No abnormal fundus autofluorescence (FAF) was detected in any child throughout the entire study follow-up period.

Self-reported side effects: perceptible scotoma, glare, prolonged afterimage duration (>6 minutes, total 8 minutes)

No child reported perceptible scotoma. Nine children reported transient glare at the beginning of treatment, mainly within the first week, but were still able to continue with the subsequent experiment. One child reported a red afterimage at 9:17 PM after RLRL treatment, which was particularly noticeable against a white background. The afterimage persisted until 9:23 PM. The parents immediately reported it to the CRC. After an additional 2 minutes of observation, the afterimage disappeared, totaling 8 minutes. The child was immediately brought to the hospital for visual acuity, OCT, and autofluorescence examinations. Best-corrected visual acuity was 1.0, OCT showed no abnormal retinal or choroidal findings, and autofluorescence examination was normal. The child subsequently withdrew from the experiment. At follow-up visits at 1, 3, 6, and 12 months thereafter, the child maintained a best-corrected visual acuity of 1.0, no autofluorescence was detected, and no abnormal changes in ocular structure or function, including retinal and choroidal OCT, were observed.

Discussion

Effect of low-intensity red light combined with defocus spectacles on axial length in myopic children

The results of this study showed no significant difference in baseline AL between the DIMS+RLRL group and the DIMS-only group (P=0.521). However, at 3, 6, 9, and 12 months, the differences in AL change were statistically significant. At 12 months, the AL change in the combination group was significantly lower than that in the control group (difference = -0.326 mm, P<0.001), representing an 84.6% reduction in axial elongation. Axial shortening was observed in 37.8% (17/45) of children in the combination group, whereas no axial shortening was observed in the control group. These results indicate that for children with continued myopia progression despite DIMS wear, RLRL can delay AL elongation and control myopia progression. The "Expert Consensus on the Application of AL in Myopia Prevention and Control Management (2023)" states that AL is one of the main parameters for assessing ocular development in children and adolescents. Unlike refractive measurements, which are affected by accommodation, AL measurement is not influenced by accommodation, and its changes follow relatively stable patterns with age, making it an important objective indicator for evaluating ocular development and predicting myopia onset and progression [16]. Similar to our findings, a 2025 clinical retrospective study followed 190 school-aged children for a mean of 301 days and showed that the annual AL change in the DIMS+RLRL combination group was -0.13 mm, significantly better than that in the RLRL-only group (-0.04 mm, P=0.0009) and the DIMS-only group (0.16 mm, P<0.0001). That study also confirmed that the combination therapy was significantly more effective than monotherapy in controlling myopia progression [17]. In summary, the combination of DIMS and RLRL not only effectively halts axial progression after DIMS intervention but can even partially reverse axial elongation, demonstrating a significant synergistic effect and clinical benefit.

Effect of low-intensity red light combined with defocus spectacles on refraction in myopic children

Our results showed no significant difference in baseline spherical equivalent refraction (SER) between the DIMS+RLRL group and the DIMS group (P=0.123). However, at 3, 6, 9, and 12 months, the differences in SER between the two groups were statistically significant (all P<0.001). After 12 months, the SER change in the DIMS+RLRL group was significantly better than that in the control group, with a between-group difference of 0.758 D in favor of the combination group, showing a hyperopic shift and slower refractive progression. Similar results have been reported in other studies. For example, Jiang et al. found that after 12 months of treatment, the SER progression in the RLRL+SVS group was -0.20 D, significantly lower than the -0.79 D in the SVS control group, with a betweengroup difference of -0.59 D [13]. Ano-

ther randomized doubleblind controlled trial published in 2023, which included 111 Chinese children aged 7-12 years, reported that after 6 months of follow-up, the mean SER change in the RLRL group was +0.06 D (a slight hyperopic shift), compared to -0.11 D in the control group, with a statistically significant difference [18]. A study published in Ophthalmology investigating RLRL intervention in high myopia showed that the mean SER change at 12 months was +0.11 D in the intervention group and -0.75 D in the control group, concluding that repeated lowlevel red light exhibits greater treatment efficacy in patients with high myopia, with 53.3% of patients showing significant axial shortening [18]. A multicenter prospective study published in 2025 even extended the scope to children with ultra-high myopia (SER ≤-10 D). In 59 children aged 3-16.3 years (including high and extreme myopia) treated with RLRL for 12 months, the mean SER increased by 0.549 D and mean AL decreased by 0.056 mm. Subgroup analysis showed comparable efficacy between the extreme myopia and high myopia groups [19]. In summary, low-intensity red light combined with defocus spectacles, consistent with previous studies, effectively slows refractive progression in myopic children, with some children even showing a hyperopic shift. Although various studies support that RLRL intervention affects SER, the change in SER does not perfectly correspond to the change in AL and cannot be explained solely by AL. Further indepth investigation of changes in other ocular structures is needed to explore possible mechanisms.

