• Clinical Research •

Role of short-wavelength filtering lenses in delaying myopia progression and amelioration of asthenopia in juveniles

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Abstract

• AIM: To evaluate the positive effects of blue-violet light filtering lenses in delaying myopia and relieving asthenopia in juveniles.

• METHODS: Sixty ametropia juveniles (aged range, 11-15y) were randomized into two groups: the test group (30 children, 60 eyes), wearing blue-violet light filtering lenses; and the control group (30 children, 60 eyes), wearing ordinary aspherical lenses. Baseline refractive power of the affected eyes and axial length of the two groups was recorded. After 1-year, the patients underwent contrast sensitivity (glare and non-glare under bright and dark conditions), accommodation-related testing, asthenopia questionnaire assessment, and adverse reaction questionnaire assessment.

• RESULTS: After 1y of wearing the filtering lenses, changes in refractive power and axial length were not significantly different between the two groups (*P*>0.05). Under bright conditions, the contrast sensitivities at low and medium-frequency grating (vision angles of 6.3°, 4.0°, and 2.5°) with glare in the test group were significantly higher than in the control group (*P*<0.05), while the contrast sensitivity at low-frequency grating (vision angles of 6.3° and 4.0°) in the absence of glare in the test group was higher than in the control group (*P*<0.05). Under glare and non-glare dark conditions, the contrast sensitivities of various frequencies in the test group did not show significant differences compared with those in the control group (*P*>0.05). In the test group, the amplitude of accommodation, accommodative lag, and accommodative sensitivity of patients wearing glasses for 6 and 12mo were significantly elevated (*P*<0.05), while the asthenopia gratings were significantly decreased (*P*<0.05). Nevertheless, in the control group, the amplitude of accommodation, accommodative lag, and accommodative sensitivity after 12mo were not significantly altered compared with baseline (*P*>0.05), and the asthenopia grating was not significantly decreased (*P*>0.05). In addition, after wearing glasses for 6 to 12mo, the asthenopia grating of patients in the test group decreased significantly compared with the control group (*P*<0.05). At 12mo, the constituent ratio of adverse reactions did not show significant difference between the two groups (*P*>0.05).

• CONCLUSION: A 1-year follow-up reveal that compare with ordinary glasses, short-wavelength filtering lenses (blue/violet-light filters) increase the low- and medium-frequency contrast sensitivity under bright conditions and improved accommodation. They effectively relieved asthenopia without severe adverse reactions, suggesting potential for clinical application. However, no significant advantages in terms of refractive power or axial length progression were found compared with ordinary aspheric lenses.

• KEYWORDS: short-wavelength filtering lenses; asthenopia; juvenile myopia

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INTRODUCTION

Blue light is an important component of natural light. Blue light hazard refers to the photochemical action induced by radiant exposure to light with a wavelength of 400-500 nm (short wavelength light), leading to retinal damage[1]. However, blue light plays an important role in perception and in distinguishing graphics and colors, regulating hormone secretion *in vivo,* maintaining circadian rhythms in animals, and maintaining refractive ability[2]. Therefore, the need for short-wavelength filtering lenses (blue/violet-light filter) is still controversial. Nevertheless, short-wavelength filtering lenses control light-sensitive stimulation, improve visual comfort and definition, and play a positive role in alleviating asthenopia in humans[3]. In the meantime, it improves contrast sensitivity

Table 1 Symptom assessment form

Grades	Symptoms
0	No symptoms
1	Occasional symptoms (less than 3 times per week), and relieved after rest.
2-4	Falls between 1-5, assessment based on individual conditions.
5	Recurrent symptoms, affecting quality of life and work, and not relieved easily with rest.
6-8	Falls between 5-9, assessment based on individual conditions.
9	Ongoing symptoms seriously affecting quality of life and work, and not ameliorated with rest.

