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Research Paper

Efficacy of repeated low-level red-light therapy combined with defocus incorporated multiple segments spectacles for controlling childhood myopia

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ABSTRACT

Objective: To evaluate the differences in the efficacy of repeated low-level red-light (RLRL) therapy combined with either single-vision spectacles (SVS) or defocus incorporated multiple segments (DIMS) spectacles in slowing myopia progression in children.

Methods: A total of 129 myopic children aged 6–14 years were recruited between July 2023 and February 2024. Participants had at least one eye with spherical equivalent refraction (SER) <-0.50D and astigmatism ≤ 3.00D after cycloplegia. They were divided into four groups: SVS, DIMS, RLRL combined with SVS (RCS), and RLRL combined with DIMS (RCD). The RCS and RCD groups wore spectacles and received daily RLRL therapy sessions. The primary outcome was the change in axial length (AL) at 12 months.

Results: After 12 months, the mean changes of AL were: 0.26 mm (95 % CI, 0.17 to 0.35 mm) for SVS, 0.16 mm (95 % CI, 0.11 to 0.21 mm) for DIMS, -0.21 mm (95 % CI, -0.45 to 0.02 mm) for RCS, and -0.14 mm (95 % CI, -0.27 to -0.01 mm) for RCD. Significant differences were observed between groups ($F = 15.18$, $P < 0.001$). Post-hoc tests showed that the RCS and RCD groups exhibited significantly greater shortening compared to the SVS and DIMS groups (all $P < 0.001$). However, no significant difference was observed between the RCS and RCD groups ($P > 0.05$). No severe adverse events or safety concerns related to RLRL therapy were observed throughout the study.

Conclusion: RLRL therapy is a potentially effective and practical approach for myopia control, demonstrating comparable efficacy when combined with either SVS or DIMS spectacles.

1. Introduction

By 2050, it is estimated that 4.76 billion people (49.8 % of the global population) will have myopia, including 1 billion with high myopia [1]. Myopia is a major public health issue, causing significant visual impairment [2]. High myopia, linked to pathological myopia [3], can lead to serious complications such as myopic maculopathy, choroidal neovascularization, retinal detachment, glaucoma, and irreversible blindness [2,4–6].

Currently, various spectacle lenses have been developed to control myopia progression, including highly aspherical lenslet (HAL), cylindrical annular refractive element (CARE), diffuse optics technology (DOT), and defocus incorporated multiple segments (DIMS) [7–9]. DIMS spectacle lenses are specially designed lenses that feature a central zone for correcting distance vision, addressing daily visual requirements, and a peripheral zone incorporating multiple segments of positive lens power to induce myopic defocus [10–12]. This defocus is designed to provide a signal that inhibits the progression of myopia and axial elongation. A 2-year randomized trial showed that myopia progression was 52 % slower and axial elongation was 62 % less in the DIMS group compared to the single vision spectacle (SVS) group [12]. The DIMS lens is one of the most representative spectacle lenses for myopia control and

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is widely adopted due to its efficacy, user-friendliness, and safety profile [10,13].

Repeated low-level red-light (RLRL) therapy, using 650 nm red light, may slow myopia progression by enhancing choroidal blood flow and thickness through photobiomodulation [14,15]. This approach is effective, user-friendly, and associated with minimal side effects. Randomized controlled trials have shown that one year of RLRL combined with SVS can reduce axial length (AL) growth by 69 %, with 25 % of participants experiencing AL shortening [16,17]. Thus, RLRL is becoming a globally recognized strategy for myopia management.

This study aims to compare the efficacy of RLRL therapy combined with SVS lenses versus DIMS lenses in controlling myopia progression and axial elongation in children. Specifically, we sought to determine whether the combination of RLRL therapy with DIMS lenses has a more significant effect on slowing myopia progression and reducing axial elongation compared to RLRL therapy with SVS lenses.

