Case Report: Effect of Haploscopic Filter on Contrast Sensitivity Function and Color Vision Tests

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SIGNIFICANCE: The options that can help patients with congenital color vision defect, to a better professional and leisure adaptation, are very limited. Different haploscopic lenses can be considered, and their effects need to be investigated in patients with different defects.

PURPOSE: The purpose of this study was to present and discuss the effect of a pair of asymmetric long-pass filters fitted for deuteranopia, with the result of a 60% improvement in distinguishing red-green plates when compared with baseline.

CASE REPORT: We report the case of a 51-year-old man with congenital deuteranopia fitted with haploscopic ChromaGen filters. During the 2-month follow-up, we observed a decrease in left-eye logMAR visual acuity and contrast sensitivity with an increased ability to discriminate the plates of different color vision tests (Ishihara, Farnsworth, and Hardy-Rand-Rittler). The visual outcomes are discussed considering the spectral sensitivity curves of each filter, measured with a spectrophotometric device.

CONCLUSIONS: This report describes an improvement in the ability to resolve color vision plates after using asymmetric haploscopic filters showing a left-eye decrease in logMAR visual acuity and contrast sensitivity function. Subjects with a history of color vision deficiency might benefit from using haploscopic filters that selectively minimize the transmittance within a specific bandwidth to improve the color discrimination in deutan color vision deficiency. The simultaneous analysis of the color vision outcomes and transmittance spectrum of the haploscopic filters might contribute to a better understanding of the mechanisms behind the claimed efficacy of these devices.

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COLOR VISION DEFICIENCY

Normal color vision is possible owing to a specific proportion of different types of photoreceptors in the central retina. These cones have different light-sensitive pigments that enable us to recognize red-green and blue-yellow components of color vision and luminance.[1] The absence of function in any type of cone photoreceptor causes congenital color vision deficiency. Researchers have determined that these defects involve the photoreceptor pigment genes. Congenital color vision deficiency is seen in 8% of male and 0.5% of female individuals.[2] The most common deficiency is associated with the reduced ability to discriminate red-green stimuli (protan-deutan defect) and is inherited as an X-linked recessive trait. The genes for the red and green pigments are quite close to one another, and because men have only one X chromosome, they are more likely to be missing or to have a recombined abnormal gene compared with women.[3] Protanopia refers to a deficiency in perceiving red hues; deuteranopia, green hues; and tritanopia, blue hues.

DIAGNOSTIC TESTS

Color vision deficiency can be detected by standardized tests, tables, and devices. However, there is a lack of uniformity on the use of color vision tests across the world.[4] Many tests for diagnosing this deficiency are in clinical use, including Ishihara and Hardy-Rand-Rittler pseudoisochromatic test plates, the Farnsworth D-15 test, the Farnsworth-Munsell 100-hue test, and the Nagel anomaloscope. Pseudoisochromatic tests are at the forefront of these methods owing to ease of use and sensitivity.[5] Ishihara test plates are the most popular and widely used pseudoisochromatic test plates, but the Hardy-Rand-Rittler test provides more information, as it includes plates that detect tritanopia in addition to protan and deutan defect and has a carefully designed set of plates to distinguish protan, deutan, and tritan deficiencies and grade their severity.[6] Color vision tests must be performed separately for each eye because deficiency types and their extents can differ in each eye.

LIMITATIONS AND AIDS

Patients with color vision deficiency have important limitations for military, security, aviation, marine, architecture, and interior design professions. Moreover, some subjects experience difficulties in daily tasks in terms of color vision, such as clothes selection, motor vehicle operation, or different video computer activities.[7] Currently, no treatment exists for congenital color vision deficiency, and the options that can help subjects are very limited. Haploscopic spectacles or contact lenses can be considered to get a wider variation in light levels, and their effects have been studied by several investigators.[8,9] These haploscopic filters are more transmissive for a specific wavelength range, while less transmissive for other wavelength ranges.