Comparison of this study with other low-intensity red light combination therapies for myopia control

Consistent with our findings, other combination therapies have shown similar synergistic effects in myopia control. For example, a multicenter randomized controlled trial evaluated the efficacy of RLRL combined with orthokeratology in children with rapidly progressing myopia. The results showed that after 12 months of treatment, the AL change in the combination group was -0.02 mm, whereas in the orthokeratologyonly group it increased by 0.27 mm, demonstrating a significant synergistic control effect of RLRL [20]. Another study in Spanish myopic children also confirmed that after 12 months of RLRL combined with orthokeratology, the combination group showed axial shortening of -0.124 mm, while the orthokeratology-only group showed axial elongation of 0.102 mm, with a statistically significant betweegroup difference [21]. A 2025 RCT evaluated the effect of RLRL combined with digital infant therapy (DIT). In 116 children aged 8-10 years, the median SER increase in the RLRL+DIT group was +0.21 D over one year, while the RLRL-only, DIT-only, and control groups showed changes of -0.06 D, -0.08 D, and -0.30 D, respectively, suggesting that combination intervention may have the potential to reverse myopia [22]. According to the "Expert Consensus on Repeated Low-Intensity Red Light Therapy for Adjuvant Treatment of Myopia in Children and Adolescents (2022)", RLRL can be used in combination with orthokeratology, defocus spectacles, or soft/rigid contact lenses. However, in the absence of evidence-based support, combination with low-concentration atropine is not recommended, because atropine-induced mydriasis may make the intraocular light dose difficult to control [3]; therefore, no experimental studies on RLRL combined with atropine have been found. Our results also support the advantages of combination therapy. In conclusion, comparing the effects of different myopia control combination therapies will become an important direction for future research, and more precise, effective, and safe combination regimens still require further clinical evidence.

Effect of low-intensity red light combined with defocus spectacles on UCVA in myopic children

Existing studies have mainly focused on the effect of RLRL combined with other methods on key myopia progression indicators such as SER and AL, with relatively limited direct assessment of its impact on uncorrected visual acuity (UCVA). In this study, except for baseline, UCVA at different time points showed significant differences among all participants ($F_{time} = 15.234$, $P_{time} < 0.001$), indicating that UCVA changed significantly over time. However, the interaction between time and treatment modality on UCVA was significant ($F_{time \times treatment} = 28.456$, $P_{time \times treatment} < 0.001$), suggesting that UCVA change trends differed significantly between treatment modalities. The UCVA in the combination group gradually improved, reaching 0.39±0.18 at 9 months and 0.38±0.18 at 12 months. Similar to our

conclusion, Xiong et al. studied 90 adolescent myopic patients divided into an observation group and a control group according to different correction methods, with 45 cases (90 eyes) each. The control group received single-vision spectacle correction, and the observation group received single-vision spectacles combined with RLRL irradiation. UCVA changes were compared before treatment and at 1, 3, and 6 months after treatment. The results showed that after 6 months, UCVA in the observation group was higher than that in the control group at the same time point ($P<0.05$) [23]. A study in young children with high myopia drew similar conclusions. That study included 40 children aged ≤10 years with high myopia, divided into an RLRL group and a full-correction single-vision spectacle (SVS) group. Regardless of the presence of amblyopia, the RLRL group had better UCVA than the SVS group at 1, 3, and 6 months after intervention, and axial elongation was significantly lower than in the SVS group ($P<0.05$), indicating that RLRL has short-term efficacy in visual improvement and myopia control in young children with high myopia [24]. Other studies have proposed different conclusions. One study compared red light therapy combined with lutein supplementation. After 12 months of follow-up in 100 myopic patients, the combination group showed sustained improvement in UCVA, which was significantly better than the control group receiving red light alone at 6 and 12 months. The study suggested that the observed visual improvement in children might be related to reduced myopia due to choroidal thickening, but also might involve a learning effect from using the same visual acuity chart throughout the experiment [25]. Therefore, conclusions that RLRL improves UCVA should be interpreted with caution.

Effect of low-intensity red light combined with defocus spectacles on subfoveal choroidal thickness in myopic children