2. Methods

2.1. Study design and setting

The study adhered to the Declaration of Helsinki principles and was approved by the Ethics Committee of the Affiliated Hospital of North Sichuan Medical College (2022ER297–1). In addition, the study has been registered in the Chinese Clinical Trial Registry (ChiCTR2200064763). Written informed consent was obtained from the guardians, and verbal assent from the participants. Participants were assigned to one of four groups based on their willingness to undergo RLRL therapy: SVS, DIMS, RLRL+SVS (RCS), or RLRL+DIMS (RCD).

2.2. Eligibility criteria

This study included children aged 6–14 years with a spherical equivalent refraction (SER) < -0.50D in at least one eye, astigmatism $\leq$ 3.00D, and best-corrected visual acuity (BCVA) $\geq$ 20/20 after cycloplegia. Participants were assessed for safety by researchers. Exclusion criteria included any pathological eye conditions other than refractive errors, systemic diseases, or previous myopia control treatments other than SVS or DIMS lenses.

2.3. Intervention

Participants in the SVS and DIMS groups wore their assigned lenses for at least 12 h daily. Those in the RCS and RCD groups followed the same lens-wearing schedule and additionally received RLRL therapy. RLRL therapy consisted of two 3-minute sessions per day, with at least a 4-hour gap between sessions, 7 days a week, conducted at home under parental supervision. If participants missed two consecutive sessions or received fewer than 12 treatments per week, a reminder was sent to the guardian. The RLRL device (Eyerising; Suzhou Xuanjia Optoelectronics Technology) emits low-level red-light at 650 $\pm$ 10 nm wavelength and 1600 lx intensity. This light, safe for direct ocular exposure, delivers 0.29 mW to a 4 mm pupil and reaches the retina [17].

2.4. RLRL therapy compliance

Therapy compliance refers to the percentage of completed treatment sessions out of the total prescribed sessions during the study period (two daily sessions, seven days a week). The device automatically logs compliance data via its internet connection.

2.5. Study outcomes

The primary outcome was the change of AL relative to baseline, assessed at the 12 months follow-up. AL was measured five times for each eye using the IOL Master 700 (Carl Zeiss Meditec), with the final result calculated as the mean of these five measurements, ensuring an accuracy of $\pm$ 0.05 mm.

The secondary outcome was the change in SER after cycloplegia relative to baseline at the 12-month follow-up. Cycloplegia was induced by administering one drop of 0.5 % tropicamide in each eye at 0, 5, and 20 min. Complete cycloplegia was confirmed when the pupil dilated to more than 6 mm and the light reflex was absent. Refractive data were measured three times for each eye using an automated refractometer (ARK-510A; NIDEK), with the final result being the average of these three measurements. The precision for both spherical (DS) and cylindrical (DC) powers was $\pm$ 0.25D SER was calculated as DS plus half of DC.

For both the RCS and RCD groups, optical coherence tomography (OCT, Heidelberg, Germany) was utilized to measure subfoveal choroidal thickness (SFCT) at the macular fovea. SFCT was defined as the perpendicular distance from the retinal pigment epithelium-Bruch's membrane complex to the outer choroidal-scleral boundary.

2.6. Efficacy of myopia control

The relative efficacy of the DIMS, RCS, and RCD groups was used to assessed efficacy of myopia control. Absolute efficacy is calculated as the control group value minus the intervention group value; relative efficacy is the absolute efficacy divided by the control group value.

2.7. Safety assessment

Safety assessments were conducted for the RCS and RCD groups. These assessments included evaluations of visual acuity (both uncorrected and best-corrected visual acuity, UCVA and BCVA), ocular alignment, anterior segment examination using a slit-lamp microscope, intraocular pressure measurement, OCT imaging to assess retinal structure and optic disc nerve fiber layer thickness, and scanning laser fundus photography.

2.8. Adverse event

Adverse event questionnaires were collected from children, parents, or guardians, documenting responses including, but not limited to glare, flash blindness, and the duration of visual afterimages. At the conclusion of the study, researchers followed up with each participant who discontinued RLRL therapy to investigate any potential side effects.