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Hence, luminous contrast occurs between the colored object and the ground, and the patient's color perception increases with no change in cone sensitivity. An interesting form of these haploscopic lenses is ChromaGen filters (ChromaGen Ltd., Chester, United Kingdom). A wide range of spherical or cylindrical powers can be added to this filter.

In this report, we present a male subject carrying a diagnosis of congenital severe deuteranopia. Herein, we describe the clinical response of the subject to color vision tests and contrast sensitivity at baseline and 2 months after use of haploscopic ChromaGen lenses. Finally, we discuss the putative underlying mechanisms leading to the improvement in color interpretation after ChromaGen filter spectroscopic analysis.

CASE REPORT

History

A 51-year-old man presented with congenital deuteranopia. There is a family history of color vision deficiency because his brother was diagnosed for the same defect. Difficulties distinguishing colors were noticed at the age of 15 years. Furthermore, a congenital cataract was diagnosed in the left eye at the age of 21 years, with no ocular anomalies in the right eye. Cataract surgery with the FineVision trifocal IOL (PhysIOL, Liège, Belgium) implantation was performed at the age of 48 years. His color vision had not been analyzed before the subject entering into his current professional activity as an educator and researcher at a university.

Ocular Examination

The patient underwent a complete ophthalmic examination, including best-corrected visual acuity, fundus examination, slit-lamp biomicroscopy, contrast sensitivity function, and color vision examination. Myopia and astigmatism with refractive errors of –0.25 D spherical power and –0.50 D cylindrical power at 90° (right eye) and –0.75 D cylindrical power at 140° (left eye) were found. The best-corrected visual acuity was measured using high-contrast (93%) and low-contrast (10%) visual acuity charts (Precision Vision, Woodstock, IL) at 4.0-m distance under a room illumination of 80 cd/m^2. Best-corrected visual acuity values of 20/20 (63 letters) in the right eye and 20/25 (59 letters) in the left eye were found at baseline (Fig. 1).

Contrast Sensitivity

The contrast sensitivity function was measured using an oriented sine wave grating device (Topcon CC-100 XP; TOPCON, Tokyo, Japan). The test was performed monocularly and binocularly using the refractive calculated correction at 2.0-m distance under 80-cd/m^2 standard photopic conditions.

Color Vision Tests

The subject was examined using three different tests to characterize the subject's color vision deficiency. Using the 24-Ishihara plate edition (Kanehara Trading Inc., Tokyo, Japan), he missed 18 of 20 plates with each eye, and he was diagnosed as an acute deutan. The subject was also examined with the Farnsworth D-15 test, and the results were consistent with deuteranopia. Finally, an on-screen Hardy-Rand-Rittler pseudoisochromatic test chart (Topcon CC-100 XP; TOPCON) clearly demonstrated the subject's severe deuteranopia (Fig. 1). The patient was tested with the recommended illuminant MacBeth Easel Lamp (MacBeth Corp., Newburgh, NY) for the Ishihara and D-15 tests and with the self-illuminated Hardy-Rand-Rittler test.

Haploscopic Lenses

ChromaGen lenses (ChromaGen Ltd.) were used to assist the subject to improve his ability to distinguish color plates. A specific filter was determined after the diagnostic routine filter selection recommended by the manufacturers. A rose-pink filter (Fig. 2) was chosen for each eye and worn by the subject binocularly, with the refractive correction calculated previously. In addition, a spectrophotometric