Table 2 Adverse reaction assessment form

Grades	Symptoms
0	No symptoms
1	Occasional symptoms (less than 3 times per week). Patients are tolerant, without a need for termination of the experiment.
2	Moderate discomfort (less than 6 times per week). Patients are basically tolerant, without a need for termination of the experiment.
3	Frequent symptoms affecting the quality of life and work. Patients are intolerant, warranting cessation of the experiment.

and visual acuity under photonic vision, improves retinal image quality, and strengthens the accommodative function, which may delay myopia progression. In this randomized controlled study, we followed up patients for 1y to evaluate whether the short-wavelength filtering lenses played a positive role in delaying myopia and relieving asthenopia in juveniles. We selected the Sanlang medical protective glasses (patent No.ZL201020301257.8 versatile anti-blue lenses), which were designed using substrate absorption, including a substrate and a coating layer. They absorb UV light shorter than 380 nm, as well as 400 to 500 nm high-energy blue light. They transmit 90% of the light in the range of 500 nm to 780 nm to ensure clear vision.

SUBJECTS AND METHODS

Subjects Between 2012 and 2014, 60 juveniles with ametropia and aged 11-15y were followed up at our Outpatient department. These 60 juveniles were all from the same school. They exhibited a refractive power of -1.0 to -5.0 D (astigmatism lower than -1.00 D, 50% of the astigmatism was included in spherical equivalent). The patients were randomized using a random number table to two groups (60 eyes of 30 patients for each group): the test group, wearing blue-violet light filtering lenses; and the control group, wearing ordinary aspherical lenses. The mean age of the patients in the test and control groups was 13.7±1.1y (14 males and 16 females) and 13.3±1.3y (15 males and 15 females); there were no significant differences between the two groups.

Patients with glaucoma, cataract, retinal detachment or denaturation, and other ocular diseases affecting vision were excluded. This study was approved by the hospital Ethics Committee. Guardians of all the subjects signed informed consent.

Research Methods At the beginning of the experiment, the patients in both groups were tested for initial visual acuity, optometry, and axial length. After wearing glasses, contrast sensitivity and glare contrast sensitivity were assessed at low, medium, and high frequencies under bright and dark conditions. Accommodation-related tests (amplitude of accommodation, accommodative lag, and accommodative sensitivity) and asthenopia questionnaire were administered. The asthenopia questionnaire included nine items: photophobia, foreign body sensation, burning sensation, blepharism, ophthalmalgia, dizziness and headache, lachrymation, nausea, vomiting, and hyperemia. Hyperemia was evaluated and recorded by the same clinician, and the remaining subjective symptoms were self-assessed by the patients using the method proposed by Liu *et al*[4] according to the severity of symptoms (Table 1). Due to the significant differences in the appearance of lenses between the two groups, blinding was not adopted in this study. Patients in the test and control groups wore glasses for one year, and filled out the adverse reaction questionnaire at the end of the experiment. Adverse reactions included presence of headache, dizziness, nausea, sleep disorder, night vision disorder, growth and developmental disorder, and dyschromatopsia (Table 2).

The patients in both groups were reviewed every 3mo for one year. At each review, they were tested for visual acuity, optometry, and axial length. All the examinations from the beginning until the end of the experiment were conducted by the same expert. Refractive power progression exceeding -0.50 D and the corrected visual acuity smaller than 5.0 suggested that the original lens was not consistent with the optometric prescription (corrected visual acuity above 5.0), and warranted lens replacement. All the subjects underwent accommodation-related detection and asthenopia questionnaire again after wearing glasses for 6 to 12mo. All the patients filled out the adverse reaction questionnaire after wearing the glasses for 12mo.

During the experiment, patients in both groups were required to avoid medications and physical therapy delaying myopia progression, and not to work at close range for longer than 3h every day. They were also asked to use the same type of eye-shield lamp.