2.9. Study termination

RLRL therapy would be discontinued if any of the following occurred: a decrease in visual acuity by two or more lines, development of a central scotoma, persistent visual afterimages lasting over 6 min on multiple occasions, structural damage to the fundus, use of alternative myopia control methods during the study, or a participant's request for withdrawal due to personal reasons.

2.10. Statistical analysis

If a participant had both eyes with SER < -0.50D, the right eye was selected for analysis; if only one eye met this criterion, that eye was chosen ($n = 5$). Data were analyzed using version SPSS 27.0. Data normality was assessed using the Shapiro-Wilk test. Continuous variables are reported as means (standard deviation), while categorical variables are presented as percentages. At the final follow-up, one-way ANOVA followed by LSD post-hoc test was used to evaluate treatment efficacy based on primary (AL change) and secondary (SER change) outcomes. The estimated mean differences and 95 % confidence intervals (CIs) were calculated based on the least squares estimation. The *t*-test was used to analyze changes in SCFT. A *P*-value of < 0.05 was considered statistically significant.

3. Results

3.1. Baseline characteristics

A total of 148 children were enrolled, with 19 withdrawing: 2 due to persistent visual afterimages lasting over 6 min on multiple occasions, 1 due to growth hormone injections, and 16 for personal reasons. This left 129 participants who completed the follow-up and were included in the analysis. No significant differences in baseline characteristics were found (all $P > 0.05$). (Table 1)

3.2. Primary outcome

After 12 months of intervention, the mean changes in AL for the SVS, DIMS, RCS, and RCD groups were 0.26 mm (95 % CI, 0.17 to 0.35 mm), 0.16 mm (95 % CI, 0.11 to 0.21 mm), −0.21 mm (95 % CI, −0.45 to 0.02 mm), and −0.14 mm (95 % CI, −0.27 to −0.01 mm), respectively, with significant differences between groups ($F = 15.18$, $P < 0.001$). The post-hoc test showed that, compared to SVS group, the mean AL changes for DIMS, RCS, and RCD were −0.10 mm ($P > 0.05$), −0.47 mm ($P < 0.001$), and −0.39 mm ($P < 0.001$); compared to DIMS group, RCS and RCD showed mean changes of −0.37 mm ($P < 0.001$) and −0.30 mm ($P < 0.001$) (Table 2, Fig. 1). However, no significant difference was found between RCS and RCD groups ($P > 0.05$). Notably, the intention-to-treat analysis (ITT analysis) results showed that 23.5 % (8/34) of RCS group and 22.9 % (8/35) of RCD group participants experienced AL shortening beyond the IOL Master's error margin (<0.05 mm) after RLRL therapy (Table 3).

3.3. Secondary outcome

After 12 months, the mean changes of SER were −0.75 D (95 % CI, −0.94 to −0.56 D) for SVS, −0.29 D (95 % CI, −0.48 to −0.10 D) for DIMS, 0.55 D (95 % CI, 0.06 to 1.04 D) for RCS, and 0.55 D (95 % CI, 0.13 to 0.96 D) for RCD, with significant differences between groups ($F = 18.70$, $P < 0.001$). The post-hoc test showed that, compared to the SVS group, the mean SER changes were 0.46 D ($P < 0.05$), 1.30 D ($P < 0.001$), and 1.30 D ($P < 0.001$) for the DIMS, RCS, and RCD, respectively; compared to the DIMS, RCS and RCD showed increases of 0.84 D ($P < 0.001$) and 0.84 D ($P < 0.001$), respectively. But no significant difference in the mean change of SER was found between the RCS and RCD groups ($P > 0.05$) (Fig. 1, Table 4). Notably, ITT analysis results showed that 20.6 % (7/34) of RCS group and 28.6 % (10/35) of RCD group participants experienced myopic regression exceeding the refractometer error margin (>0.25D) after RLRL therapy (Table 3).

