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Comparative Analysis of Tinted X-Chrome Contact Lenses and Red Filters on Color Vision Impairment

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ABSTRACT

Accurate color vision is necessary for doing daily tasks efficiently. Even so, numerous individuals experience color vision impairment. **Objective:** To evaluate and compare the effect of x-chrome contact lenses (CLs) and red filters on color vision deficient. **Methods:** Cross-sectional study was conducted at Madinah Teaching Hospital, Faisalabad. Data were collected by non-probability purposive sampling technique. Congenital color blindness, 15-35 years, red-green deficient were included. Acquired color blindness, active ocular diseases, systemic diseases were excluded. 30 red-green color vision deficient, divided in 2 groups, 15 used CLs and 15 used RF. Visual acuity, contrast sensitivity, stereopsis and color vision were recorded at baseline and after wearing lenses. Data were analyzed by using SPSS version 23.0. **Results:** Mean age was 24.53 ± 6.68. After using x-chrome CL, mean number of correctly read plates increased to 22.55 ± 1.27 from the baseline evaluation of 1 ± 1.679 (p=0.00). Comparably, baseline performance was 1 ± 1.89 plates successfully read; using red filters, that number increased to 22.89 ± 1.03 (p =0.00). With red filters, the mean contrast sensitivity decreased from 1.35 ± 0.32 to 1.31 ± 0.56 (p = 0.004), and with x-chrome lenses, it decreased from 1.34 ± 0.45 to 1.32 ± 0.97 (p = 0.02). Mean stereopsis value was 55.33 ± 13.02 prior to x-chrome contact lens insertion; this value decreases to 67.33 ± 12.47 (p = 0.00). Likewise, mean stereopsis value was 54.02 ± 11.05 before to applying red filters, it decreases significantly to 66.89 ± 11.98 (p = 0.00). **Conclusions:** X-Chrome CLs and red filter has significantly improved color vision. Visual acuity remains unchanged. Contrast sensitivity and stereopsis showed slight reduction in both groups.

INTRODUCTION

A condition affecting the eyes that makes it difficult to see and differentiate between certain hues is called color vision insufficiency (CVD) [1]. Although complete color blindness where only grayscale vision is possible is exceedingly rare, the phrase "color blindness" is frequently used to describe CVD. This may be an acquired or congenital disorder [2]. Color Vision Deficiency (CVD) is a common congenital defect, more common in males [3,4]. People sometimes don't become aware of their color vision deficiency until they are subjected to pre-employment exams, or even later, when they are subjected to routine health screenings [5, 6]. Such delayed diagnoses can cause psychological strain and have a direct impact on livelihoods, which makes them very upsetting. As a result, CVD can seriously limit employment prospects and have an impact on mental health [7, 8]. To effectively carry out daily duties precisely, one needs accurate color vision [9]. It is especially significant for professionals in the medical field, industrial workers, pilots, sailors, and signalmen. Therefore, before assigning individuals to various roles in both government and private companies, color vision evaluations must be performed [10, 11]. The main cause of color vision impairment is genetics, most commonly x-linked recessive inheritance, but it can also develop as a result of diseases such retinitis pigmentosa, diabetes, glaucoma, and macular degeneration [12-18]. Medical professionals can use a variety of instruments to evaluate CVD in clinical settings. Of them, the Ishihara plates test is particularly noteworthy [19]. No cure currently exists for any type of CVD, though efforts to enhance color vision