Measurement of Contrast Sensitivity Contrase sensitivity was measured using a CGT-1000 Contrast Glare tester (Takagi Seiko, Nagano, Japan). The size of the pupils was 2.5-4 mm at an examination distance of 35 cm. Under bright adaptation (85 cd/m^2), bright adaptation combined with glare, dark adaptation (3 cd/m^2) and dark adaptation plus glare, monovision and glare contrast sensitivity under the best corrected visual acuity were assessed after the patients adapted to the darkroom for about 10min. In glare testing, brightness of the glare source was set to the highest level (40 000 cd/m^2), and the duration for the presence of visual target was set to 0.2s, with an interval of 2s. Hollow ring with visual targets of 6.3°, 4.0°, 2.5°, 1.6°, 1.0°, and 0.7° corresponded to visual angles of 28.6', 18.0', 11.4', 7.2', 4.5', and 2.9' respectively, with the corresponding circumference/degree of 1.0, 1.7, 2.6, 4.2, 6.6, and 10.4 cpd at 35 cm respectively. The visual angle of 6.3°-4.0° represented low-frequency, 2.5°-1.6° was medium-frequency, and 1.0°-0.7° was high-frequency light. Contrast thresholds of each spatial frequency were transformed using -lg contrast sensitivity for statistical analysis.

Accommodation-related Detection Amplitude of accommodation was determined in patients of the two groups using a push-up method after wearing different glasses. An object was gradually moved towards the patient, which increased the divergence of the light and stimulated accommodation, to determine the ability of the eye to change the diopter with respect to the shape of proximal stimulants.

After wearing different glasses, patients in both groups underwent accommodative lag examination using fused cross cylinders (FCC) test to evaluate the status of the tested eye in visualizing near targets.

Accommodative sensitivity refers to the ability to control accommodative status. After wearing glasses, the frequency of human eyes to effectively alter the accommodation within 1min was tested using flippers (±2.0 D) to represent the accommodative sensitivity.

Statistical Analysis Statistical analyses were performed using SPSS 17.0 (SPSS, USA). Normality of each group was tested using a non-parametric approach (binomial test). Intragroup comparisons were performed using paired *t*-test. Intergroup comparisons were conducted using independent-samples *t*-test. Constituent ratios of gender and adverse reactions were compared between the two groups using Chi-square test. $P<0.05$ was considered statistically significant in all the tests.

According to sample size calculation for mean comparison between two groups, $N=[Z_{\alpha/2}+Z_{\beta}]\sigma/\delta]^2$ $(Q_1^{-1}+Q_2^{-1})$, combined with our pre-experimental results, the sample size was estimated as N=30. Therefore, we recruited 100 subjects in total, including 35 patients randomly selected in each group according to the inclusion criteria. At the end of 1-year follow-up, 30 patients remained in each group, and the remaining 10 patients were lost to follow-up.

Table 3 Patients' age and gender

Groups	Age (a)	M (*n*)	F (*n*)
Test group	13.67±1.09	14	16
Control group	13.27±1.29	15	15

Table 4 Changes in refractive power and axis oculi at baseline and after 1-year in the two groups mean±SD

Parameters	Test group	Control group	*P*
Baseline refractive power (D)	-2.81±0.96	-2.67±0.93	0.442
Refractive power at 3mo (D)	-2.95±0.93	-2.77±0.95	0.298
Refractive power at 6mo (D)	-3.10±0.98	-2.95±0.92	0.363
Refractive power at 9mo (D)	-3.14±0.99	-3.05±0.94	0.536
Refractive power at 1a (D)	-3.24±0.98	-3.15±0.95	0.638
Difference of refractive power at 1a (D)	0.47±0.40	0.43±0.34	0.461
Baseline axis oculi (mm)	25.62±0.86	25.32±0.96	0.071
Axis oculi at 1a (mm)	25.73±0.87	25.47±0.92	0.108
Difference of axis oculi	0.11±0.13	0.15±0.26	0.332

Independent-samples *t*-test.

RESULTS

Patients' Baseline Data There were no significant differences between the two groups for age (independent-samples *t*-test: $P=0.199$) and gender (Chi-square test: $P=0.796$) (Table 3).