Table 1
Demographic and baseline characteristics of the participants.

Characteristic	SVS ($n = 30$)	DIMS ($n = 30$)	RCS ($n = 34$)	RCD ($n = 35$)	P
Age (yrs) [a]	9.13 (2.56)	9.63 (2.27)	8.68 (2.13)	9.03 (2.08)	0.41
Sex (Female%) [b]	14 (46.7 %)	13 (43.3 %)	18 (52.9 %)	10 (28.6 %)	0.21
AL (mm)[a]	25.01 (0.94)	25.20 (0.82)	24.96 (1.24)	25.11 (1.31)	0.82
SER (D)[a]	−4.32 (1.81)	−4.33 (1.85)	−3.25 (2.77)	−4.10 (2.52)	0.19
SFCT (μm)[c]	—	—	267.91 (45.49)	273.75 (45.73)	0.60

Note: Data are presented as mean (SD), number (%).
[a], One-way Analysis of Variance
[b], Chi-square test.
[c], Independent Samples *t*-test. SVS, single-vision spectacles; DIMS, defocus-incorporated multiple segment; RCS, repeated low-level red-light therapy combined with single-vision spectacles; RCD, repeated low-level red-light therapy combined with defocus incorporated multiple segments spectacle lenses; AL, axial length; SER, spherical equivalent refraction; SFCT, subfoveal choroidal thickness.

3.4. Efficacy of myopia control

Compared to the average change in the SVS group, DIMS, RCS, and RCD groups demonstrated efficacy in delaying for AL growth and reducing SER shift towards myopic progression at 38.5 % vs. 180.8 % vs. 153.8 % and 61.3 % vs. 173.3 % vs. 173.3 %, respectively (Table 5).

3.4. Exploratory outcome

Compared to baseline, SFCT increased significantly after 12 months of RLRL therapy in both the RCS and RCD groups. The mean changes were 86.38 μm (95 % CI, 40.59 to 132.17 μm) in the RCS group and 62 μm (95 % CI, 31.18 to 92.82 μm) for RCD. However, no statistically significant difference was observed between the groups ($P > 0.05$). (Fig. 1, Table 6).

3.6. Safety and adverse events

During follow-up, participants in the RCS and RCD groups receiving RLRL therapy underwent safety assessments every 3 months. These assessments included UCVA, BCVA, ocular alignment, anterior segment examination, intraocular pressure measurement, OCT for retinal and optic disc nerve fiber layer evaluation, and scanning laser fundus photography. No serious adverse events, such as sudden vision loss or ocular structural damage, were observed.

4. Discussion

This study integrates the effective RLRL with the widely adopted DIMS for myopic children. This 12-month analysis revealed no statistically significant difference in change of AL, SER and SFCT between the RCS and RCD groups. While DIMS lenses have been shown to be effective for myopia control, they are associated with higher costs compared to SVS lenses [13,18,19]. This study provides valuable insights into the selection of myopia control spectacles that are both effective and cost-efficient when used in conjunction with RLRL therapy.

4.1. Efficacy differences

In this study, the 12-month follow-up demonstrated that DIMS outperformed SVS in inhibiting the progression of SER (0.46D) towards myopia, although no significant difference in the inhibition of axial growth. Nucci et al. [20] found that the DIMS group exhibited superior efficacy in delaying SER progression compared to the SVS group, while only 10 % of patients in the DIMS group showed no increase in AL. However, some published clinical studies on DIMS have demonstrated a statistically significant difference in the control of axial length progression between the DIMS and SVS groups. For example, a study by Lam et al. reported significantly less axial elongation in the DIMS group compared to the SVS group at 12 months [12]. This discrepancy may be attributed to higher AL, SER and astigmatism levels in our participants. Younger age, or difference in maternal myopia severity may also account for the discrepancy. Domas et al. found that higher baseline astigmatism and younger age can affect SER and AL treatment outcomes. Additionally, severe maternal myopia has been associated with greater SER progression [21].