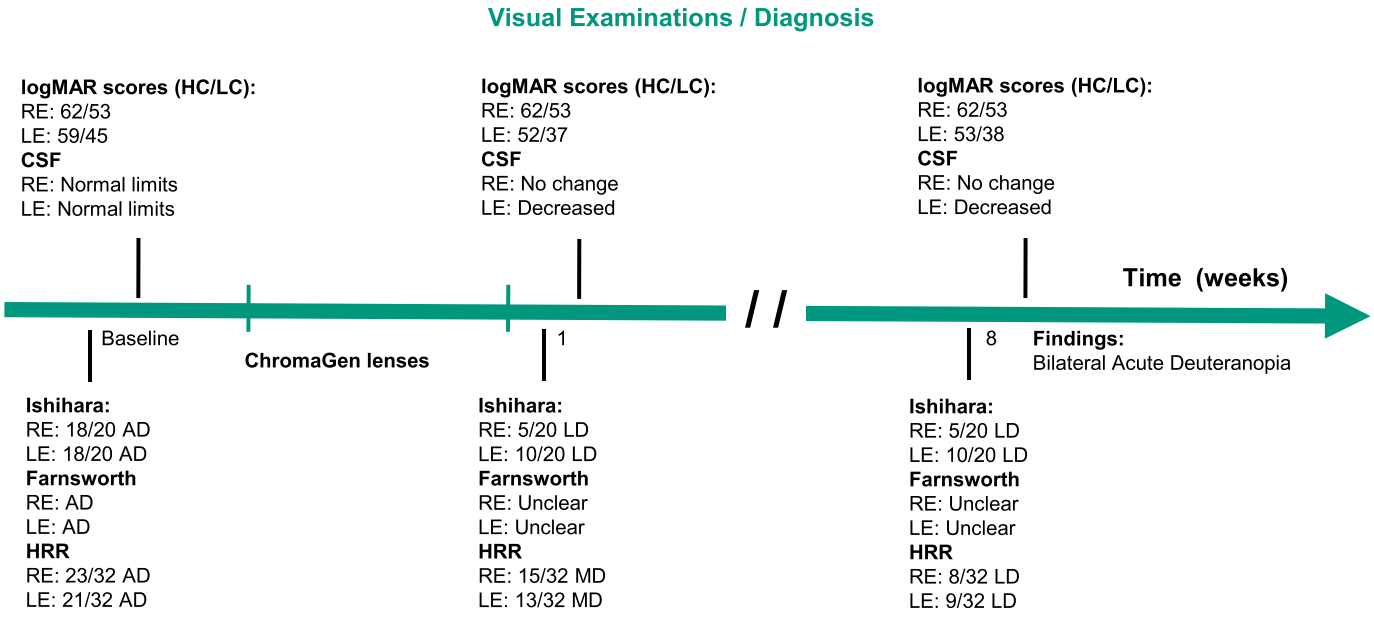

FIGURE 1. Clinical timeline: 51-year-old White man diagnosed and managed for deutan deficiency. AD = acute deutan; CSF = contrast sensitivity function; HC = high-contrast; HRR = Hardy-Rand-Rittler test; LC = low-contrast; LD = low deutan; LE = left eye; MD = mild deutan; RE = right eye.

