Research Article

Are X-Chrome Lenses An Occupational Succor for the Colour Vision Defectives?

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Abstract

Purpose: To understand total visual experience of a colour vision defective, this study evaluated responses with X-Chrome lenses on three most prevalent colour vision testing techniques.

Methods: The colour vision responses were assessed at baseline and after wearing X-Chrom lenses on Ishihara's plates, Edridge Green Lantern and anomaloscope of 51 defective males in the age range of 13-41 years in a non-randomized intervention study.

Results: While red and orange lenses gave better results on Ishihara's plates in terms of SS increase in mean number of plates read (p=0.03) and on anomaloscope by shift of Aq values towards normal range (not SS, p=0.44) but green lenses increased mean number of colours seen on Edridge Green Lantern (p=0.03).

Conclusions: The red and orange lenses absorb shorter wavelengths of light facilitating red-green blinds to improve on techniques testing red/green defect i.e. Ishihara's and anomaloscope. However, green lenses may have improved hue discrimination on Edridge Green Lantern.

Keywords: X Chrom lens, Colour vision defectives, Colour vision defect- treatment, Ishihara's plates, Edridge Green Lantern, Anomaloscope, Absorption spectrum of X Chrom lens

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Introduction

The accurate colour vision is required for performing day to day activities with perfection. However the colour vision deficiency is common among general population and the reported prevalence of colour vision defects is about 8% in males and 0.4% in females.[1,2] An accurate colour vision is extremely vital for people working in occupations such as pilots, industrial workers seamen, signal men and doctors. It is therefore mandatory to do colour vision assessment before appointing the candidates to various posts in government and other organisation after colour vision assessment. Colour vision deficiency is mostly inherited (having X-linked recessive inheritance) but it may also be acquired i.e. due to diseases like diabetes, glaucoma, macular degeneration and retinitis pigmentosa; excessive use of therapeutic drugs like barbiturates, digoxin, chloroquine, ethambutol and phenytoin; or intracranial injury. Though the colour vision defect created by inheritance is irreversible but acquired colour vision defect is reversible to some extent.

The colour vision is generally tested by using Ishihara's Pseudoisochromatic Plates. Presently Ishihara's Pseudoisochromatic Plates and Edridge's Green Lantern are two techniques incorporated in Gazette of India for conducting medical examination of candidates before recruitment into government services related to different professions.[3,4] However, anomaloscopeis considered to be the most accurate tool to test and classify colour blindness and is considered gold standard.

It was stated by Farnsworth that "the basic colour mixture ratios and other stimulus data by which normal or defective colour vision is described are unaffected by medicine, training or other therapy."[5] In other words colour deficiency is incurable. Although this may be true, it is possible to alter the colour appreciation of a colour defective even though one cannot provide normal colour perception. A variety of methods have been proposed for altering the colour perception of colour defective.[6,7] The idea of using filters as aids was initially proposed by Seebeck[8] and has since that time received a great deal of interest with reports of new devices as recently as Kernell (1974).[9]

X-Chrome lens is a corneal contact lens which corrects colour deficiency when applied to one eye only.[10] X-Chrom lens is a broad band filter in the form of a contact lens that is worn in one eye and used in a binocular viewing situation. The aim of this study was to see if X-Chrom lenses improve test scores and evaluate the results with use of three colour vision testing techniques.

Material and Methods

A total of 51 colour vision defective (CVD) male subjects, within age range of 13-41 years, attending the outpatient department of Ophthalmology, Guru Nanak Eye Centre, New Delhi, were included in this non-randomized intervention study without control. From the previous clinical experience it is found that the success rate of X- Chrom lens is 75%.[11]Taking the success rate of 60% to 90% means, 15% absolute error with 95% confidence level, the sample size came out to be 33 using Epi info software package of CDC Atlanta & WHO. So, 51 colour deficient subjects were taken for this study.

Only subjects having best corrected visual acuity of 6/6 separately in each eye were included in this study. The subjects having contraindication to wear contact lenses e.g. dry eyes, lid defects, mebomian gland dysfunction etc. and subjects having glaucoma and diabetes were excluded from the study.