SFChT is a key indicator for assessing blood supply and structural status of the posterior segment of the eye and is important in various ocular diseases, including myopia [26]. Our results showed that the change in SFChT over time differed significantly between the DIMS+ RLRL combination group and the DIMS-only control group, depending on the treatment modality. In the combination group, SFChT continuously increased from 1 to 6 months after treatment, reaching a peak at month 6 (289.6± 52.6 μm), an increase of 24.4±17.3 μm from baseline. Thereafter, it slightly decreased at 9 and 12 months, reaching 278.4±53.9 μm at 12 months, still 13.2±27.4 μm above baseline. Current consensus holds that SFChT is not constant but is influenced by many physiological factors and is closely related to ocular biometric parameters such as AL and refraction [27]. Previous views suggested that the development of myopia is mainly characterized by progressive axial elongation accompanied by corresponding choroidal thinning [28]; this negative correlation has been widely reported and is considered a typical feature of myopia progression [29]. However, some studies have shown that axial shortening and choroidal thickening are not completely synchronized, suggesting that posterior segment structural changes may drive axial changes, and scleral remodeling may also be involved [30]. Multiple systematic reviews and meta-analyses have confirmed that RLRL treatment significantly increases SFChT and delays axial elongation at 3-, 6-, and 12-month follow-ups, and this effect is consistent across different ages and myopia severities. For example, a clinical trial in 74 children aged 6-16 years showed that SFChT increased by 23.23 μm, 31.58 μm, and 35.30 μm at 1, 3, and 6 months after LLRL treatment, respectively [31]; pooled effects showed significant SFChT increases of approximately +43.65 μm and +25.07 μm at 3 and 6 months, respectively, while AL increased significantly less than in controls at 3, 6, and 12 months [3]. However, different OCT devices used in previous studies may affect the accurate assessment of SFChT changes induced by RLRL [32]. The SFChT increase observed in our study (13.2±27.4 μm) is lower than previously reported, which may be related to differences in OCT devices and measurement methods. Therefore, caution should be exercised when directly comparing choroidal thickening magnitudes across studies, considering inconsistencies in study design, participant characteristics, and measurement instruments and methods [33]. Currently, it is believed that RLRL's myopia control effect is partly achieved through choroidal thickening, which may relieve scleral hypoxia and promote scleral remodeling via related signaling pathways [34]. In summary, RLRL's myopia control effect is not solely dependent on choroidal thickening; other

ocular structures may also participate in the control process [35], including the anterior segment, and the specific mechanisms require further experimental investigation.

Effect of low-intensity red light combined with defocus spectacles on central retinal thickness in myopic children

When assessing the effect of RLRL therapy on ocular structures, central retinal thickness (CRT) is a key observational indicator. The macula, as the core region of central vision, has structural integrity that directly affects visual function. Although numerous studies have confirmed that RLRL effectively delays axial elongation and increases choroidal thickness, its effect on the retina adjacent to the choroid, especially macular retinal thickness, remains an important aspect for evaluating the safety of this therapy and elucidating its mechanism of action [36]. Therefore, clarifying the specific effect of RLRL on macular retinal thickness is important for comprehensively evaluating its clinical value and potential risks. There is currently no consensus on whether RLRL therapy affects macular retinal thickness in myopic children, with different studies reporting inconsistent or even contradictory results [23, 37]. A 2025 randomized single-blind parallel-controlled trial included 70 myopic children randomly assigned to an RLRL group or a control group. After 9 months of continuous treatment, the results showed that while RLRL effectively delayed the increase in refraction and AL, no retinal structural changes were found, and functional examinations including microperimetry revealed no visual function damage [38]. Similarly, another 2024 randomized clinical trial in pre-myopic children, which included 94 children followed for up to 12 months, found no significant difference in central retinal thickness between the RLRL group and the control group ($P>0.05$), indicating that the treatment did not cause changes in subfoveal retinal thickness [39]. Other studies have observed different results. A multicenter, randomized, parallel-group, single-blind clinical trial published in 2024 specifically evaluated the efficacy of RLRL in 202 children aged 7-12 years with high myopia. After 12 months of treatment, the study found that RLRL not only effectively shortened AL but also increased retinal thickness in the perifoveal and peripheral regions, whereas CRT in the control group significantly thinned in the peripheral region. Multiple linear regression analysis further confirmed a significant correlation between CRT changes and AL changes [37]. Meanwhile, potential effects of RLRL on macular cone density have raised safety concerns. A 2025 retrospective cohort study warned about the long-term safety of RLRL. Using high-resolution adaptive optics scanning laser ophthalmoscopy (AOSLO), the study evaluated the effect of RLRL on cone photoreceptor density in 52 myopic children (97 eyes) aged 5-14 years, compared with 47 untreated children. The results showed that after at least one year of RLRL treatment, AOSLO detected a significant decrease in cone density within 0.5 mm of the fovea in the treatment group, especially in the temporal region. The study concluded that long-term RLRL treatment is associated with decreased perifoveal cone density and mild retinal abnormalities in some children, suggesting the need for further in-depth research on the long-term safety of RLRL [40]. The results of our study showed that during the 12-month follow-up, there was no significant difference in CRT changes between the two groups ($P>0.05$). At 12 months, CRT was 254.2±21.4 μm in the DIMS+RLRL combination group and 250.4±27.1 μm in the DIMS control group, with no statistically significant difference at any time point, suggesting that low-intensity red light therapy has no significant effect on central retinal thickness and is safe, consistent with most experimental results. Future studies should use more precise detection methods to further evaluate retinal function and cellular structure.

