



Original Article

The Effect of Tinted Filters on the Visual Function of Patients with Retinitis Pigmentosa

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Abstract

Purpose: To investigate the effect of tinted filters on contrast threshold (CT) and visual evoked potentials (VEPs) in patients with retinitis pigmentosa (RP).

Methods: In this cross-sectional study, RP patients with best corrected visual acuity better than 1 log MAR were evaluated. The CT was measured using the Freiburg Acuity and Contrast Test, and pattern reversals were analyzed for both time and frequency components. The effects of gray (15% light transmission, 410 nm cutoff), brown (18% light transmission, 410 nm cutoff), and yellow (27% light transmission with a 470 nm cutoff) tinted filters were evaluated and compared.

Results: Eighteen participants (mean age 32.78 ± 7.35 years; 72.2% male) were evaluated. The mean CT of Weber was $3.46 \pm 3.2\%$. Yellow filters decreased CT (mean difference [MD]: -0.597% , $P = 0.054$). Brown filters did not produce a significant change in the CT (MD: 0.233% , $P = 0.620$), while the gray filters caused a significant increase in the CT (MD: 1.423% , $P = 0.004$). Mode frequency (Fmod) decreased with gray filters (MD: -2.33% , $P = 0.004$). The latency and amplitude of VEPs improved with yellow filters ($P < 0.05$) but worsened with gray filters ($P < 0.05$). Additionally, the spherical equivalent showed an inverse correlation with CT in patients with RP ($r = -0.997$, $P < 0.001$).

Conclusion: Using tinted filters as a low-vision aid can modify contrast sensitivity and both frequency and time domains of VEPs in patients with RP. Yellow filters appear to improve visual function, whereas gray filters may worsen it.

Keywords: Contrast Sensitivity; Retinitis Pigmentosa; Tinted Filters

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INTRODUCTION

Retinitis pigmentosa (RP) is the most common form of retinal dystrophy, which typically presents bilaterally and causes progressive loss of vision.^[1-3] The disease initially damages rod photoreceptors, followed by cone involvement.^[4] As a result, patients develop night blindness, tunnel vision, and impaired contrast due to abnormalities in rod function and the magnocellular and parvocellular pathways.^[5, 6] Fundus examination reveals bone spicule pigmentation, vascular narrowing, and optic disc pallor.

Patients with RP exhibit higher levels of photophobia, especially to short-wavelength light, as well as light scattering. These disturbances reduce visual quality and contrast sensitivity across a range of spatial frequencies, most prominently at low spatial frequencies and under dim illumination.^[7] The use of tinted filters as a contrast-enhancing technique can reduce recovery time following changes in light adaptation by regulating both the intensity and wavelength of light entering the eyes, thereby improving visual function.^[8] Coring Photochromic Filters (CPF) have been proposed as the gold standard for low vision rehabilitation.^[9] However, controversy remains regarding the optimal filter wavelength for RP patients given the heterogeneous nature of the disease. Various filters, such as orange,^[9] yellow,^[7] or red^[10] have been evaluated in different studies; yet uncertainty persists concerning the most effective type and intensity for different clinical situations.

Previous studies on the effectiveness of color filters in RP have largely relied on subjective assessments, such as contrast sensitivity, yielding inconsistent results.^[11, 12] Objective tests, such as visual evoked potentials (VEPs), may provide a more reliable means of evaluating filter effects. Evidence suggests that pattern-reversal VEPs are altered in patients with RP,^[13] and this test can objectively quantify changes in contrast sensitivity.^[14]

Given the conflicting findings in the literature, the present study evaluated the effect of three commonly used tinted filters on contrast threshold (CT), along with electrophysiological responses, in patients with RP. The filters were selected based on their potential clinical utility in patients with RP, and the study design incorporated substantial reductions in ambient light (approximately 70-85%) to assess the differential impact of each filter.

METHODS

Participants

This cross-sectional study was conducted on 18 eyes from patients aged 23-49 years with RP, recruited from the Iran RP Center in 2020. The diagnosis of RP was established primarily on clinical grounds, including a history of night blindness, restricted visual fields (with an intact central visual field of at least 30°), and characteristic fundoscopic findings such as bone spicule pigmentation, vascular narrowing, and optic disc pallor.^[1] Inclusion criteria were: best-corrected visual acuity (BCVA) better than 1 LogMAR (logarithm of the minimum angle of resolution) in the randomly selected study eye, minimal or no cataract presence, and absence of clinically detectable macular cysts. Participants were fully informed about the study, and written informed consent was obtained. The study adhered to the tenets of the Declaration of Helsinki and was approved by the Ethics Committee of Iran University of Medical Sciences.