In contrast, RCS (−0.21 mm) and RCD groups (−0.14 mm) demonstrated significantly greater efficacy in reducing AL growth compared to either SVS (0.26 mm) or DIMS groups (0.16 mm) alone (all $p < 0.001$). Regarding SER suppression, DIMS (−0.29D), RCS (0.55D), and RCD groups (0.55D) were all more effective than SVS groups (−0.75D), with RCS and RCD exhibiting superior performance over DIMS (all $p < 0.001$). A substantial body of evidence from multiple multicenter

Table 2
Cumulative change in axial length from baseline to 12 months.

Cumulative Change Mean (95 % Confidence Interval)						
Visit	SVS (mm)	DIMS (mm)	RCS (mm)	RCD (mm)	F	P
3 mos	0.11 (0.07 to 0.15)	0.05 (0.02 to 0.08) §	−0.07 (−0.11 to −0.03) §§,¶¶	−0.11 (−0.15 to −0.07) §§,¶¶	28.73	< 0.001
6 mos	0.18 (0.12 to 0.25)	0.12 (0.08 to 0.16)	−0.04 (−0.12 to 0.03) §§,¶¶	−0.12 (−0.19 to −0.05) §§,¶¶	22.03	< 0.001
9 mos	0.23 (0.11 to 0.35)	0.17 (0.11 to 0.23)	−0.02 (−0.12 to 0.07) §§,¶¶	−0.13 (−0.22 to −0.04) §§,¶¶	15.04	<0.001
12 mos	0.26 (0.17 to 0.35)	0.16 (0.11 to 0.21)	−0.21 (−0.45 to 0.02) §§,¶¶	−0.14 (−0.27 to −0.01) §§,¶¶	15.18	<0.001

Note: SVS, single-vision spectacles; DIMS, defocus-incorporated multiple segment; RCS, repeated low-level red-light therapy combined with single-vision spectacles; RCD, repeated low-level red-light therapy combined with defocus incorporated multiple segments spectacle lenses; Post-hoc tests: §, compared to SVS, $P < 0.05$.
§§ , compared to SVS, $P < 0.001$
¶, compared to DIMS, $P < 0.05$.
¶¶ , compared to DIMS, $P < 0.001$; all other comparisons showed no significant differences.