Effect of low-intensity red light combined with defocus spectacles on corneal curvature in myopic children

Although the effects of RLRL on AL and refraction have been extensively discussed, its influence on anterior segment parameters such as CC remains unclear. It is worth noting that although choroidal thickening induced by RLRL treatment shows a macro-trend correlation with myopia control effects, in-depth analysis reveals that the relationship is not simply linear or directly causal [41]. Changes in choroidal thickness may more reflect the physiological state of the fundus rather than being the sole driver of refractive changes. Other ocular structures may also participate in the myopia control

mechanism induced by RLRL; therefore, monitoring changes in CC is still necessary. A 2025 systematic review and meta-analysis addressed this issue. The study aimed to evaluate the effect of RLRL on refractive development in children using dose-response meta-analysis, including 12 randomized controlled trials with a maximum follow-up of 12 months. The primary outcome measures included AL, spherical equivalent refraction error, and anterior CC. The results confirmed that RLRL was significantly superior to the control group in delaying axial elongation and myopia progression, but RLRL showed no statistically significant effect on anterior CC; RLRL did not significantly affect anterior CC in children [42]. This conclusion is consistent with our study. So, besides CC, what specific roles do other ocular structures play in myopia control? This question requires further experimental validation.

Effect of low-intensity red light combined with defocus spectacles on fundus autofluorescence in myopic children

Fundus autofluorescence (FAF) is a noninvasive imaging technique that assesses the health and metabolic activity of retinal pigment epithelium (RPE) cells by mapping the distribution of endogenous fluorophores in the fundus [43]. The main source of fluorescence is lipofuscin accumulated in lysosomes within RPE cells, which undergoes characteristic changes in various retinal diseases [44]. The Optos fundus autofluorescence used in this study employs laser scanning, which, due to its short examination time, improves comfort and compliance in children and is not affected by macular pigment, showing potential for routine clinical monitoring [45]. Additionally, safety monitoring of low-intensity red light irradiation has made its long-term effects on the retina and associated monitoring tools a focus of academic attention [3]. Although no abnormal autofluorescence was found in this study, FAF can be used to record RPE lipofuscin load and temporal changes, helping to detect potential RPE stress or pathological changes, and can provide additional safety information during long-term follow-up of red light therapy, especially when there is a risk of RPE-related genetic or degenerative conditions or when new maculopathy occurs [45].

Self-reported side effects: transient glare and prolonged afterimages

Regarding the subjective sensation of glare, previous studies have only sporadically reported discontinuation due to glare [3]. In this study, nine children reported transient glare or dazzling at the beginning of treatment, mainly within the first week of treatment. However, after careful communication, they were able to continue and complete the experiment. These nine children showed no abnormal changes in ocular structure or function at subsequent follow-ups at 1, 3, 6, 9, and 12 months. After the first month of this study, essentially no children complained of glare or dazzling, indicating that the first month of use is a critical period for children's compliance. During this period, providing timely and detailed explanations to parents and children, maintaining good communication, and alleviating children's anxiety and parents' concerns will help improve RLRL compliance and ensure that participating children can be included in comparative analyses.

One child discontinued the study because of an afterimage duration exceeding 6 minutes (approximately 8 minutes). An afterimage is the phenomenon in which an observer briefly perceives an image after the visual stimulus has been removed [46]. When the retina is stimulated by bright light, photosensitive pigments in the photoreceptors are largely consumed, reducing their sensitivity to subsequent stimuli and producing a negative afterimage. Additionally, downstream neurons connected to the photoreceptors may exhibit rebound excitation or inhibition after stimulus cessation, contributing to afterimage formation [47]. Other studies involving low-intensity red light have also observed varying degrees of prolonged afterimage duration [48]. Therefore, the afterimage issue deserves indepth clinical discussion. The 2022 "Expert Consensus on RLRL Adjuvant Treatment of Myopia" cited a case report by Liu et al., in which a 12-year-old patient developed excessively long afterimages during red light therapy, and examination revealed ellipsoid zone disruption and a central scotoma, requiring immediate treatment discontinuation and medical attention [3]. However, whether these findings are directly related to red light irradiation has been questioned. Shojikishi from Tokyo Medical and Dental University published a let-

ter to the editor expressing a different opinion, suspecting Stargardt disease based on the child's early OCT finding of "dark choroid". In the subsequent follow-up at 1, 3, 6, and 12 months, the child had a best-corrected visual acuity of 1.0, no autofluorescence, and no abnormal changes in ocular structure or function, including retinal and choroidal OCT. However, upon careful history-taking, the child reported that the afterimage was more noticeable against a white background, suggesting that background color plays a key role in visual perception. Studies have shown that the perceived color of a stimulus is influenced by its surrounding environment, and this hue shift is not constant [49]. The contrast between background and target color can interfere with discrimination ability, and background color is an important variable affecting color perception and judgment. However, existing evidence directly examining the relationship between background color and the specific visual phenomenon of afterimages is still limited. Current research mostly focuses on the effects of background color on immediate color recognition, emotional perception, and visual search tasks, rather than on afterimages after stimulus cessation [50]. Most current red light studies rely on children's self-reported afterimage duration without standardizing background color, which may introduce error. Therefore, exploring the relationship between background color and afterimages, developing a standardized background device for afterimage monitoring after red light therapy, and achieving standardization of afterimage detection may be important research directions for the future.