Refractive Power and Axis Oculi The baseline refractive powers of the test group (60 eyes) and control group (60 eyes) were -2.81±0.96 D and -2.67±0.93 D, respectively ($P=0.442$), and there were no significant differences in refractive power after wearing glasses for 1y between the two groups (Table 4). The changes in refractive power of the two groups during the 1-year follow-up (4 visits). The baseline axial lengths of the test and control groups were 25.62±0.86 mm and 25.32±0.96 mm, respectively ($P=0.071$). The axial length was not significantly different between the two groups after 1-year ($P=0.108$) (Table 4).

Contrast Sensitivity Baseline contrast sensitivity with and without glare under bright conditions was measured in patients of the test group (60 eyes) and control group (60 eyes) wearing different glasses (Table 5). The contrast sensitivities at medium and low-frequency grating (visual targets of 6.3°, 4.0°, and 2.5°) in the presence of glare were significantly higher in the test group compared with those in the control group ($P<0.05$), while the contrast sensitivity at low-frequency grating (visual targets of 6.3° and 4.0°) in the absence of glare in the test group was also higher than in the control group (independent-samples *t*-test, $P<0.05$). Meanwhile, there were no differences

Table 5 Contrast sensitivity and glare contrast sensitivity under bright conditions between the two groups mean±SD

Visual target	Glare			No glare		
group	Test group	Control group	*P*	Test group	Control group	*P*
6.3°	1.89±0.12	1.84±0.17	0.031[a]	1.97±0.07	1.92±0.14	0.025[a]
4.0°	1.89±0.12	1.83±0.17	0.042[a]	1.92±0.02	1.87±0.16	0.048[a]
2.5°	1.79±0.19	1.72±0.20	0.046[a]	1.82±0.19	1.83±0.16	0.906
1.6°	1.50±0.26	1.47±0.17	0.501	1.64±0.17	1.67±0.19	0.340
1.0°	1.25±0.15	1.27±0.26	0.565	1.39±0.21	1.32±0.21	0.095
0.7°	0.89±0.29	0.84±0.31	0.399	0.89±0.26	0.86±0.19	0.365

[a]*P*<0.05. Independent-samples *t*-test.

Table 6 Comparison of contrast sensitivity and glare contrast sensitivity under dark condition between the two groups mean±SD

Visual target	Glare			No glare		
group	Test group	Control group	*P*	Test group	Control group	*P*
6.3°	1.77±0.12	1.72±0.17	0.061	1.76±0.12	1.72±0.15	0.099
4.0°	1.79±0.12	1.77±0.15	0.585	1.74±0.15	1.78±0.13	0.110
2.5°	1.64±0.21	1.65±0.21	0.717	1.59±0.21	1.60±0.15	0.825
1.6°	1.36±0.17	1.36±0.26	0.855	1.57±0.61	1.60±0.19	0.340
1.0°	1.13±0.15	1.16±0.26	0.435	1.15±0.21	1.22±0.21	0.081
0.7°	0.80±0.18	0.83±0.25	0.530	0.56±0.31	0.61±0.29	0.386

Independent-samples *t*-test.

in contrast sensitivities at each frequency grating under glare dark as well as non-glare dark conditions between the two groups (Table 6; independent-samples *t*-test, *P*>0.05).