Examinations

A comprehensive systemic and ocular history was obtained from all patients, and demographic data were recorded accurately. Optometric examinations were performed to determine the BCVA under standard conditions using the Huvitz HCP-7000. Refractive status was assessed with the Huvitz Auto Refractor HRK-8000A. A complete dilated fundus examination (using 1% tropicamide) was performed with the Hagg-Streit BM 900 LED slit lamp and the Volk +90 D non-contact slit-lamp lens to verify compliance with the inclusion criteria.

Three Cocoons Filters (Polare lens technology) were evaluated: (1) gray filter with 15% visible light transition and 410 nm UV cutoff; (2) brown filter with 18% visible light transition and 410 nm UV cutoff; and (3) yellow filter with 27% visible light transition and 470 nm UV cutoff. Changes in the CT, mode frequency (Fmod), amplitude, and the latency of the P100 wave of the pattern-reversal VEP with each filter were analyzed. Filter selection and density were based on the luminous efficiency function.^[15] Additionally, these filters are among the most commonly used filters in patients with retinal structural disorders.^[16] The optical density of the filters was chosen to evaluate changes in the

intensity of light entering the eye, in addition to the chromatic properties of the filters.

Contrast Threshold (CT) Evaluation

CT is defined as the lowest level of contrast required to detect a target. Contrast sensitivity is the inverse of the numerical value of the CT. In the present study, CT was measured based on the Weber criterion using the Freiburg Acuity and Contrast Test (FrACT). FrACT, a reliable test for measuring contrast sensitivity, was administered at a distance of 1.5 m, where one pixel on the screen corresponded to 0.57 arcminutes under standardized lighting conditions. The Landolt C optotype, presented in eight different directions, was displayed randomly three times for each filter to measure CT.^[17]

Filters were mounted over the patients' corrective lenses using clips. To minimize afterimage effects, a 10-minute adaptation period was allowed between filter conditions. The order of filter application was randomized for each patient. Participants were instructed to identify the Landolt C optotypes, and their responses were recorded for all four conditions. All measurements were performed with undilated pupils.

Visual Evoked Potential (VEP) Evaluation

VEPs were evaluated using the MetroVision electrodiagnostic system (MonoPack 1, Perenchies, France). Tests were performed under mesopic lighting and in accordance with ISCEV standards.^[18] No electronic devices were placed near the participants to avoid interference. Gold cup electrodes (ground, active, and reference) were positioned according to the international 10-20 system. Patients were seated one meter from the stimulus screen with refractive error fully corrected.

For optimal signal quality, the scalp surface was cleaned with alcohol, and electrodes filled with conductive gel were affixed using medical adhesive. Electrode-skin resistance was maintained below 50 Ω , with inter-electrode differences <3 Ω . Binocular pattern-reversal VEPs were elicited using a 30-arcminute check size at high contrast, presented on a 19-inch monitor with a mean luminance of 50 cd/m². The mean luminance of the test room was 80 cd/m². The stimuli were reversed at a temporal frequency of 1 Hz (two reversals per second).

P100 amplitude, latency time, and Fmod were measured under four randomized conditions: baseline (no filter), yellow filter, brown filter, and gray filter. To reduce carryover effects, a washout interval was provided between filter conditions. VEP recordings were performed one day after the initial examinations and CT testing. Each recording consisted of 100 sweeps averaged for reproducibility, and all waveforms were recorded twice.

The frequency-domain analysis was performed using the Welch power spectral density (PSD) of the VEP responses. Fmod was defined as the frequency corresponding to the peak of the PSD, representing the dominant frequency component of the signal.^[19] While time-domain VEP reflects changes in the signal over time, frequency-domain VEP demonstrates the distribution of power across frequencies. Assessing both domains allowed a more comprehensive evaluation of visual signal transmission.