A detailed history was elicited for education qualification, occupation, systemic/ocular disease or positive history of drug intake which could affect colour vision status and any positive family history for colour vision defect.

Ocular examination included record of distance visual acuity and near visual acuity. The subjects who did not have 6/6 distance vision in both eyes (separately) were subjected to proper refraction to acquire best corrected distance visual acuity (BCVA) of 6/6 in both eyes (separately) and best corrected near visual acuity of N6 in both eyes separately. A detailed ocular examination was done to rule out any significant anterior or posterior segment abnormality. The intraocular pressure measurement was done with applanation tonometry.

The subjects were examined with use of Ishihara's charts, Edridge Green Lantern and Neitz Anomaloscope. Pre-test (i.e. before application of X-chrome contact lenses) the test was done for each eye separately, while wearing full refractive correction and in proper lighting conditions. Though routine screening in schools and at other places is binocular but as eye diseases may affect each eye differently thus monocular testing was used. The subjects were explained all the three procedures and it was made sure that they understood the test. The subjects were not allowed to wear "tinted" contact lenses or "tinted" glasses during pre-test examination.

The 38th edition (2012) of Ishihara's plates was used. The Ishihara's plates were shown to subjects at 30 cm distance for 4 seconds in a room which was lit adequately by daylight. All the subjects were tested on 25 plates. These 25 plates include all types- Introduction (1), screening or transformation (2-9), vanishing (10-17), hidden (18-25) and those used to classify red-green blindness (22-25).

For Edridge's green lantern, a combination of colours (dark red, red, yellow, green, signal green, blue, purple and white) was shown through aperture 13 mm which is the largest size aperture (and is incorporated in Gazette of India) in "disc 1" to a subject in dark room at distance of 6 m. The subjects were asked to identify various colours. A record was be made for colours identified/not identified through these apertures. According to the colours used in lantern, eight groups were formed - "DR", "R", "Y", "G", "SG," "B", "P" and "W." A record was also be made of colours "identified" and colours "not identified."

NeitzAnomaloscope OT II having red wavelength of 670 nm, yellow wavelength of 588 nm and green wavelength of 545 nm was used for this study. Standardized procedures and conditions were used for anomaloscope test administration. The level and type of illumination was kept constant. Initially Linksz (1964)[12] procedure was used. The subject was asked to adjust the yellow test knob to obtain a luminance match. The yellow scale value evaluates relative luminosity losses of colour defective subjects. In red-colour blindness, the green colour shades look much brighter than red ones. The three parameters noted for subjects include the matching range (number of match points), the match midpoint (Aq) and the length of personal matching line.[13]The match range is defined as the obtained range of settings under neutral adaptation. The match midpoints are converted into anomalous quotients (Aq) or comparative scores and these appear on screen of anomaloscope. The length of personal matching line was graded to find severity of red-green blindness.

The contrast sensitivity was assessed using Functional Acuity Contrast Testing (F.A.C.T) chart. The subjects were made to read five rows (A, B, C, D, E) of nine grating patches. Thus the higher the score for a particular row, the better is the contrast sensitivity.

For using X-Chrom lenses, initially the dominant eye was found out. The dominant eye of subjects was found by dominant eye test.[14]

Following this, the subjects were given trial X-Chrom lenses of red, green, orange and yellow type to wear in non-dominant eye, as is done conventionally[10,15] while other eye was left uncovered.

The subjects were made to read Ishihara's plates binocularly, recognise colours through Edridge Green Lantern binocularly and see through anomaloscopetwo fields in a telescopic view with eye wearing X-Chrom lens while other eye was open.[11,16] The parameters which were evaluated included visual acuity, colour vision perception and contrast sensitivity before and after wearing X-Chrom lenses. The visual acuity was tested using Snellen's chart, the contrast sensitivity was assessed using Functional Acuity Contrast Testing (F.A.C.T) chart and the colour vision perception was tested using above three colour vision testing techniques.