Safety of low-intensity red light for myopia control

Red light therapy has been widely used clinically for various systemic diseases, including ocular diseases, with good efficacy. However, its safety remains a concern for both clinicians and patients. The children in this retrospective cohort study underwent one year of RLRL treatment, demonstrating short-term safety. Animal experiments have shown that highpower or continuous laser irradiation can cause retinal damage. For example, continuous irradiation of the rat fundus with a helium-neon laser at 30 mW/cm^2 for 15 minutes per day over 3 days resulted in pathological findings including full-thickness retinal elevation, disorganized inner and outer nuclear layers, and increased internuclear spaces [51]. Wang Yipeng et al. [52] also showed that daily 30-minute irradiation with a 650 nm, 2 mW laser for 6 months induced photodamage in chicken retinas, as evidenced by significantly decreased levels of superoxide dismutase and retinal hemoglobin [53]. These studies suggest that red light is readily absorbed by the retina and may cause photodamage if used improperly. Retinal damage from red light is influenced by multiple factors, including incident wavelength, power density, spot size, and exposure time. Jiang et al. [38] used the same manufacturer and model of 2 mW semiconductor laser source as in our study, and the measured power after passing through a 4-mm pupil was 0.29 mW, which is within the safe range. However, the follow-up and intervention periods in current clinical trials are still relatively short; therefore, the long-term safety of RLRL for myopia control in children and adolescents requires confirmation from longer-term studies. Zhu et al. [53] evaluated the safety of RLRL therapy using multifocal electroretinography, contrast sensitivity, and OCT. They found that after 6 months of treatment, the response density and amplitude of the P1 wave of the first ring of multifocal electroretinography increased significantly, high-spatial-frequency contrast sensitivity improved significantly at 12 months, the relative reflectance of the ellipsoid zone increased at 6 months ($P=0.029$), and the relative reflectance of the photoreceptor outer segment increased significantly at both 6 and 12 months ($P<0.001$), with no evidence of retinal structural or functional damage [53]. In addition, the potential effect of RLRL on biological rhythms deserves attention. A 2025 study investigating the sensitivity of the rodent visual system to red light showed that even brief and weak red light exposure could significantly activate the master circadian clock in the suprachiasmatic nucleus, rapidly suppress melatonin secretion, and cause phase shifts in daily activity rhythms. Therefore, the authors recommended cautious use of red light in animal experiments and husbandry to minimize interference with research outcomes [54]. This finding suggests that when using red light therapy for myopia control, its possible effects on circadian rhythms and related physiological processes, such as melatonin secretion, must be fully considered, as

these processes themselves may also participate in the regulation of ocular growth [55].

Limitations of this study

First, due to the retrospective design, this study is subject to inherent biases, including selection and information bias. Although baseline characteristics were comparable, the non-randomized assignment based on treatment history may have introduced confounding by indication. Second, myopia control spans the entire developmental process of children, but the follow-up period of this study was only one year, making it difficult to assess long-term efficacy and safety. Our research group has already planned a longer-term prospective study based on these findings. Furthermore, this study did not include a post-treatment washout period, so it cannot answer whether there would be a refractive rebound after discontinuation similar to that seen with atropine withdrawal. If refractive rebound occur, what would be its timing and severity? Therefore, the next step is to plan a prospective follow-up of children who discontinue RLRL after the clinical observation period ends, in order to further confirm the rebound effect after long-term use. Additionally, although the ages of the two groups were comparable, the retrospective nature of the study precluded the collection of detailed individual lifestyle factors, such as electronic device usage time, writing posture, and outdoor activity time, which may have confounded the results. Finally, and most importantly, the primary consideration in myopia control is the safety. Regarding long-term safety, neither this study nor other reports have reached a consensus; controversy remains. This requires further research in animal experiments. Furthermore, the lack of a sham irradiation control group, a common limitation in retrospective studies, should be acknowledged. Although we attempted to mitigate this by using highly objective, automated measurement devices (e.g., IOL-Master, OCT) for the primary and secondary outcomes, the possibility of a placebo effect due to the additional attention received by the combination group cannot be entirely excluded. This limitation should be carefully considered when interpreting the results.

Disclosure of conflict of interest

None.

Address correspondence to: Xianglong Yi, Department of Ophthalmology, The First Affiliated Hospital of Xinjiang Medical University, No. 137 South Liyushan Road, Xinshi District, Urumqi 830054, Xinjiang Uygur Autonomous Region, China. E-mail: yixianglong1010@163.com

References

[1] Chen J, He XG, Wang JJ, Xie H, Du LL, Yang JLX, Huang JN, Zou HD and Xu X. Forcasting the prevalence of myopia among students aged 6-18 years in China from 2021 to 2030. Zhonghua Yan Ke Za Zhi 2021; 57: 261-267.