Sample Size

The sample size was estimated based on a study by Janaky et al,^[20] which reported a mean P100 latency of 136.5 ± 15.84 ms in patients with RP. Assuming an error margin of 7 ms, a significance level of 0.05, and a 10% dropout rate, a minimum of 22 participants was required.

Statistical Analysis

Quantitative variables were presented as mean \pm standard deviation. Normality of the distribution was evaluated using the Kolmogorov-Smirnov test. Differences among conditions were analyzed using repeated-measures ANOVA. Pairwise comparisons between each filter and baseline values were conducted with *t*-tests. Mean differences were calculated as the difference between baseline and post-filter values. Correlations between parameters were assessed using Pearson's or Spearman's correlation coefficients, depending on the normality of the distributions. A *P*-value <0.05 was considered statistically significant. Statistical analyses were performed with SPSS software (version 26.0; SPSS Inc., Chicago, IL, USA).

RESULTS

A total of 22 participants were enrolled, but 4 were excluded for not cooperating with the study tests.

Table 1. Mean and standard deviation of Weber contrast threshold with and without tinted filters

| Weber contrast threshold (%) | Mean \pm SD (95% CI) | MD | P-value ² |
|------------------------------|-----------------------------------|--------|----------------------|
| Without filter | 3.46 \pm 3.21 (1.85 to 5.05) | 0 | – |
| Yellow filter | 2.86 \pm 2.31 (1.70 to 4.01) | –0.597 | 0.054 |
| Brown filter | 3.69 \pm 2.75 (2.31 to 5.05) | 0.233 | 0.620 |
| Gray filter | 4.88 \pm 3.76 (3.00 to 6.74) | 1.423 | 0.004 |
| P-value ¹ | <0.001 | | |

MD, mean difference between each measurement and baseline (without filter); P-value¹, repeated-measures ANOVA, used to evaluate differences across all conditions; P-value², Paired *t*-test, used to compare each filter condition with baseline (without filter); P-values <0.05 were considered statistically significant.

Table 2. Mean and standard deviation of VEP parameters in patients with retinitis pigmentosa, with and without filters

| | Amplitude (μ v) | | | Latency (msec) | | | Fmod (Hz) | | |
|----------------|-----------------------------------|--------|-------|--------------------------------------|--------|-------|-------------------------------------|--------|-------|
| | Mean \pm SD (95% CI) | MD | P2 | Mean \pm SD (95% CI) | MD | P2 | Mean \pm SD (95% CI) | MD | P2 |
| Without filter | 4.31 \pm 2.61 (3.01 to 5.61) | 0 | – | 119.0 \pm 8.24 (114.9 to 123.1) | 0 | – | 8.83 \pm 3.58 (7.05 to 10.62) | 0 | – |
| Yellow filter | 4.69 \pm 2.80 (3.30 to 6.08) | 0.382 | 0.001 | 115.4 \pm 7.22 (111.7 to 118.9) | –3.611 | 0.001 | 10.11 \pm 2.51 (8.86 to 11.36) | 1.278 | 0.832 |
| Brown filter | 4.18 \pm 2.54 (2.91 to 5.45) | –0.129 | 0.139 | 120.0 \pm 7.42 (116.3 to 123.6) | 1.000 | 0.195 | 7.50 \pm 2.20 (6.40 to 8.60) | –1.333 | 0.750 |
| Gray filter | 4.07 \pm 2.46 (2.84 to 5.29) | –0.243 | 0.012 | 121.0 \pm 8.93 (116.5 to 125.4) | 2.000 | 0.015 | 6.50 \pm 1.94 (5.53 to 7.47) | –2.333 | 0.004 |
| P1 | <0.001 | | | <0.001 | | | <0.001 | | |

μ v, microvolt; msec, millisecond; Hz, hertz; MD, mean difference between each measurement and baseline (without filter); P1, repeated-measures ANOVA, used to evaluate differences across all conditions; P2, paired *t*-test, used to compare each filter condition with baseline (without filter); P-values <0.05 were considered statistically significant.

Ultimately, 18 participants (mean age: 32.78 \pm 7.35 years; 72.2% male [14 individuals]) were included in the analysis. The mean spherical equivalent (SE) and BCVA were -2.20 ± 4.04 D and 0.73 ± 0.26 LogMAR, respectively.