The results were recorded in tabular form and compared for statistical analysis for change in colour perception in colour vision deficient subjects with use of X-Chrom lenses. Additionally change in visual acuity and contrast sensitivity was also found.

Results

A total of 51 colour vision defective (CVD) male subjects, attending the out-patient department of Guru Nanak Eye Centre, New Delhi, were included in this study. The subjects were educated and worked in occupations like civil services, medicine, office work and included students. None of the subjects had any systemic/ocular disease which is known to affect colour vision status or had any positive history for any drug intake. None of the subjects had any anterior segment or posterior segment abnormality or a positive family history of colour vision defect.

The maximum number of subjects fell within age group of 21-30 years (30 subjects) followed by 13-20 years (14 subjects); 31-40 years (6 subjects); 41 years (1 subject); and the mean age of all subjects was 24.45 ±5.63 years.

All the subjects had distance best corrected visual acuity of 6/6 in each eye separately and near best corrected visual acuity of N6 in each eye separately. The mean correction required for right eye was -0.24 ± 0.54D and for left eye was -0.16 ± 0.54D.

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The range of intraocular pressure in right eye was 12-20 mmHg (mean was 15.83 ± 3.05 mmHg) and in left eye was 12-20 mmHg (mean was 15.19±1.89 mmHg).

On analysis with Ishihara's charts, out of 25 plates, these 51 colour vision defective could read Ishihara's plates and the mean number of plates "read" in right eye were 4.55 ± 4.27 (range being 1-19 plates) and in left eye were 5.0 ± 5.15 (range being 1-25). Pretest 48 subjects had lower grade perception (could read ≤ 13 plates) and 3 subjects had higher grade perception (could read ≥ 17 plates). None had middle grade of perception (could read 14-16 plates). While using plates 22-25 during pre-test, under pretest conditions - 28 subjects were green blind, 8 were red blind and 15 could not be diagnosed for type of defect. With use of Edridge Green Lantern, the range for number of colours "seen correctly" by colour vision defectives in both eyes varied from 0 to 8 and pretest mean was 4.27 ± 1.57 for right eye and 4.31 ± 1.47 left eye. The range for number of colours "not seen correctly" by for both eyes varied from 0 to 8 and pretest mean was 3.73 ±1.57 for right eye and 3.69 ± 1.47 for left eye.

With the use of anomaloscope, different types of match patterns were seen as given below and both eyes gave identical results.

Table 1 showing distribution of right and left eyes with respect to number of points matched and consequent Aq values of subjects which are obtained from match mid-point

R/G mixture with yellow luminance	Right eye	Aq values (Right eye)	Left eye	Aq values (Left eye)
No match	2	Nil	2	Nil
All points	33	0- infinity	33	0-infinity
1-7 point match	16	0-5.81	16	0-5.25

2 subjects did not match the R/G mixture with varying yellow luminance in both eyes thus though being colour vision defective but they could not be classified into any type of colour vision defect. A total of 33 subjects matched the R/G mixture with varying yellow luminance at all points, thus they had full blown colour vision defect i.e. anopia and Aq value (Anomalous quotient value) ranged till infinity. A total of 16 subjects matched the R/G mixture with varying yellow luminance at points which may be 1 to 7 points.

On anomaloscope, both eyes had same type of colour vision defect. For type of colour vision defect, in both eyes, the number of subjects having unclassified colour vision defect were 3 (no match obtained, no Aq value); having deutranopia were 27; having deuteranomaly were 5; having protanopia were 16; and having protanomaly were 0. The subjects who had "anopia" were those who matched at all points and type of colour vision defect (red or green) was calculated from shape of graph line as protanopes set the yellow control to higher numbers (35 to 40) at the green end (zero) of the mixture scale and low numbers (0 to 5) at red end (near 73); and deuteranopes make minimal adjustment with yellow knob on the anomaloscope leaving it near setting made by normal observer (i.e. around 15) for all red-green mixtures matched at low yellow luminance values throughout the R-G scale i.e. from 0 to 73. It is known that those having "anomaly" match at more than one point but they do not match at extremes of anomaloscope (unlike anopic patients) and their Aq values lie outside normal range (of 0.7 to 1.4). The Aq values decide type of colour vision defect.