[2] Khanal S, Tomiyama ES and Harrington SC. Childhood myopia part I: contemporary treatment options. Invest Ophthalmol Vis Sci 2025; 66: 6.

[3] Youssef MA, Shehata AR, Adly AM, Ahmed MR, Abo-Bakr HF, Fawzy RM and Gouda AT. Efficacy of Repeated Low-Level Red Light (RLRL) therapy on myopia outcomes in children: a systematic review and meta-analysis. BMC Ophthalmol 2024; 24: 78.

[4] Schmucker C and Lagrèze WA. Multifocal optics for myopia control. Klin Monbl Augenheilkd 2024; 241: 1129-1133.

[5] Bao J, Huang Y, Li X, Yang A, Zhou F, Wu J, Wang C, Li Y, Lim EW, Spiegel DP, Drobe B and Chen H. Spectacle lenses with aspherical lenslets for myopia control vs single-vision spectacle lenses: a randomized clinical trial. JAMA Ophthalmol 2022; 140: 472-478.

[6] Lanca C, Repka MX and Grzybowski A. Topical review: studies on management of myopia progression from 2019 to 2021. Optom Vis Sci 2023; 100: 23-30.

[7] Németh J, Tapasztó B, Aclimandos WA, Kestelyn P, Jonas JB, De Faber JHN, Januleviciene I, Grzybowski A, Nagy ZZ, Pärssinen O, Guggenheim JA, Allen PM, Baraas RC, Saunders KJ, Flitcroft DI, Gray LS, Polling JR, Haarman AE, Tideman JWL, Wolffsohn JS, Wahl S, Mulder JA, Smirnova IY, Formenti M, Radhakrishnan H and Resnikoff S. Update and guidance on management of myopia. European Society of Ophthalmology in cooperation with International Myopia Institute. Eur J Ophthalmol 2021; 31: 853-883.

[8] Liu T, Wang J, Liu Y, Liu S, Gao Z, Li X and Zhang W. Effects of monochromatic light on eye growth regulation and Myopia control. Photodiagnosis Photodyn Ther 2025; 55: 104735.

[9] Tang J, Liao Y, Yan N, Dereje SB, Wang J, Luo Y, Wang Y, Zhou W, Wang X and Wang W. Efficacy of repeated low-level red-light therapy for slowing the progression of childhood myopia: a systematic review and meta-analysis. Am J Ophthalmol 2023; 252: 153-163.