Amplitude of Accommodation, Accommodative Lag, and Accommodative Sensitivity There no differences in baseline amplitude of accommodation, accommodative lag, and accommodative sensitivity between the two groups (*P*=0.523, 0.701, and 0.080, respectively). In the test group, after wearing the glasses for 6mo, the amplitude of accommodation was significantly improved (*P*=0.001), accommodative lag was significantly decreased (*P*=0.027), and accommodative sensitivities of both eyes were significantly improved (*P*=0.034) compared with baseline. In the control group, the amplitude of accommodation, accommodative lag, and accommodative sensitivity at 6 and 12mo after wearing glasses did not show significant differences compared with baseline values (*P*>0.05). Six months after wearing glasses, the amplitude of accommodation was significantly increased in the test group compared with the control group (*P*=0.025), while accommodative lag and accommodative sensitivity did not show significant differences between the two groups (*P*=0.216 and 0.154, respectively). After wearing the glasses for 12mo, the amplitude of accommodation was significantly increased (*P*=0.008) and the accommodative lag was decreased (*P*=0.046) in the test group compared with the control group, while the accommodative sensitivity did not show significant differences between the two groups (*P*=0.448) (Table 7).

Asthenopia Grading All the patients underwent asthenopia grading at baseline, as well as at 6 and 12mo after wearing glasses (Table 8). At baseline, there were no differences in asthenopia grading between the two groups (*P*=0.816). After wearing glasses for 6mo, the asthenopia grading in the test group was significantly decreased compared with the control group (*P*=0.024). Glasses significantly reduced the asthenopia grade in the test group (*P*=0.016), while the difference in asthenopia grade before and after wearing glasses was not significantly different in the control group (*P*=0.725). Similarly, asthenopia grading was significantly decreased after wearing glasses for 12mo in the test group compared with the control group (*P*=0.013). Glasses significantly reduced asthenopia grade in the test group (*P*=0.01), while the difference before and after wearing glasses was not significant in the control group (*P*=0.596).

Adverse Reactions At the end of the experiment, patients in both groups filled out an adverse reaction questionnaire (Table 9). The results showed that one patient in the test group occasionally manifested dyschromatopsia (1 point) and another patient occasionally showed night vision disorder (1 point), with a 6% constituent ratio of adverse reactions. Meanwhile, in the control group, one patient occasionally manifested headache (1 point), with a 3% constituent ratio of adverse reactions. There were no differences between the two groups for the frequency of adverse reactions (χ^2= 0.351, *P*=0.554).

Table 7 Comparison of amplitude of accommodation before and after wearing glasses in the two groups mean±SD

Parameters	Baseline	Glasses for 6mo	*P* (baseline *vs* after 6mo of wearing glasses)	Glasses for 12mo	*P* (baseline *vs* glasses for 12mo)
Amplitude of accommodation in test group (D)	12.17±1.10	12.53±1.13	0.001[a]	12.58±1.14	0.001[a]
Amplitude of accommodation in control group (D)	12.05±0.87	12.10±0.95	0.370	12.07±0.95	0.709
P (test group *vs* control group)	0.523	0.025[a]		0.008[a]	
Accommodative lag in test group (D)	0.45±0.23	0.39±0.25	0.027[a]	0.37±0.46	0.006[a]
Accommodative lag in control group (D)	0.46±0.25	0.45±0.26	0.582	0.46±0.22	0.748
P (test group *vs* control group)	0.701	0.216		0.046[a]	
Accommodative sensitivity in test group (C/M)	10.42±1.11	10.53±1.03	0.034[a]	10.68±1.10	0.001[a]
Accommodative sensitivity in control group (C/M)	10.78±1.17	10.82±1.13	0.532	10.83±1.08	0.659
P (test group *vs* control group)	0.080	0.154		0.448	

[a]*P*<0.05. Independent-samples *t*-test, paired *t*-test.

Table 8 Comparison of asthenopia grading before and after wearing glasses between the two groups mean±SD

Groups	Baseline	Glasses for 6mo	*P* (baseline *vs* glasses for 6mo)	Glasses for 12mo	*P* (baseline *vs* glasses for 12mo)
Test group	10.23±1.55	9.10±2.11	0.016[a]	8.80±1.79	0.01[a]
Control group	10.13±1.76	10.03±1.77	0.725	9.97±1.73	0.596
P (test group *vs* control group)	0.816	0.024[a]		0.013[a]	

[a]*P*<0.05. Independent samples *t*-test, paired *t*-test.