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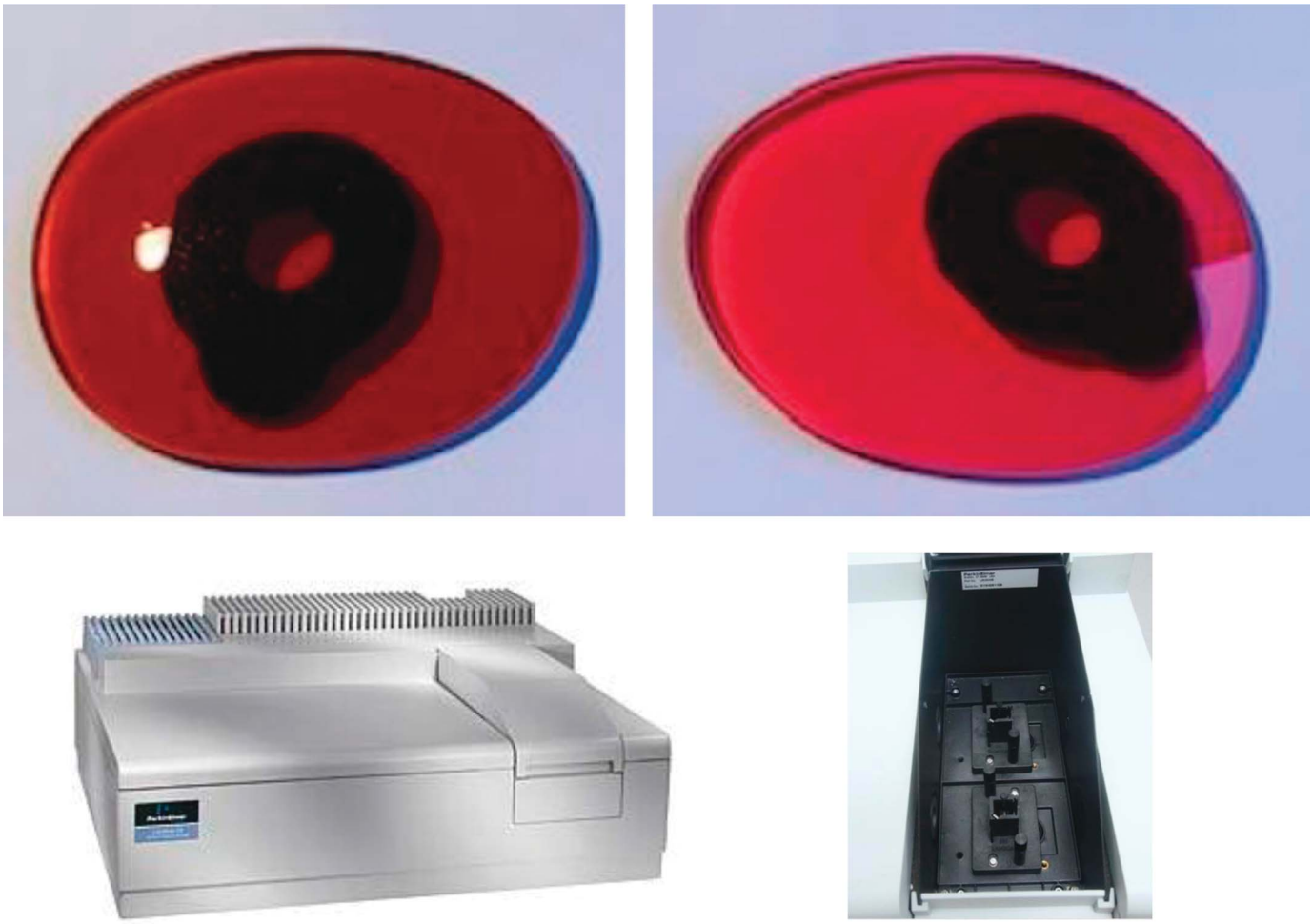

FIGURE 2. ChromaGen haploscopic filters (top) marked to be analyzed with the PerkinElmer Lambda 25 UV/Vis spectrophotometer (bottom).

analysis was made using a Lambda 25 UV/Vis spectrometer (PerkinElmer, Waltham, MA). Spectrophotometric measurements for the right and left ChromaGen filters are presented in Fig. 3.

Visual Outcomes

No changes in best-corrected visual acuity were found when comparing baseline, 1-week, or 2-month examinations of the right eye, but logMAR scores were diminished by seven and eight letters using the high- and low-contrast charts, respectively, after the 2-month examination of the left eye. When the contrast sensitivity function was examined after using ChromaGen haploscopic glasses, results were similar for the right eye when comparing baseline and 2-month follow-up visits to the subject wearing ChromaGen glasses, but decreased contrast sensitivity was found for 12- and 18-c/d spatial frequencies in the 2-month follow-up visit (Fig. 4) for the left eye.

Ishihara plates performed with the filters in place revealed that 5 of 20 were missed, and diagnostic plates suggested a mild deutan defect. The Farnsworth D-15 test showed an unclear pattern (Fig. 5) with a trend toward tritan failure, whereas Hardy-Rand-Rittler plates revealed a moderate deutan pattern with a binocularly 40% (40% right eye and 20% left eye) improvement in distinguishing red-green plates when compared with baseline. In addition, the patient reported to have an aesthetic handicap because of a "rose-pink fantasy image," suggesting that it occurred occasionally only during a comfortable sporadic use, mainly during personal indoor activities.