[10] Dong J, Zhu Z, Xu H and He M. Myopia control effect of repeated low-level red-light therapy in Chinese children: a randomized, double-blind, controlled clinical trial. Ophthalmology 2023; 130: 198-204.
[11] Chen Y, Xiong R, Chen X, Zhang J, Bulloch G, Lin X, Wu X and Li J. Efficacy comparison of repeated low-level red light and low-dose atropine for myopia control: a randomized controlled trial. Transl Vis Sci Technol 2022; 11: 33.
[12] He X, Wang J, Zhu Z, Xiang K, Zhang X, Zhang B, Chen J, Yang J, Du L, Niu C, Leng M, Huang J, Liu K, Zou H, He M and Xu X. Effect of repeated low-level red light on myopia prevention among children in china with premyopia: a randomized clinical trial. JAMA Netw Open 2023; 6: e239612.
[13] Jiang Y, Zhu Z, Tan X, Kong X, Zhong H, Zhang J, Xiong R, Yuan Y, Zeng J, Morgan IG and He M. Effect of repeated low-level red-light therapy for myopia control in children: a multicenter randomized controlled trial. Ophthalmology 2022; 129: 509-519.
[14] Lam CSY, Tang WC, Zhang HY, Lee PH, Tse DYY, Qi H, Vlasak N and To CH. Long-term myopia control effect and safety in children wearing DIMS spectacle lenses for 6 years. Sci Rep 2023; 13: 5475.
[15] Lam CS, Tang WC, Tse DY, Tang YY and To CH. Defocus Incorporated Soft Contact (DISC) lens slows myopia progression in Hong Kong Chinese schoolchildren: a 2-year randomised clinical trial. Br J Ophthalmol 2014; 98: 40-45.
[16] Yang Y, Liu S, Gao W, Wang L, Liu N, Zhang S, Yang L and Cheng L. Synergistic effect of defocus incorporated multiple segment glasses and repeated low level red light therapy against myopia progression. Sci Rep 2025; 15: 3996.
[17] Song D, Zhang P, Meng T, Yao J and Sheng M. Axial length/corneal radius ratio for the diagnosis of myopia in children and adolescents: a meta-analysis. Clin Exp Optom 2026; 109: 851-861.
[18] Zheng Z, Jiang X, Chen R and Dong L. Efficacy comparison of atropine, orthokeratology and repeated low-level red-light therapy for myopia control in children: a systematic review and network meta-analysis. Br J Ophthalmol 2025; 109: 1215-1220.
[19] Tian L, Cao K, Fan WY, Ohno-Matsui K, Ma DL, Duan AL and Jie Y. Non-invasive low-level red-light therapy for axial length control in pediatric extreme myopia. iScience 2025; 28: 113459.
[20] Xiong R, Wang W, Tang X, He M, Hu Y, Zhang J, Du B, Jiang Y, Zhu Z, Chen Y, Zhang S, Kong X, Wei R, Yang X and He M. Myopia control effect of repeated low-level red-light therapy combined with orthokeratology: a multicenter randomized controlled trial. Ophthalmology 2024; 131: 1304-1313.
[21] Fernández Fidalgo MJ, Ferigo Ferrel VD, Wu Y, Qi Z, Yin-Moe Aung Y, Chen Y, Zhu Z and Fernández-Velázquez FJ. Repeated low-level red-light therapy combined with orthokeratology for myopia control in Spain: a randomised controlled study. Br J Ophthalmol 2026; 110: 771-777.
[22] Yang K, Wang Y, Li X, Liu S, Shi H and Qiao L. One-year changes in axial length and refraction in children using low-level red light and distant-image screen for myopia control: a randomized controlled trial. Front Med (Lausanne) 2025; 12: 1542620.
[23] Ji M, Ba T, Li H, Wang D, Zhang G and Wang W. Impact of repeated low-level red-light therapy on axial length, refraction, and macular retinal blood flow density in adolescents with mild to moderate myopia. Photodiagnosis Photodyn Ther 2025; 52: 104499.
[24] Zhou L, Xing C, Qiang W, Hua C and Tong L. Low-intensity, long-wavelength red light slows the progression of myopia in children: an Eastern China-based cohort. Ophthalmic Physiol Opt 2022; 42: 335-344.
[25] Li T, Li J, Deng C, Yang F, Ran J, Wang E, Qin W, Yang M, Li X, Li L, Wang D, Wang H, Xu Z, Guo Y, Wang A, Lu W, Li Z, Qian X and Yan J. Effect of lutein ester supplement on choroidal thickness in children: a randomized controlled trial. Transl Vis Sci Technol 2025; 14: 7.
[26] Wu H, Wang Y, Li X, Liu M, Lu Y, Liu M, Rui X, Sun Y, Qu J and Zhou X. Biomarker changes of choroidal architecture preceding myopia onset in Chinese school children: a 3-year prospective cohort study. Br J Ophthalmol 2026; [Epub ahead of print].
[27] Shao L, Zhao H, Zhang R, Zhou W and Wei WB. Distribution and associated factors of choroidal thickness in highly myopic eyes-a real-world study based on a Chinese population. Eye (Lond) 2025; 39: 102-108.
[28] Xiong F, Tu J, Mao T, Yu L, Lin N and Liao H. Subfoveal choroidal thickness in myopia: an OCT-based study in young Chinese patients. J Ophthalmol 2020; 2020: 5896016.
[29] Xu M, Yu X, Wan M, Feng K, Zhang J, Shen M, Drobe B, Chen H, Qu J and Bao J. Two-year longitudinal change in choroidal and retinal thickness in school-aged myopic children: exploratory analysis of clinical trials for myopia progression. Eye Vis (Lond) 2022; 9: 5.
[30] Liu Y, Wang L, Xu Y, Pang Z and Mu G. The influence of the choroid on the onset and development of myopia: from perspectives of choroidal thickness and blood flow. Acta Ophthalmol 2021; 99: 730-738.