Table 9 Comparison of constituent ratios of adverse reactions between the test and control groups after wearing glasses for 1y

Groups	Headache	Dizziness	Nausea	Sleep disorder	Night vision disorder	Growth and development disorder	Dyschromatopsia	Constituent ratio of adverse reactions
Test group	0	0	0	0	1	0	1	6%
Control group	1	0	0	0	0	0	0	3%
P								0.554

Chi-square test.

DISCUSSION

Foulds *et al*[5] found that chicks with myopia caused by red light exposure progressed to hyperopia after transfer to short-wavelength light, which indicated that blue light affected the refractive development but also reversed the existing myopia in an animal model. In addition, Jiang *et al*[6] found that blue light interfered with the progression of optical defocused myopia in guinea pigs, with thickened choroid membranes. Nevertheless, the impact of blue-light filter on refractive development in juveniles has not been investigated in clinical trials. The present study strongly suggests that juveniles wearing glasses for 1y showed no significant differences in refractive power and axial length between the test group wearing blue-violet light filtering lenses and the control group wearing ordinary aspheric lenses. Although short-wavelength filtering lenses improve accommodative function and visual quality, they promoted defocused myopia, resulting in an insignificant effect on myopia progression.

In order to investigate the differences in contrast sensitivity between the blue-violet light filtering lenses and ordinary lenses under bright and dark conditions, we simulated night-time driving under glare. Glare testing has been widely used to detect visual quality. In this experiment, contrast sensitivities with and without glare were measured under bright and dark conditions. The results revealed that the contrast sensitivities at medium- and low-frequency conditions of brightness and glare in patients wearing short-wavelength filtering lenses were significantly increased (P<0.05). Yap[7] studied the change in contrast sensitivity after wearing yellow filter, and found that yellow light filter significantly increased the sensitivity in normal individuals in medium- and low-spatial frequency. Yuan *et al*[8] and Niwa *et al*[9] investigated implantation of blue light-filtering intraocular lens made of polymethylmethacrylate (PMMA) after cataract surgery, and found that it was significantly better than the non-blue-light filtering intraocular lens in terms of spatial contrast sensitivity at medium and low frequencies, which was consistent with the present study. Thus, under normal light and glare conditions, wearing short-wavelength filtering lenses improves the medium- and low-frequency contrast sensitivity, resulting in improved visual quality.

This study demonstrated that under glare dark and non-glare dark conditions, the contrast sensitivities at each frequency grating did not show significant differences between the test (60 eyes) and control (60 eyes) groups (P>0.05). Night vision sensitivity depends on the number of photons absorbed by the rhodopsin pigment in rod cells. This absorption depends on wavelength and peaks at about 498 nm. With age, the number of rod cells may be reduced by 30%[10], leading to decreased night vision sensitivity[11]. Wirtitsch *et al*[12] found that under 500, 5, and 0.5 lx brightness, the blue-light filtering intraocular lenses decreased the visual contrast compared with transparent intraocular lenses, and the difference was significant under low brightness. Mester *et al*[13] conducted a 12-month follow-up of patients implanted with blue-light filtering intraocular lenses, and found decreased blue color vision under dark conditions. In the present study, there were no significant differences between the test and control groups for contrast sensitivities with gratings of different frequencies under glare dark and non-glare dark conditions, indicating that the medium- and low-frequency contrast sensitivity of the short-wavelength filtering lenses did not display a significant advantage compared with the ordinary aspheric lenses under dark condition. Nevertheless, a previous study showed that contrast sensitivity was not significantly decreased at different frequencies using blue-light filtering intraocular lenses[14], but these subjects were elderly people with decreased dark contrast sensitivity, while the subjects in the present study were juveniles wearing glasses that filtered less blue-light compared with intraocular lenses, resulting in insignificantly decreased contrast sensitivity under dark condition.