To check a time-dependent effect, the patient was instructed to gradually increase the use of the ChromaGen filter glasses during daily activities. After a 2-month period, Ishihara plates revealed the same 5 of 20 errors found in the previous session, the Farnsworth D-15 test showed an unclear pattern (Fig. 5), and the Hardy-Rand-Rittler test revealed a slight deutan pattern with a binocular 60% (80% right eye and 40% left eye) improvement in distinguishing red-green plates when compared with baseline ability (Fig. 1).

All experimental protocols were carried out according to the guidelines approved by the ethics committee of the Universidade de Santiago de Compostela, Spain, and in accordance with the Declaration of Helsinki. Informed consent was obtained from the patient for the publication of this case report and accompanying images.

DISCUSSION

Previous Studies

There are a few studies on the use of long-pass filters to improve color vision discrimination in subjects with color vision deficiency.

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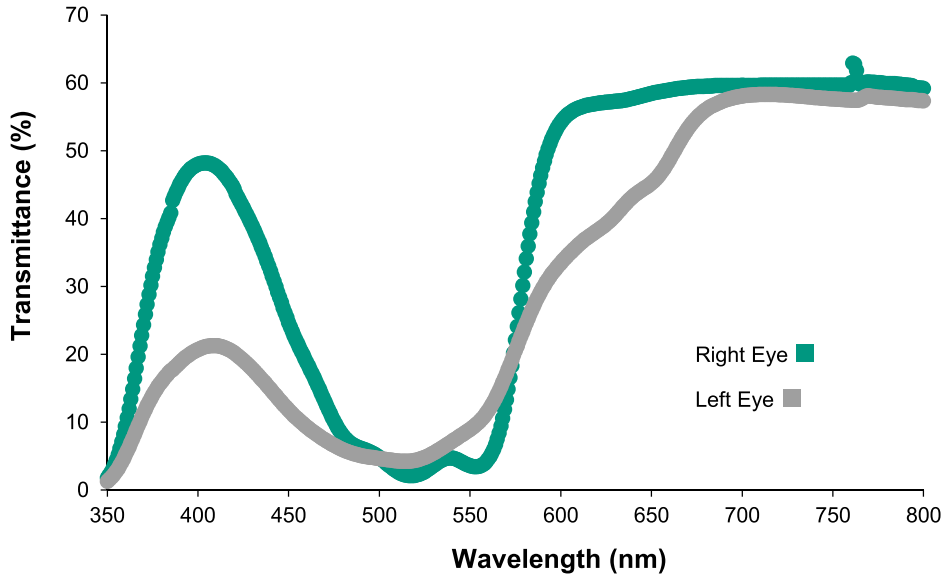

FIGURE 3. ChromaGen lens transmittance analysis of the right and left filters used in this study. Note the asymmetric configuration around the confusion axis.

Authors using haploscopic filters such as X-Chrom on patients with protan defect have found a mixed effect, allowing the patient to improve color interpretation capacity but decreasing best-corrected visual acuity and contrast sensitivity.[9,10] When this filter was used in deutan subjects, Sato et al.[10] found that, although the red filter improves the performance of deutans to arrange the caps in the D-15 test, this is not the case for protans. More recently, different authors have applied the ChromaGen filter as a contact lens aid with similar findings.[9] It seems that haploscopic filters used to induce changes in color vision deficiency by altering the patient's luminance contrast differ between the protan and deutan types, resulting in deuteranopes' performance improvement, while protanopes' performance deteriorates.