[31] Pang X, Jin X, Fu A, Wang W, Zhao B, Shang L, Chang M, Ma N and Zheng G. Effect of repeated low-level red light versus 0.01% topical atropine on myopia progression: a randomized crossover-controlled trial. Transl Vis Sci Technol 2025; 14: 22.
[32] Lee CO, Zhang X, Yuan N, Tang S, Chen LJ, Cheung CY and Yam JC. Comparison of choroidal thickness measurements between spectral domain optical coherence tomography and swept source optical coherence tomography in children. Sci Rep 2021; 11: 13749.
[33] Asmussen A, Smith BS, Møller F and Jakobsen TM. Repeatability and inter-observer variation of choroidal thickness measurements using swept-source optical coherence tomography in myopic danish children aged 6-14 years. Acta Ophthalmol 2022; 100: 74-81.
[34] Chen YJ, Jeon IC, Cho SS and Park DH. RLRL therapeutic feasibility and potential mechanism on myopia. Int J Mol Sci 2025; 27: 428.
[35] Xie X, Corradetti G, Song A, Pardeshi A, Sultan W, Lee JY, Yu F, Zhang L, Chen S, Chopra V, Sadda SR, Xu B and Huang AS. Age- and refraction-related changes in anterior segment anatomical structures measured by swept-source anterior segment OCT. PLoS One 2020; 15: e0240110.
[36] Wang Y, Ye J, Shen M, Yao A, Xue A, Fan Y, Huang S, Wang J, Lu F and Shao Y. Photoreceptor degeneration is correlated with the deterioration of macular retinal sensitivity in high myopia. Invest Ophthalmol Vis Sci 2019; 60: 2800-2810.
[37] Liu G, Liu L, Rong H, Li L, Liu X, Jia Z, Zhang H, Wang B, Song D, Hu J, Shi X, Du B and Wei R. Axial shortening effects of repeated low-level red-light therapy in children with high myopia: a multicenter randomized controlled trial. Am J Ophthalmol 2025; 270: 203-215.
[38] Jiang Z, Chen S, Wang R and Ma J. Safety of and chorioretinal circulation during repeated low-level red-light therapy for myopic children. Clin Exp Ophthalmol 2025; 53: 119-132.
[39] Liu Z, Sun Z, Du B, Gou H, Wang B, Lin Z, Ren N, Pazo EE, Liu L and Wei R. The effects of repeated low-level red-light therapy on the structure and vasculature of the choroid and retina in children with premyopia. Ophthalmol Ther 2024; 13: 739-759.
[40] Liao X, Yu J, Fan Y, Zhang Y, Li Y, Li X, Song H and Wang K. Cone density changes after repeated low-level red light treatment in children with myopia. JAMA Ophthalmol 2025; 143: 480-488.
[41] Xiong R, Zhu Z, Jiang Y, Wang W, Zhang J, Chen Y, Bulloch G, Yuan Y, Zhang S, Xuan M, Zeng J and He M. Longitudinal changes and predictive value of choroidal thickness for myopia control after repeated low-level red-light therapy. Ophthalmology 2023; 130: 286-296.
[42] Ren Q, Chu Z, Qiu Z, Cheng H and Liu L. Effects of repeated low-level red light on refractive development during childhood: a systematic review and dose-response meta-analysis up to 12 months. Front Med (Lausanne) 2025; 12: 1657295.
[43] Schmitz-Valckenberg S, Pfau M, Fleckenstein M, Staurenghi G, Sparrow JR, Bindewald-Wittich A, Spaide RF, Wolf S, Sadda SR and Holz FG. Fundus autofluorescence imaging. Prog Retin Eye Res 2021; 81: 100893.
[44] Ach T and Bermond K. Autofluorescence of the human retinal pigment epithelium in normal aging and in age-related macular degeneration: histology and clinical correlation. Klin Monbl Augenheilkd 2019; 236: 672-681.
[45] Arrigo A, Aragona E, Battaglia Parodi M and Bandello F. Quantitative approaches in multimodal fundus imaging: state of the art and future perspectives. Prog Retin Eye Res 2023; 92: 101111.
[46] Kingdom FAA, Touma S and Jennings BJ. Negative afterimages facilitate the detection of real images. Vision Res 2020; 170: 25-34.
[47] Kronemer SI, Holness M, Morgan AT, Teves JB, Gonzalez-Castillo J, Handwerker DA and Bandettini PA. Visual imagery vividness correlates with afterimage conscious perception. Neurosci Conscious 2024; 2024: niae032.
[48] Zhu Y, Qi X, Li Y, Ding G, Qian Y, Lou Y, Kong X, Zhang Y, Li J, Li X and Qian X. Correlation between repeated low-level red light-induced afterimage and axial changes in myopia control. Photodiagnosis Photodyn Ther 2024; 50: 104400.
[49] Patel KY, Wilcox LM, Maloney LT, Ehinger KA, Patel JY and Murray RF. An equivalent illuminant analysis of lightness constancy with physical objects and in virtual reality. Behav Res Methods 2025; 57: 170.
[50] Caves EM, Davis AL, Nowicki S and Johnsen S. Backgrounds and the evolution of visual signals. Trends Ecol Evol 2024; 39: 188-198.
[51] Araújo ME, Paies MB, Arrais AB, Lobo FL, de Lima RRM and Caldas SGFR. Retinal damage related to high-intensity light-emitting diode exposure: an in vivo study. Am J Orthod Dentofacial Orthop 2022; 161: e353-e360.
[52] Wang Y, Chen S, Yang W and Kong J. Safe dose of 650 nm low-power semiconductor laser irradiation in chicken retina. Chin J Exp Ophthalmol 2020; 573-580.
[53] Zhu M, Liu Y, Fang D, Li M, Fu T, Yao K, Wang P, Sun X and Xiang Y. Safety of repeated low-level red-light therapy for children with myopia. Photodiagnosis Photodyn Ther 2024; 47: 104198.

[54] Sanchez-Cano A, Luesma-Bartolomé MJ, Solanas E and Orduna-Hospital E. Comparative effects of red and blue LED light on melatonin levels during three-hour exposure in healthy adults. Life (Basel) 2025; 15: 715.

[55] Westwood E, Smith S, Mann D, Pattinson C, Allan A and Staton S. The effects of light in children: a systematic review. J environ psychol 2023; 89: 102062.