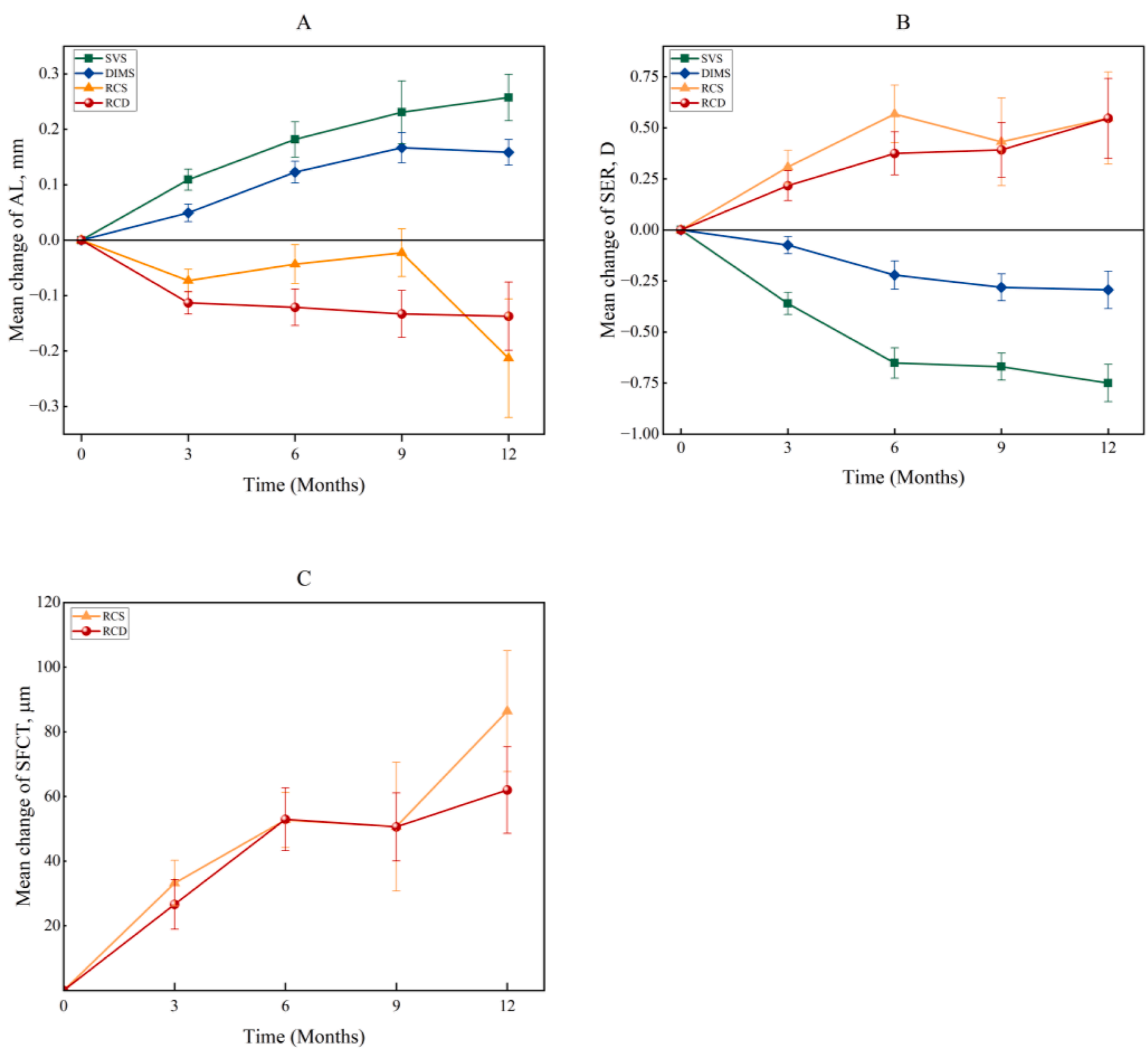

Fig. 1. Multi-group line charts display cumulative changes from baseline in (**A**) Axial Length (AL), (**B**) Spherical Equivalent Refraction (SER), and (**C**) Subfoveal Choroidal Thickness (SFCT) for each group. (*Note*: SVS, single-vision spectacles; DIMS, defocus-incorporated multiple segment; RCS, repeated low-level red-light therapy combined with single-vision spectacles; RCD, repeated low-level red-light therapy combined with defocus incorporated multiple segments spectacle lenses.).

randomized clinical trials has demonstrated the significant efficacy of RLRL in controlling myopia [17,22–25]. Notably, our study innovatively found no statistically significant difference between lens design and RLRL efficacy. Compared to the SVS group, DIMS was only 38.5 % effective in delaying AL growth, while RCS and RCD group were 180.8 % and 153.8 %, respectively. In terms of inhibiting SER myopic drift, DIMS was 61.3 % effective, whereas RCS and RCD were 173.3 % and 173.3 %, respectively. This effectiveness may be attributed to an 85.2 % (IQR, 78.2 % - 90.0 %) compliance rate. Jiang et al. observed that increasing compliance from <50 % to >75 % improved efficacy in suppressing AL

Table 3
Proportion of participants with axial length shortening >0.05 mm and hyperopic shift >0.25 D at 12 months.