Present Study

During the 2-month follow-up, the ChromaGen glasses used in this study did not cause a reduction of visual acuity and contrast sensitivity in the right eye but did in the left eye, with no apparent binocular effect. However, we found an increased ability to discriminate the plates of different color vision tests, which is in good agreement with findings described recently by other authors using different filters.[10,11] However, our findings are not completely in agreement with data reported by Ilhan et al.,[9] who found fewer benefits of ChromaGen in deutan patients and decreased visual acuity and contrast sensitivity. Moreover, in the present study, we found a remarkable asymmetric effect, with major visual outcomes involving the filter with lower transmittance values (Fig. 1). The severity of the deficiency analyzed, the implemented ChromaGen filter configuration, the individual filter selection procedure, and the refractive error at baseline may be possible explanations.

Haploscopic Filters

The spectrophotometric analysis used in this study revealed that the right eye's ChromaGen filter was more permeable to short (with a peak of 50% transmittance in 404 nm) and large wavelengths (with a maximum value of 60% transmittance for 762 nm), whereas medium wavelengths were less permeable, showing two relative minimum values of transmittance <5% at 517 and 553 nm, both within the green light spectrum. Spectrophotometry of the ChromaGen lens for the left eye showed a decreased transmission for short wavelengths (with a relative maximum value of 23% transmittance for 409 nm), a further decrease in medium-wavelength transmission (showing a minimum value of 5% transmittance at 514 nm), and a higher transmission for longer wavelengths, with a peak of 60% transmittance for 705 nm. These patterns of transmission may well explain the tritan trait observed in the graphs corresponding to the Farnsworth test using the ChromaGen glasses. A different spectrophotometric pattern of blocked wavelengths inducing decreased light transmittance can be observed for each eye to obtain an individual eye response. Therefore, luminous contrast occurs between the colored stimuli and the ground. Thus, color discrimination increases, yet the illumination of the retina decreases. That circumstance explains some visual limitation in best-corrected visual acuity or contrast sensitivity found in this study for the left eye and by other authors using similar haploscopic filters, such as X-Chrom,[12] or ChromaGen contact lens wear.[9]

The medium-wavelength band cutoff configuration observed in the filters used in this study, coinciding with the peak of spectral sensitivity of the human eye, might enhance the chromatic discrimination around the axis of confusion. That is, ChromaGen filters induce differences in the luminance between combination colors, changing the spectral stimuli perceived by the patient when judging chromatic content. Moreover, that asymmetric configuration could be responsible for the rose-pink fantasy image reported by the patient. In this context, Slezak et al.[13] have studied binocular rivalry in observers presented with stimuli differing systematically in spatial structure and chromaticity. These authors found that the chromaticity need not be identical in two gratings for their ambiguous form above and below fixation to be resolved by grouping, a process involving a binocular competition process of neural representations of chromaticity. Hence, this fantasy effect experienced by the proband may be a binocular rivalry phenomenon. Because the technique introduces transmittance differences between the