The mean CT of Weber was 3.46 \pm 3.2%. The yellow filter decreased CT with borderline significance (MD: -0.597% , $P = 0.054$). The brown filter produced no significant change (MD: 0.233%, $P = 0.620$), whereas the gray filter significantly increased CT (MD: 1.423%, $P = 0.004$) [Table 1].

The mean Fmod at baseline was 8.83 \pm 3.58 Hz, which significantly decreased with the gray filter (6.50 \pm 1.94 Hz, $P = 0.004$). The yellow and brown filters did not significantly affect the Fmod ($P > 0.05$). P100 amplitude increased with the yellow

filter (4.31 \pm 2.61 to 4.69 \pm 2.80 μ v, $P = 0.001$) and decreased with the gray filter (4.07 \pm 2.46 μ v, $P = 0.012$). Latency was reduced with the yellow filter (MD: -3.611 ms, $P = 0.001$), but increased with the gray filter (MD: 2.000 ms, $P = 0.015$). These electrophysiological changes are summarized in Table 2.

Correlation analysis revealed that SE was inversely correlated with CT in patients with RP ($r = -0.997$, $P < 0.001$). This correlation persisted with color filters, with the strongest correlation observed for the yellow filter ($r = -0.904$, $P < 0.001$; brown filter: $r = -0.661$, $P = 0.003$; gray filter: $r = -0.755$, $P < 0.001$).

DISCUSSION

This study evaluated the effect of tinted filters on changes in CT and VEP in both frequency and time domains in patients with RP. In individuals with restricted visual fields, conventional low-vision aids such as telescopes and microscopes provide limited benefit.^[21] In contrast, tinted filters not only protect ocular tissues from blue-light hazards but also reduce chromatic aberration, Rayleigh scatter, UV-induced lenticular fluorescein, and rod-cell oversaturation, thereby enhancing visual function by selectively controlling the light wavelength and intensity.^[7, 22]

In our study, the yellow filter showed a borderline improvement in CT. Given the relatively low BCVA of participants (0.73 ± 0.26 LogMAR), even modest changes in CT may contribute to functional improvements. Several prior studies support the beneficial effect of yellow or short-, wavelength-absorbing filters in RP.^[7, 23, 24] Cedrum-Sanchez et al demonstrated that filters with a 450 nm cutoff improved visual discrimination under dim illumination in RP patients by reducing diffraction, scatter, and aberrations.^[7] Wetzel et al also reported significant improvements in CS with customized cutoff filters.^[24] However, other studies suggest that tinted filters are more effective in patients with anterior scatter than in RP or diabetic patients,^[25] findings that conflict with our results and those of Sadeghpour et al.^[25, 26] Morrissette et al reported that users of a CPF 550 nm filter as a low-vision aid experienced reduced adaptation time to changes in illumination, along with improved visual functioning and ocular comfort.^[27] In the study by Eperjesi et al, RP patients were excluded due to the progressive nature of their condition;^[9] whereas our study demonstrates reliable outcomes for this group.

The observed differences can be explained by Carracedo et al's findings, who reported that the use of the CPF 527 filter (orange range) increases CS in RP patients, both with and without glare, with the greatest effect observed at a spatial frequency of 3 CPD and no effect at 12 CPD. Additionally, based on subjective reports and questionnaire responses, the subjects expressed greater satisfaction when using the filter.^[16] Importantly, the transmitted spectrum and the specific test used to assess CS can strongly influence outcomes, as different tests evaluate different ranges of spatial frequencies.

Variability in outcomes may be attributed to differences in test methodology, transmitted spectrum, spatial frequency range, and patient age. For instance, Mahjoob et al reported greater improvements with yellow filters in elderly patients with low vision than in the younger ones.^[28] Similarly, ambient lighting has been shown to influence filter efficacy. Abraham et al observed that yellow filters had maximal benefit at 100 lux in patients with maculopathy, while effectiveness in cataract varied with brightness and cataract severity.^[8] Filter density also plays a role, with Kalikivayi et al noting that yellow and pink filters improved CS by up to 60% at low densities but worsened it at higher densities.^[29]