In both eyes**,** the number of subjects having no personal matching line were 2 (no match obtained, no Aq value); number of subjects having personal matching line of 73 scale length units were 33 (matched all points); and number of subjects having personal matching line of intermediate length were 16 (matched at points ranging from 1-7). Out of these 16 subjects, all subjects had some Aq values and their personal matching lines ranged from 0 to 60 scale units. Taking range from 0-73 scale units, the mean values in right eye were 58.00 ±25.49 scale units and in left eye were 58.47 ± 24.30 scale units.

After application of X-Chrom lenses, the subjects experienced either no change or only minor changes (i.e. from 6/6 to 6/6 P or from 6/6 to 6/9) after use of lenses. There was no SS difference between changes induced by different coloured X -Chrome lenses.

The X-Chrome lenses are conventionally used unilaterally on non-dominant eye and responses are assessed binocularly after wearing X- Chrome contact lenses in one eye. Thus to compare the post-test bilateral response with pre-test responses which are different in two eyes, the pre-test response of two eyes "was averaged" and then compared with post-test binocular response in order to see if there is any change/improvement.

There was a statistically significant difference (p= 0.03) between mean number of plates read before and after wearing X-Chrome lenses. This suggests that colour discrimination definitely improves with use of these lenses. The best results were obtained with Red X-Chorme lens followed by orange, yellow and green lenses (ROYG). While improvement in number of plates or numerals was seen in 22-25 plates with use of X-Chrome lenses, it was seen that 16%, 40%, 76% and 20% showed an improvement with green, orange, red and yellow lenses. Thus best results were seen with red followed by orange, yellow and green lenses (ROYG). Posttest subjects who could read ≤ 13 plates were 44, 33, 9 and 42; subjects who could read 14-16 plates were 2, 6, 8 and 2; and subjects who could read ≥ 17 plates were 5, 12, 34 and 7 with green, orange, red and yellow lens respectively. Thus maximum improvement was seen with red followed by orange, yellow and green lens in decreasing order (ROYG).

On Edgridge Green Lantern, it is visible that though the range of colours seen posttest reduced from pretest range (0-8) but there was an increase in mean number of colours seen posttest as many subjects could recognize more number of colours than pretest. There was a SS increase (p=0.03) in "mean" number of colours seen posttest with green lenses only, thus best result was seen with green lenses, these were followed by orange, yellow and red lenses respectively (GOYR). However, if total number of subjects showing improvement were counted, the best improvement was seen with orange followed equally by green and yellow and then with red lenses (OG=YR).

On anomaloscope, there was no SS difference (p=0.44) between mean pretest and mean posttest values of Aq with use of lenses. However the shift towards normal range (0.7-1.4) was seen in red lenses followed by green, yellow and orange lens (RGYO). By altering the colour perception it was seen that all the lenses shifted Aq values above 1.4 i.e. towards green blindness.

While 32 patients were green blind and 16 subjects were red blind pretest, only 7, 11, 4 and 16 subjects remained green blind posttest and 13, 3, 10 and 7 remained red blind posttest, but on the other hand, when both remaining categories were considered i.e. patients having no match (Nil) or no definite Aq value (as number of matches were more), it was found that this number increased from 3 subjects pretest to 31, 37, 36 and 28 subjects posttest with use of green, orange, red and yellow X-Chrome lenses.

Pretest, 2 subjects had no personal matching line, 31 subjects had personal matching line of 73 scale units and 18 subjects had personal matching line of length varying between 5-66.5 scale units and this is being called intermediate group. After wearing X-Chrome lenses this number altered to 6, 32, 13 (0-63 scale units) with green lens; 6, 30 and 15 (0 to 63 scale units) with orange lens; 10, 7 and 34 (0 to 63 scale units) with red lens and 7, 30 and 14 (0 to 60 scale units) with yellow lens. The last group i.e. intermediate group had some Aq value. As is visible SS decrease in length of personal matching line was seen with red lens. The red lens gave best results (largest decrease in length of personal matching line) followed by yellow, green and last of all orange (RYGO).