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have been made. One method is to use tinted x-chrome contact lenses, and another is to utilize red filters [20, 21]. The X-chromosome's spatial frequency is used to build tinted x-chrome contact lenses that are used to treat defects in red-green color vision [22, 23]. When worn in only one eye, the x-chrome lens is a corneal contact lens that corrects color deficiencies. It is employed in binocular viewing scenarios and functions as a broad-band filter. It is a color-coded contact lens, worn monocular in the non-dominant eye. The lens is red in center and transparent in peripheral. The principle is to create what is referred to as retinal rivalry, which results in the brain being able to better distinguish between shades of colors [23, 24]. Through the process of retinal rivalry, information from each eye is alternated such that a new perception of color discrimination is observed by an individual. Red filters have been suggested as a therapy strategy for people who are color deficient. These filters absorb other colors and preferentially transmit red wavelengths, which may improve color perception in a scene, provide it a warmer tone, and create contrast between various colors [25, 26]. The study's objectives were to evaluate and compare the effects of red filters and x-chrome contact lenses on patients who also had a red-green color vision defect in terms of their visual function (visual acuity, contrast sensitivity, and color vision). The purpose of this study is to determine the most effective modality for patients with CVD to enhance their visual functions.

METHODS

A cross sectional study design was conducted at Madinah Teaching Hospital, Faisalabad. The duration of study was from January 2024 to April 2024. IRB approval letter number is TUF/IRB/265/23 given by ethical institutional review board of The University of Faisalabad on 26 December 2023. 30 participants were included in the study's sample, which was calculated using Rao software. These individuals divided in two groups 15 individuals in each group, group 1 used x-chrome contact lenses while group 2 used red filters. Non probability purposive sampling technique was used in this study. Inclusion criteria for this study were aged 15-35 years, both genders, emmetropes, congenital color blindness, red-green deficient. Exclusion criteria was acquired color blindness, refractive errors, patient with dry eye, contact lens user, active ocular disease, systemic disease (diabetes, multiple sclerosis, alzheimer's disease and parkinson's disease), optic nerve disorders, glaucoma and macular degeneration. LogMAR chart was employed to evaluate visual acuity and the Titmus Fly Test was utilized to test stereopsis. The Pelli-Robson Chart was utilized to ascertain the contrast sensitivity. Ishihara Plates was used for the assessment of red-green color vision defiency. X-Chrome contact lenses were worn by subjects in group 1 who had a red-green color vision deficit, while red filters were used by subjects in group 2. For the collection of data, a self-structured proforma was used to investigate visual acuity, color vision, contrast sensitivity and stereopsis. Verbal consent was taken from the patients, when patients were agreed then written consent was also taken from the patients and detailed history was taken. After obtaining the subject's informed consent, the data were collected. The objective of the research was also discussed to the subject. A comprehensive eye examination using a slit lamp was performed in an attempt to recruit patients. Using a non-probability purposive sampling technique, thirty patients with color vision impairments have been selected for this study and split into two groups. Fifteen patients in group 1 used x-chrome contact lenses, and fifteen patients in group 2 wore red filters. After that, baseline pre-screening records of visual function tests were completed for both groups. These tests included visual acuity, contrast sensitivity, the Titmus fly test, and the Ishihara testing for color vision evaluation. Patients then had the intervention (red filter and x-chrome contact lenses) on for six hours, during which time visual function tests were performed afterward to analyze the post-intervention data for both groups. Patients wear x-chrome contact lenses and red filters monocularly. To determine whether using red filters or x-chrome CLs may improve color discrimination, the same color vision test (ishihara testing) from the pre-screening were performed yet again. Any modifications to visual acuity brought about by the filters or lenses were measured. X-Chrome CLs and red filters were used, and their possible effects on stereopsis were assessed in light of how they may affect color perception. On a scale of 0 to 10, patients in both groups were asked to rate how satisfied they were with the intervention either the red filter or the x-chrome contact lenses. The minimal degree of satisfaction or dissatisfaction with the intervention was represented by a score of 0, and the highest level of satisfaction was indicated by a score of 10. Descriptive statistics was used to analysed age distribution, gender distribution, occupation, family history and color vision interpretation. Paired t-test was used to analyse contrast sensitivity and stereopsis with and without both interventions. The contrast sensitivity and stereopsis of both groups were compared using an independent t-test to determine which modality red filters or x-chrome contact lenses.