	SVS	DIMS	RCS	RCD
ΔAL < −0.05 mm	0 % (0/30)	3.3 % (1/30)	18.6 % (8/43)	17.8 % (8/45)
ΔSER > 0.25D	0 % (0/30)	3.3 % (1/30)	16.3 % (7/43)	22.2 % (10/45)

Note: SVS, single-vision spectacles; DIMS, defocus-incorporated multiple segment; RCS, repeated low-level red-light therapy combined with single-vision spectacles; RCD, repeated low-level red-light therapy combined with defocus incorporated multiple segments spectacle lenses; ΔAL, change of axial length; ΔSER, change of spherical equivalent refraction.

growth by 32.2 % and controlling SER progression by 46 % [17].

There were no significant differences between RCS and RCD groups in suppressing AL growth, preventing SER myopic shift, and increasing SFCT thickness. In the RCS and RCD groups, 18.6 % and 17.8 % of participants, respectively, experienced AL shortening (>0.05 mm), while 16.3 % and 22.2 % exhibited a hyperopic shift (> 0.25D). This may be related to photobiomodulation-induced SFCT thickening. RLRL at 650 nm may enhance choroidal blood flow through photothermal and photochemical effects, improving scleral hypoxia and stimulating enzyme activities such as catalase and cytochrome c oxidase. This promotes mitochondrial metabolism, ATP synthesis, protein synthesis, wound healing, anti-inflammation, and reduces retinal oxidative stress and cell apoptosis, ultimately slowing excessive AL growth [15,26–30].

It is crucial to acknowledge that a rebound effect may occur to some extent following the discontinuation of RLRL therapy. Xiong et al. [31] conducted a comparative study among children who discontinued RLRL therapy after two years, those who continued the treatment, and those who had never received it. Their results demonstrated a moderate rebound effect associated with the cessation of RLRL therapy. This highlights the necessity for extended follow-up to comprehensively assess the long-term efficacy of this therapy and to investigate more optimized usage strategies.

4.2. Safety and adverse events

During the follow-up period, 69 participants who received RLRL therapy completed the seven mandatory safety evaluations at 3-month intervals. Notably, no serious adverse events, such as vision loss or ocular structural damage, were observed in any of the participants. Extensive clinical evidence, including multiple studies, reviews, and meta-analyses, has consistently demonstrated the favorable safety profile of RLRL therapy [14,17,22–25]. Liu et al. reported a case of a 12-year-old girl with high myopia and conjunctivitis who developed foveal outer retinal ellipsoid layer rupture and a significant decrease in BCVA after RLRL treatment [32]. Her vision and ocular structure returned to normal after treatment discontinuation. Though no serious adverse events were detected, two participants withdrew due to persistent visual afterimages lasting over 6 min on multiple occasions. This suggests hypersensitivity to RLRL therapy in such individuals. Therefore, strict inclusion criteria and comprehensive safety assessments, particularly focusing on posterior segment examinations, should be implemented. Potential risks, including sudden vision loss, central scotoma, and prolonged afterimages, must be closely monitored to ensure safety.

4.3. Limitations

Although this study yielded promising results, it is important to acknowledge certain limitations. The 12-month study duration was insufficient for assessing long-term efficacy. Furthermore, potential confounding factors such as parental myopia history and outdoor activity duration were not accounted for in the data collection process. Additionally, specific details regarding the brand and coating of the

Table 5
Efficacy of myopia control at 12 months.

Variables	DIMS	RCS	RCD
Absolute efficacy (relative efficacy,%)			
AL (mm)	0.1 (38.5 %)	0.47 (180.8 %)	0.40 (153.8 %)
SER (D)	−0.46 (61.3 %)	−1.3 (173.3 %)	−1.3 (173.3 %)

Note: SVS, single-vision spectacles; DIMS, defocus-incorporated multiple segment; RCS, repeated low-level red-light therapy combined with single-vision spectacles; RCD, repeated low-level red-light therapy combined with defocus incorporated multiple segments spectacle lenses. AL, axial length; SER, spherical equivalent refraction. Absolute efficacy = value in single-vision spectacle group − value in intervention group; relative efficacy = (value in single-vision spectacle group − value in intervention group)/value in single-vision spectacle group.