There was no significant difference between contrast sensitivity scores for all 5 different rows posttest with use of any of the X-Chrome lens as compared to pretest values. Whether the factual CS scores would increase or decrease posttest from pretest values, even this pattern was also not fixed.

Discussion

In this study, 51 colour vision defectives in the age range of 13-41 years were tested for alteration in colour perception after using four different types of X-Chrome lenses i.e. green, orange, red and yellow. We have evaluated effect of X-Chrome lenses with use of three testing techniques – Ishihara's Plates, Edridge Green Lantern and Anomaloscope. To the best of our knowledge this is the first Indian study of its kind.

Matsumoto et al[17]and Kassar et al (16 subjects)[18] found that test scores improved in all subjects on Ishihara's. Ditmar and Keener[19] found an overall improvement of 61% on Dvorine plates, 50% improvement on Hardy-Rand-Ritter plates and 35% improvement on AO pseudoisochromatic plates. In our study, there was a SS increase in mean number of plates read posttest as compared to pretest scores. The grades of perception also improved after wearing X-Chrome lenses.

As for Edridge Green Lantern, the workers have attributed this lack of improvement to the fact that hue discrimination is required for success on this test, which hue discrimination is not improved by X-Chrome lenses. La Bissoniere[20] also found that X-Chrome lens seemed to diminish the total number of shades that a colour vision defective could correctly identify. He found that after using X-Chrome lenses on deuteranomalous subjects for 50 hours, the score was not improved on Holmgren wool test or Farnsworth-Munsel 100 Hue test. Rather an increase of about 50% in total error score was there. Thus deuteranomaly was seen to worsen with X-Chrome lens. Posttest, none of our subjects could recognize all 8 colours correctly, which implied that X-Chrome lenses induced an alteration in perception of colours but these could not be perceived in same way as these appear to a normal person thus could not be named correctly by colour defectives to increase the total test scores.

On anomaloscope, there was no SS difference between mean pretest and mean posttest Aq values with use of lenses. However the shift towards normal range of Aq values (i.e. 0.7-1.4) was seen in red lenses followed by green, yellow and orange lens (RGYO) in decreasing order. By altering the colour perception it was seen that all the lenses shifted Aq values above 1.4 i.e. towards green blindness. Similar finding was reported by Matsumoto et al,[17] who found that there was a tendency for the mean settings of all 4 subjects but one (who was a protanope) to be shifted towards green (more scale readings) during lens wear. They found that subjects generate their own isoluminant stimuli in two portions of test display. Siegel,[15] who worked with red lenses, stated that green is greatly absorbed in red lens as less of middle wavelengths (of spectrum VIBGYOR) were transmitted through it. We feel that due to alteration in shades of perceived colours through anomaloscope, the colour vision defectives improve their scores by matching brightness[6] and not the actual colour. It may also be that red X-Chrome lenses enhance red wavelength and green X-Chrome lenses enhance green wavelength and orange may be enhancing the wavelengths of light which lie neighboring to red wavelength and yellow lenses may be enhancing wavelengths of light which lie neighbouring to green wavelength if position of wavelengths in spectrum are seen (VIBGYOR), thus the test scores of subjects on anomaloscope may have improved.[11,21]

Conclusion

The X-Chrome lenses do not affect visual acuity or contrast sensitivity of subjects wearing these. The red and orange lenses absorb shorter wavelengths of light facilitating red-green blinds to improve on techniques testing red/green defect i.e. Ishihara's and anomaloscope. However, green lenses may have improved hue discrimination on Edridge Green Lantern. Thus these X Chrome lenses appear to be complimentary to one another and different lenses may improve performance in different situations.

Conflict of Interest: None

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