Accommodation is one of the important functions of eyes[15]. It facilitates clear focus of objects at different distances on the retina by normal eyes corrected for refractive error by changing the refractive state of the eyes. Parameters reflecting accommodation include accommodative amplitude, lag value, and sensitivity[16]. A few studies reported that subjective symptoms of near vision discomfort were associated with various accommodative parameters: a smaller accommodation of amplitude, worse accommodative sensitivity, and smaller accommodative lag value suggest significant subjective visual fatigue[17-18]. This study revealed that wearing short-wavelength filtering lenses for 6mo increased the accommodation of amplitude significantly, decreased the accommodation of lagged value, and increased the accommodation of sensitivity in patients, which significantly alleviated the onset of asthenopia. Therefore, asthenopia and the total asthenopia score were significantly reduced in the group of patients wearing short-wavelength filtering lenses for 6 and 12mo. On the other hand, in the control group, the accommodation amplitude, lag values, and sensitivity after wearing glasses for 6 and 12mo did not show significant differences compared with baseline (P>0.05). The total asthenopia score was not changed significantly. After wearing glasses for 6 and 12mo, accommodations of amplitude were significantly increased in the test group compared with the control group. Compared with the control group, accommodations of lag value in the test group did not show significant difference after wearing glasses for 6mo, while it was significantly decreased after for 12mo. Furthermore, compared with the control group, accommodation of sensitivity in the test group did not show significant differences after wearing glasses for 6 and 12mo. This effect might be attributed to the remarkable improvement in the accommodation of amplitude in the test group, while the accommodations of lag value and sensitivity showed greater differences at baseline between the two groups, and were not improved significantly in the test group after wearing glasses, which led to non-significant differences between the two groups. A previous study revealed that yellow light stimulates the large cell system of the lateral geniculate body as well as increases its activity[19]. It improves the stability of the eyes, as well as the sensitivity of movement, convergence, accommodation, reading abilities and other large cell functions, and ultimately improves reading performance, which undoubtedly alleviates visual stress and fatigue in juveniles engaged in long periods of reading. Ray *et al*[20] studied dyslexia in children manifesting as convergence and dys-adaptation, and found that the sensitivity of movement, convergence, accommodation, reading ability and other large cell functions were improved in children after wearing yellow light filter for 3mo, which was associated with short- and long-term effects. In the present study, accommodative function was improved in both eyes in the test group, and asthenopia and reading stress were reduced, which is supported by Ray *et al*[20].

Since blue light filters may alter the perception and discrimination to graphics and color, night vision, and human circadian rhythm, an adverse reaction questionnaire was administered to the subjects, and the results showed that there were no differences between the two groups. Augustin[21] reviewed the impact of blue-light filter on night vision, contrast vision, color vision, and circadian rhythm and found that blue-filtering intraocular lens had no effect on these parameters. In the present study, the patients in the test group did not show severely decreased visual acuity, dyschromatopsia, dyscoimesis, or other adverse reactions.

Finally, the present study showed that short-wavelength-filtering lenses (blue/violet light filters) improved medium- and low-frequency contrast sensitivity by optimizing ambient light into the eyes, resulting in a better retinal image quality compared with ordinary glasses. Furthermore, the short-wavelength-filtering lenses removed glare-related light components from the natural light, resulting in a soft and comfortable vision. It also improved the accommodative

function of the eyes, and alleviated asthenopia. In this experiment, patients in the test group did not manifest severe decline in nocturnal visual acuity, dyschromatopsia, dyscoimesis, or other adverse reactions.

Compared with ordinary aspheric lens, short-wavelength-filtering lenses did not show significant advantages in refractive power and axial length, possibly because of the short-term follow-up and small sample size. Furthermore, no design data related to adverse reactions were available. Thus, additional classification and analysis of adverse reactions are needed. In addition, due to obvious differences in the lens between the two groups, blinding was not possible. We hope to address this limitation by improving lens technology in the future. Finally, the questionnaire about adverse effects was subjective and a more reliable tool is needed.

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