RESULTS

Descriptive statistics analysis was used to investigate the age distribution; the selected age range was 15-35 years. Total number of color vision deficient subjects was 30. In this study 15 was the minimum age while 35 was maximum age. The mean of the age distribution was 24.53 ± 6.68. Descriptive statistics analysis was used to investigate the gender distribution among 30 subjects. The gender

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distribution reveals that there were 20 males (66.7%) and 10 females (33.3%). Frequency distribution showed that 4 (13.33%) patients had no family history on record, while 26 participants (86.66%) had a family history of color vision impairment. A descriptive statistical analysis of the 30 individuals' occupations indicated that 14 were students, 12 were office workers (including teachers and administrative staff), and 4 were factory workers (Table 1).

Table 1: Demographic Variable Analysis

Variables	Frequency (%)
Age Distribution (n=30)	
Age (Mean ± SD)	24.53 ± 6.68
Gender Distribution N (%)	
Male	20 (66.66%)
Female	10 (33.33%)
Family History of Color Vision Impairment N (%)	
No	26 (86.66%)
Yes	4 (13.33%)
Occupation N (%)	
Others (Students)	14 (46.67)
Office Worker (Teachers, Administrative Staff)	12 (40 %)
Factory Worker	4 (13.33 %)

Ishihara's plates were used for assessment of color vision deficiency. A paired t-test analysis for Group 1 demonstrated that the mean number of correctly read plates at baseline was 1 ± 1.67, which significantly increased to 22.55 ± 1.27 with the use of x-chrome contact lenses (p = 0.00). Similarly, the red filter group's mean number of correctly read plates at baseline was 1 ± 1.89, but after applying the red filters, that number increased significantly to 22.89 ± 1.03 (p = 0.00). These results show that wearing red filters and x-chrome contact lenses improved color vision in both groups. There was no reduction in binocular visual acuity with x-chrome contact lens and red filter remains same in all CVD patients. Contrast sensitivity was examined using a paired t-test both with and without intervention (x-chrome and red filters). The outcomes demonstrated that both therapies significantly reduced contrast sensitivity. The mean contrast sensitivity dropped (p = 0.004) for the red filter intervention, going from 1.35 ± 0.32 to 1.31 ± 0.56. Comparably, the mean contrast sensitivity for the x-chrome intervention dropped from 1.34 ± 0.45 to 1.32 ± 0.97 (p = 0.02). This suggests that contrast sensitivity is greatly decreased by both x-chrome and red filters. Titmus fly test was used for assessment of stereopsis. The results of the analysis indicate that there were differences in the stereopsis. Prior to the x-chrome contact lens insertion, Group 1's mean value was 55.33 ± 13.02. Following insertion, the average values were 67.33 ± 12.47, with a p-value of 0.00. Likewise, prior to employing red filters, Group 2's mean value was 54.02 ± 11.05. Following the application of red filters, the mean values were 66.89 ± 11.98, with a p-value 0.00. The mean stereopsis values decreased after both therapies in comparison to the baseline. Significant results were found using paired t-tests, suggesting that both x-chrome contact lenses and red filters reduce stereopsis (Table 2).

Table 2: Comparisons of Color Vision, Contrast Sensitivity, Stereopsis With and Without Contact Lenses and Red Fillers

Groups	Group 1 (X-Chrome CL) (Mean ± SD)			Group 2 (Red Filters) (Mean ± SD)		
Intervention	Baseline	With X-Chrome CL	p-value	Baseline	With RF	p-value
Color Vision Assessment	1 ± 1.67	22.55 ± 1.27	0.00	1 ± 1.89	22.89 ± 1.03	0.00
Contrast Sensitivity	1.34 ± 0.45	1.32 ± 0.97	0.02	1.35 ± 0.32	1.31 ± 0.56	0.004
Stereopsis	55.33 ± 13.03	67.33 ± 12.47	0.00	54.02 ± 11.05	66.89 ± 11.98	0.00

X-Chrome contact lenses and red filters were compared for efficacy using the Ishihara test with an independent t-test. Both treatments help patients distinguish between colors and improve their perception of color, according to the highly non-significant results (0.71). An independent t-test was conducted to compare the contrast sensitivity for group 1 (X-chrome contact lens) and group 2 (red filter). There was no significant difference p=0.61 in the score. Mean value for group 1 mean=1.32 ± 0.97 for group 2 mean=1.31 ± 0.56. Contrast sensitivity was reduced after use of CLs and red filter. An independent t test was conducted to compare the steropsis for group 1 (X-chrome contact lens) and group 2 (red filter). There was no significant difference p=0.98 in the score. Mean value for group 1 mean= 67.33 ± 12.47 for group 2 mean= 66.89 ± 11.98. Contrast sensitivity was reduced after use of CLs and red filter (Table 3).