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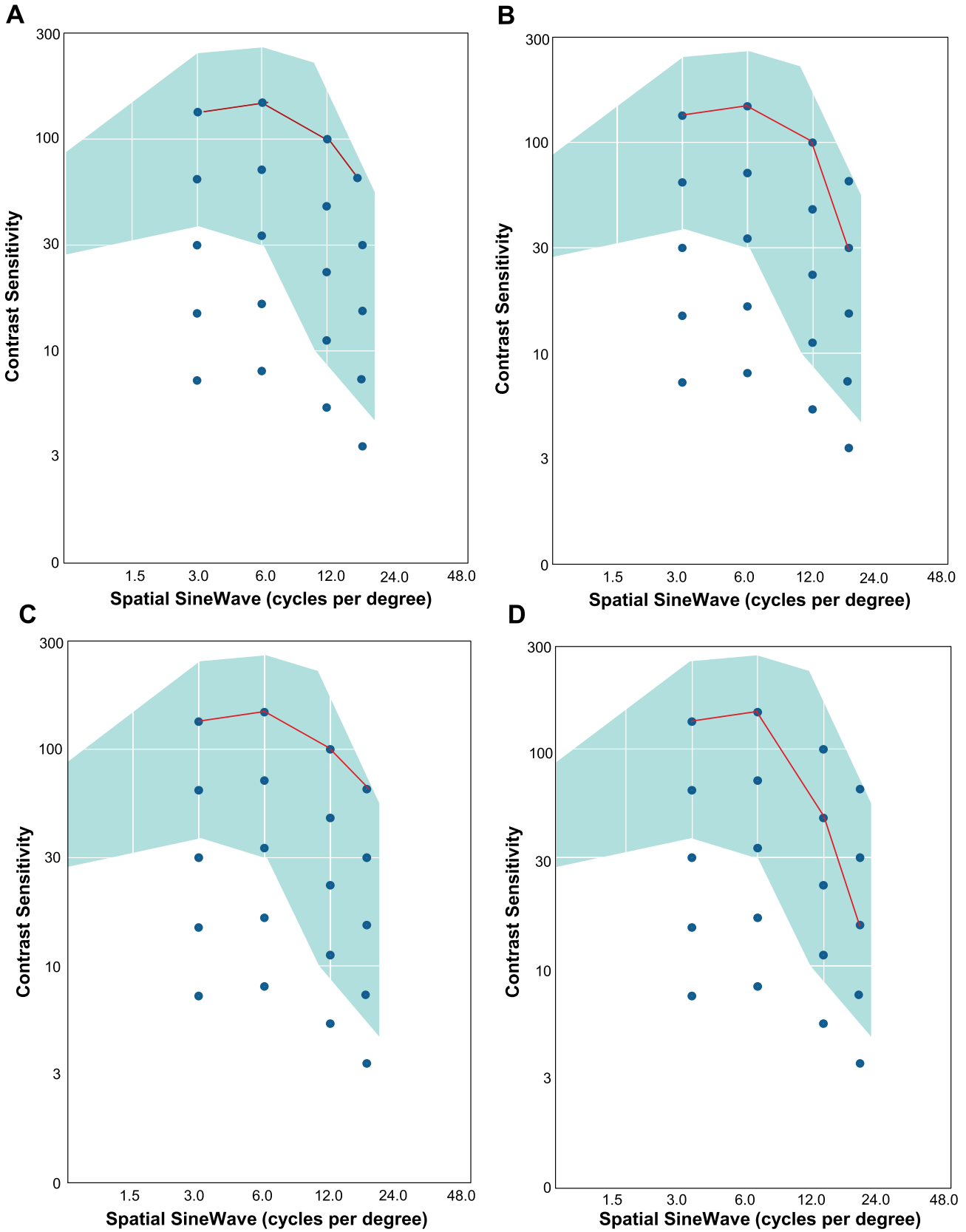

FIGURE 4. Contrast sensitivity function measured at baseline for the right eye (A) and left eye (B) and then after 2 months of using ChromaGen haploscopic glasses for the right eye (C) and left eye (D). Note the major decrease in the 18-c/d spatial frequency for the left eye with the ChromaGen lens.