Based on the findings of the current study, yellow filters also increased the amplitude and reduced latency without a significant change in Fmod. Paranhos et al^[31] demonstrated a reduction in P100 wave amplitude in patients with RP compared to normal subjects, which is likely related to changes in the parvocellular and magnocellular pathways as well as higher-order visual pathways.^[6] Cellular evaluations have also shown that S-cones in patients with RP are more severely affected than L- and M-cones.^[35] Therefore, it appears that filtering short wavelengths may reduce the activity of S-cone cells, thereby improving visual function.^[32]

Since the Fmod component reflects information transformed into the frequency domain for processing in the brain,^[19] the absence of a significant difference in this domain, combined with positive changes in the temporal components of the VEP, suggests that while the use of a yellow filter in patients with RP does not alter the transmitted information, it may help modulate negative lateral components and thereby enhance the speed of information transmission to the visual cortex. This effect, together with the borderline improvement observed in CS, could contribute to better visual performance in patients with RP. Nevertheless, factors such as variations in frequency content, filter density, lighting conditions, and the severity of RP may influence the effectiveness of the intervention. These variables should therefore be carefully considered in clinical decision-making to optimize patient outcomes.

In contrast, brown filters had no significant effect on CT or electrophysiological parameters in our study. As filters with the highest absorption below 550 nm showed the greatest CS improvements,^[33] the higher absorption range of brown filters (up

to ~600 nm) may explain the limited efficacy.^[34] This shows that the wavelengths in the range of approximately 500-600 nm play a beneficial role in the visual performance of individuals with RP, and further investigation of this effect is recommended in future studies. Electrophysiological evaluations in the present studies also indicate that the use of the brown filter does not affect either the time or frequency domains of VEP.

Interference with color perception is one of the major limitations of color filters.^[35] Although filters such as EnChroma have been shown to enhance color discrimination in people with color vision deficiencies,^[36] their use in those without such defects may cause disturbances in color perception. Based on this concern, Orlande et al recommended red filters for patients with RP and light sensitivity due to their protective effect on disease progression. However, this tint has been reported to induce Tritan-like color vision abnormalities, disturb sleep, and exacerbate night vision.^[10] Therefore, a comprehensive evaluation of different aspects of the visual system is essential when prescribing filters. Notably, Orlande et al also indicated that yellow filters with a 470 nm cut-off do not produce any of these adverse effects.^[10]

Fez et al showed that while the use of color filters may improve CS, it also introduces errors in color discrimination, whereas the use of gray filters did not affect discrimination.^[37] In contrast, the results of the present study show that gray filters significantly reduce CS in patients with RP, thereby greatly diminishing both the quality of vision and life. Electrophysiological evaluations further revealed that gray filters reduce Fmod, increase latency, and also decrease the amplitude of the P100 wave. Mahjoob et al found that gray filters in healthy individuals increase the CS in high light intensity (54000 lux, equivalent to sunlight exposure).^[38] Conversely, Bailie et al indicate that in age-related macular degeneration, neutral density filters reduce both CS and visual acuity.^[39] Similarly, Huchzermeyer et al observed that in occult macular dystrophy associated with RP1L1, perifoveal L- and M-cone function is reduced and remains dependent on intact rod cell activity.^[40] Taken together, these findings suggest that differences in cone and rod cell function in patients with RP may shift the spectral balance toward rod cell activity, thereby producing variable outcomes in visual function, CS, and electrophysiological responses. Further research is needed to clarify these mechanisms.

The results of the present study demonstrated an inverse correlation between CT and SE. Stoimenova reported that the CS of patients with myopia is lower than that of emmetropic ones, and that CS decreases with increasing degrees of myopia.^[41] In contrast, Li et al found that CS at low spatial frequencies in low and moderate myopia is higher than in other types of refractive error; however, with increasing spatial frequency and the overall decrease in CS across all refractive errors, myopia was associated with higher CS than other refractive errors at high spatial frequencies.^[42] Karatepe et al also noted that hyperopia is associated with the lowest CS among refractive errors.^[43] Consistent with these findings, our results indicate that an increase in hyperopia (or a reduction in myopia) is negatively associated with contrast sensitivity.

In summary, this study showed that tinted filters may serve as effective low-vision aids for patients with RP, as they can modify both contrast sensitivity and electrophysiological responses. Specifically, yellow filters appear beneficial in improving visual quality, whereas gray filters should be avoided in these individuals.

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None.

Conflicts of Interest

None.

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