Table 3: Comparative Analysis of Color Vision, Contrast Sensitivity, Stereopsis Both Groups

Variable	Group 1 (X-chrome CL) Mean ± SD	Group 2 (Red Filters) Mean ± SD	p-value
Color Vision Assessment	22.55 ± 1.27	22.89 ± 1.03	0.71
Contrast Sensitivity	1.32 ± 0.97	1.31 ± 0.56	0.61
Stereopsis	67.33 ± 12.47	66.89 ± 11.98	0.98

Following the evaluation of the mean number of correctly read plates by patients in the two groups, the number of subjects was also assessed according to pass/fail responses. However, all subjects passed the Ishihara test monocularly when red filters and x-chrome contact lenses were placed in the non-dominant eye. However, 2 patients in group 1 using x-chrome lenses and 3 subjects in group 2 using red filters failed the test binocularly. If a CVD subject answers "pass," it means they properly identified the Ishihara plate; if they answer "fail," it means they either didn't identify the plate at all or identified it wrongly, classifying them as either protanopia or deuteranopia. The color vision of CVD individuals was analyzed using descriptive statistics both before and after they wore x-chrome contact lenses and red filters (Table 4).

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Table 4: Color Vision Assessment of Both Groups

Number of Subjects	Group 1 (With X-Chrome Contact Lens)		Group 2 (With Red Filters)	
Interpretation	Pass	Fail	Pass	Fail
Monocular	15	0	15	0
Binocular	13	2	12	3

Both the red filter users and the x-chrome contact lens users were asked to rate their level of satisfaction on a 0–10 scale after the evaluation. A score of 0 represented the least amount of satisfaction or dissatisfaction while a score of 10 represented the highest level of contentment. A mean satisfaction score of 7.01 with a standard deviation of 1.01 was recorded by users of x-chrome contact lenses, while a mean satisfaction score of 5.7 with a standard deviation of 1.32 was reported by users with red filters (Table 5).

Table 5: Level of Satisfaction

Level of Satisfaction	Group 1 (Mean ± SD)	Group 2 (Mean ± SD)
	7.01 ± 1.01	5.7 ± 1.32