Table 6
Change in subfoveal choroidal thickness after repeated low-level red-light therapy compared to baseline.

Visit	RCS (μm)	RCD (μm)	*t*	*P*
Cumulative Change Mean (95 % Confidence Interval)				
3 mos	33.20 (18.72 to 47.67)	26.62 (10.90 to 42.34)	0.63	0.53
6 mos	52.72 (35.04 to 70.40)	52.96 (33.08 to 72.83)	−0.02	0.99
9 mos	50.67 (4.71 to 96.63)	50.58 (28.21 to 72.95)	0.00	0.997
12mos	86.38 (40.59 to 132.17)	62.00 (31.18 to 92.82)	1.09	0.29

Note: RCS, repeated low-level red-light therapy combined with single-vision spectacles; RCD, repeated low-level red-light therapy combined with defocus incorporated multiple segments spectacle lenses.

Table 4
Cumulative change in spherical equivalent refraction from baseline to 12 months.

Visit	SVS (D)	DIMS (D)	RCS (D)	RCD (D)	*F*	*P*
Cumulative Change Mean (95 % Confidence Interval)						
3 mos	−0.36 (−0.47 to −0.25)	−0.07 (−0.16 to 0.01) [§]	0.31 (0.14 to 0.47) [§§,¶¶]	0.22 (0.07 to 0.36) [§§ ¶]	19.25	< 0.001
6 mos	−0.65 (−0.80 to −0.50)	−0.22 (−0.36 to −0.08) [§]	0.57 (0.27 to 0.86) [§§,¶¶]	0.38 (0.16 to 0.59) [§§,¶¶]	31.99	< 0.001
9 mos	−0.67 (−0.81 to −0.53)	−0.28 (−0.43 to −0.14) [§]	0.43 (−0.05 to 0.91) [§§,¶¶]	0.39 (0.10 to 0.68) [§§,¶¶]	18.00	< 0.001
12 mos	−0.75 (−0.94 to −0.56)	−0.29 (−0.48 to −0.10) [§]	0.55 (0.06 to 1.04) [§§,¶¶]	0.55 (0.13 to 0.96) [§§,¶¶]	18.70	< 0.001

Note: SVS, single-vision spectacles; DIMS, defocus-incorporated multiple segment; RCS, repeated low-level red-light therapy combined with single-vision spectacles; RCD, repeated low-level red-light therapy combined with defocus incorporated multiple segments spectacle lenses; post-hoc tests: [§], compared to SVS, $P < 0.05$.
[§§], compared to SVS, $P < 0.001$.
[¶], compared to DIMS, $P < 0.05$.
[¶¶], compared to DIMS, $P < 0.001$.

DIMS lenses were not specified, which could affect reproducibility and comparability. While these factors are anticipated to have minimal impact on the overall findings, future studies should standardize these parameters to enhance the robustness of the research.

5. Conclusions

In this 12-month study of children aged 6–14 with myopia, DIMS alone do not suppress AL growth. However, RLRL therapy combined with either SVS and DIMS can effectively control AL growth and even reduce it in more than 16 % of the patients. While DIMS can slow myopic shift in SER, the combination therapy is more effective, inducing a hyperopic shift in more than 16 % of the patients. RLRL therapy also increases SFCT, regardless of lens design. No serious adverse events related to RLRL therapy were observed. Combining RLRL therapy with SVS provides efficacy equivalent to its combination with DIMS, while offering a less cost-effective approach for myopia control.

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CRediT authorship contribution statement

Chang-Kang Luo: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Chun-Yan Lai:** Formal analysis, Data curation, Conceptualization. **Jia-Hao Tan:** Investigation, Data curation. **Wei Zhao:** Investigation, Data curation. **Qing-Qing Tan:** Writing – review & editing, Supervision, Resources, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare that they have no conflict of interest regarding this work.

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