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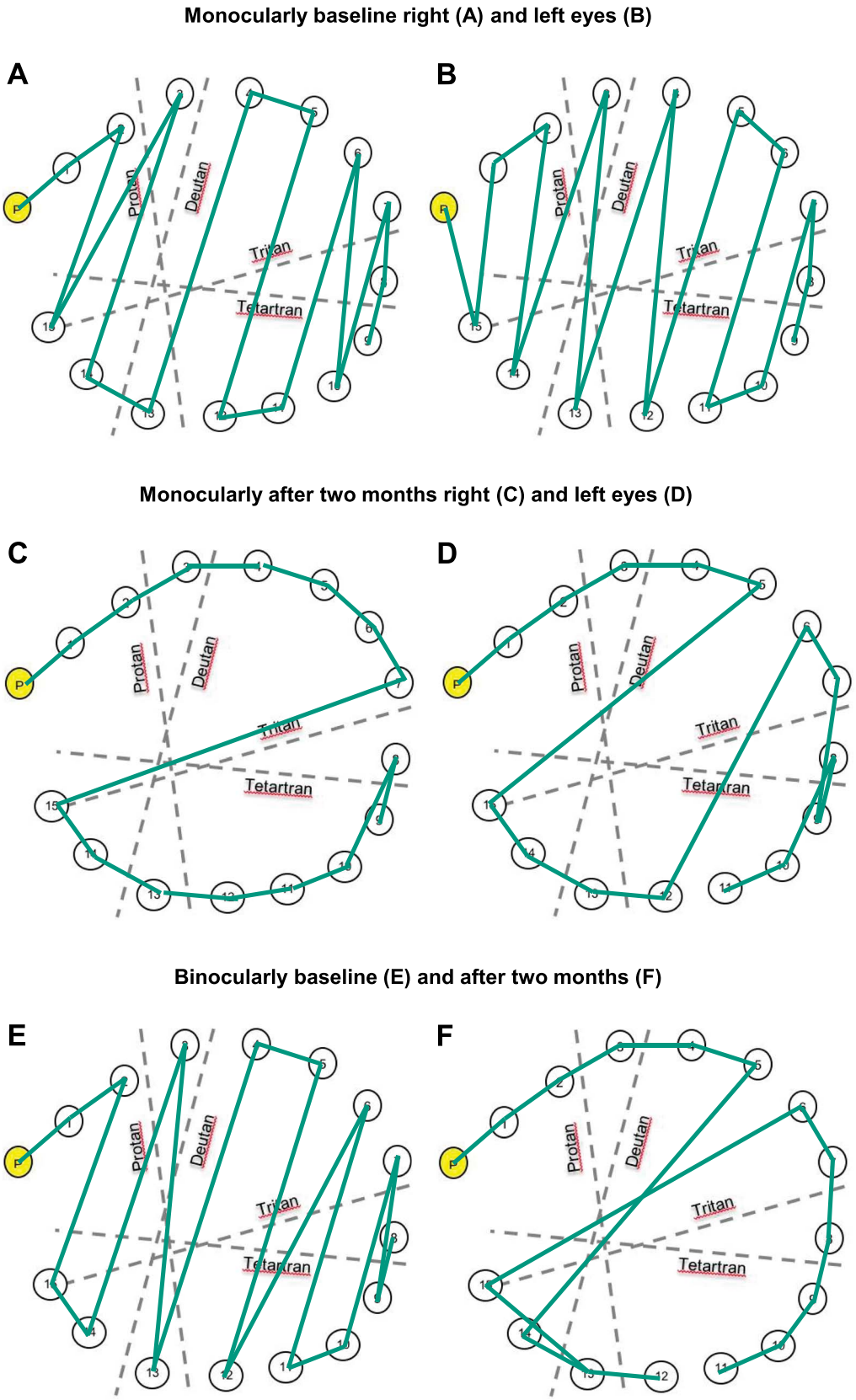

FIGURE 5. Farnsworth D-15 graphs for both eyes. Right eye (A) and left eye (B) at baseline. Right eye (C) and left eye (D) after 2 months of using ChromaGen lenses. Binocular effect at baseline (E) and after 2 months of using ChromaGen lenses (F).

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eyes, it would be interesting to evaluate the effect of applying two filters with a similar band cutoff pattern in the performance of different color vision tests and subjective visual outcomes experienced in subjects with color vision deficiency using these haploscopic aids.

CONCLUSIONS

In conclusion, this report describes an improvement in the ability to interpret colors after using asymmetric ChromaGen filter glasses that also introduce a left-eye decrease in visual acuity and contrast sensitivity but with no binocular alteration. The ChromaGen filters tested in this case report selectively minimize the transmittance within a specific bandwidth to improve the color discrimination in deutan defect. Knowing the subjective changes described by the patient, we recommend the ChromaGen filters to him for part-time use. The simultaneous analysis of the color vision outcomes and transmittance spectrum of the haploscopic filters might contribute to a better understanding of the mechanisms behind the claimed efficacy of these devices.

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