DISCUSSION

Almutairi N *et al.*, conducted study in which red filter significantly improved color discrimination, particularly the deutan subjects. Improved subjects improved from severe deutan to mild deutan in all deutan subjects and from severe protan to mild deutan in one subject when tested with ColorDx with mean value of 34.9 ± 2.5 and 50 ± 9.34 and p=0.006, respectively, Red filter was a highly clinically significant in improvement of color perception of CVD subjects while in addition performance with red filter was significantly better compared to enchroma 34.9 ± 2.5 and 49.6 ± 7.8 p=0.004, respectively and green filter 34.9 ± 2.5 and 51.0 ± 8.8 p =0.003 respectively [27]. Current study concluded that in a comparable manner, the mean number of plates correctly read at baseline with red filters was 1 ± 1.89; after putting red filters, the number ascended to 22.89 ± 1.03. These results show that wearing red filters improved color vision. Both studies concluded that wearing red filter improve the color vision of CVD subjects (Red-Green Deficient) so both studies correlate with each other by showing significant improvement in color vision. Sodhi PK *et al.*, conducted in which the mean number of "TES/plates not read" was 8.23 ± 6.04 and following use of red-tinted lenses, the TES reduced to 6.16 ± 6.27 the mean reduction in errors was 2.11 ± 4.54 (P value = 0.001). In category 22-25 plates, the mean number of TES/plates not read was 1.58 ± 1.67 and following the use of red-tinted lenses, this reduced to 1.14 ± 1.53 the mean reduction in errors was 0.47 ± 1.05 (p=0.001) which showed significant improvement in color vision deficient subjects [28]. Present study concluded Group 1, at baseline 1 ± 1.67 plates were correctly read on mean. This mean increased to 22.55 ± 1.27 with x-chrome contact lenses. These results show that wearing x-chrome contact lenses improved color vision, so both studies correlate and shown significant results. Brinda HS *et al.*, conducted study that 7 patients were having protanomaly while 3 were having deutranomaly. Mean value and standard deviation for the contrast sensitivity after wearing chrome lens was 0.07 and 0.057 respectively with p value = 0.010 shows that there was no significant change in contrast sensitivity with wearing a x-chrome contact lens [29]. Current study concluded that the mean contrast sensitivity dropped (p = 0.004) for the red filter intervention, going from 1.35 ± 0.32 to 1.31 ± 0.56. Comparably, the mean contrast sensitivity for the x-chrome intervention dropped from 1.34 ± 0.45 to 1.32 ± 0.97 (p = 0.02). Previous study showed that no significant change in contrast sensitivity after wearing x-chrome contact lens while current study revealed that there was reduction in contrast sensitivity after wearing x-chrome contact lens and red filter. Mutalib HA *et al.*, conducted study that showed that the mean value and standard deviation value of stereopsis at baseline was 2.62 ± 0.6. While after wearing type 1 light red contact lens the means value and standard deviation value increases to 5.10 ± 1.4 while wearing type 2 dark red contact lens the mean values and standard deviation increases to 5.76 ± 1.51 which shows reduction in stereopsis [30]. The current study showed that Prior to the x-chrome contact lens insertion, Group 1's mean value was 55.33 ± 13.02. Following insertion, the average values were 67.33 ± 12.47, with a p-value of 0.00. Likewise, prior to employing red filters, Group 2's mean value was 54.02 ± 11.05. Following the application of red filters, the mean values were 66.89 ± 11.98, with a 0.00 p-value. The mean stereopsis values decreased after both therapies in comparison to the baseline. Both studies concluded that stereopsis shows reduction after wearing contact lens and red filter. A significant gap in this research is the lack of subsequent assessments. More specifically, the impact of using red filters and contact lenses on participants' daily activities was not evaluated. A thorough understanding of the long-term efficacy and useful uses of these modalities is hampered by this lack of follow-up. In order to assess the long-term efficacy and practicality of red filters and x-chrome contact lenses in improving daily tasks and general visual function particularly color vision further research should examine follow-up assessments. The sample size in this study is limited, necessitating future research with a larger sample size to better understand the implications. Participants also differed in their preferences based on factors other than functioning. Beauty-obsessed people frequently selected x-chrome contact lenses. Red filters were preferred by those who found it difficult to adjust to these contact lenses but desired effectiveness despite the fact they weren't appealing either when worn on a single lens. Red filters and x-chrome contact lenses should be regarded as potential

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therapy choices for those with red-green color vision insufficiency, according to the study's findings. It has been demonstrated that these therapies enhance color perception and the capacity to differentiate between different color tones. Consequently, it is advised that people with color vision deficits use red filters or x-chrome contact lenses to improve their color vision, especially if they work in fields like fine art or graphic design where accurate color discrimination is necessary.

CONCLUSIONS

Red filters and x-chrome contact lenses have been demonstrated to improve color vision deficiencies in CVD patients when compared to baseline findings. The two treatment options showed promise in improving the individuals' color vision impairment associated with CVD. Both before and after wearing contact lenses and filters, visual acuity remains unaltered. On the other hand, using red filters with x-chrome contact lenses reduced contrast sensitivity and stereopsis.

Authors Contribution

Conceptualization: MJ
Methodology: AA, AM, MA
Formal analysis: NZ
Writing, review and editing: MJ, MF

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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