

Efficacy of Enchroma eyeglasses on chromatic discrimination in Thai congenital red-green deficiency

**Adjunct Professor Sakchai Vongkittirux,
Wiranut suddisa, Picha Thunpimon, Juraiporn Suntirumjairuk,
Pojcharapol Silpsamrit, Papavarin Sirikietsoong, Nutnicha Neti
Nonthapan Narong, Pinmada Makornwattana**

Department of Ophthalmology, Faculty of Medicine, Thammasat University, Thailand

Objective: To test the efficacy of Enchroma glasses for improving vision in Thai population with congenital green and red perception.

Methods: Diagnostic test study was conducted in an ophthalmology outpatient department, Thammasat University, Thailand, During 5 November 2019 - 16 December 2020

Results: All 60 participants are separated into Green, Red, and Green and Red type cases. 39 Green cases (65%), 15 Red cases (25%), and 6 Green and Red type cases (10%). The severity of the eyes' color perception is categorized into mild, moderate, and severe, with values 11.7%, 73.3%, 15.0% respectively. The Ishihara test (number of corrected reading) before and after wearing Enchroma glasses had a P value of 0.004. The Farnsworth test before and after wearing Enchroma glasses had a P value of 0.606. The severity of the color deficiency before and after wearing the Enchroma glasses had a P value of 0.597.

Conclusion: The Ishihara test results during which Enchroma glasses are worn revealed a higher score in comparison to when the glasses are not worn, with a P value of 0.004. However, in the Farnsworth test, there is no difference between before and after wearing the glasses with a P value of 0.606. There are also no significant differences found in the severity of the chromatic aberration when comparing before and after wearing the glasses, with a P value of 0.597.

Keywords: Enchroma, Color deficiency

EyeSEA 2021;16(1):62-68

DOI: <https://doi.org/10.36281/2021010206>

Introduction

Color vision deficiency is a common eye problem in the population. People with color deficiency cannot see colors like other people. This interferes with some work or certain types

of occupations. The quality of life affected by the color vision disorders depends on many factors. These include the type of color that the abnormality occurs and the severity of the condition. In cases of mild color deficiency, some people can still see colors, while in severe cases, only black and white may be seen. Color vision disorders are divided into two main groups: congenital color deficiency and acquired color deficiency, of which, the former is the most

Correspondence to:

Sakchai Vongkittirux, *Department of Ophthalmology, Faculty of Medicine, Thammasat University, Thailand.*

Email: vosakchai@gmail.com

Received : January 25, 2021

Accepted : February 2, 2021

Published : June 30, 2021

common form. Congenital color deficiency is more common in men than in women. Since the genes that control color vision are on the X chromosome, studies have found about 8 percent of males have color vision disorders while 0.5 percent¹ of females are affected. The congenital color deficiency can be divided into 3 subgroups, according to the types of cone photoreceptor (cone cell). A group of monochromatism with two types of cone cells (Dichromatism) may lack a red cone, which is called protanopia, or lack of a green cone, which is called deuteranopia, and those who lack blue cone cells are called this group tritanopia. This group uses the remaining 2-color cones to translate the results into different colors, the group with three types of cone cells (Trichromatism) sees the colors as normal people. However, if there are all 3 colors but one of them has a diminished capacity to respond to the red–green color system, it is called anomalous trichromatism. If the red cone is less than normal it may be called red depletion, it is called protanomalous, and people with less green cones. (Green depletion) is called deuteranomalous and people with less blue cones. (Blue depletion) is called tritanomalous. Protanomalous and deuteranomalous patients are more commonly found in the clinical setting. Congenital red-green color vision deficiency is the most common group in the population. Color vision deficiency can be diagnosed by testing with a kit for a color vision disorder such as the Ishihara test or the Farnsworth M100 test. Although there is currently no cure for the condition, various visual innovations have been developed. For instance, EnChroma glasses are innovated to help people with color vision deficiency see colors more precisely. Enchroma develops optical lens technology that selectively filters out wavelengths of light at the precise point where this confusion or excessive overlap of color sensitivity occurs. The M and L cones

are altered in such a way that there is a greater amount of difference in color discrimination along the so-called “confusion line” for that individual. Currently, there are multiple color vision aids being developed to help people with a myriad of color vision disorders. In this study, the authors aim to test the performance of such devices. The rationale of this study is to examine the efficacy of EnChroma glasses to aid vision in Thai population with congenital red-green color deficiency.

Methods

This study is approved by the Human Research Ethics Committee of the Faculty of Medicine, Thammasat University, Thailand. We performed a diagnostic study by collecting data from examination and diagnosis with congenital eye discoloration at the Ophthalmology Department, Thammasat University Hospital, during 5 November 2019 to 16 December 2020. Firstly, we excluded the patients with compromised visual acuity and severe red color vision deficiency. The participants will receive all necessary details of the research and sign a consent form to participation. The participants will undergo a visual acuity test with a near chart and a set of color vision test which comprises of an Ishihara test, and a Farnsworth 15 hue test without the Enchroma glasses then the participants will wear Enchroma glasses for at least 30 minutes to adjust color perception, then repeat the set of color vision tests. Lastly, the participants will be asked to fill out a satisfaction questionnaire on the use of the Enchroma glasses. For the Ishihara test we use 24-plate Ishihara testing, it is a number of plates that the patients can read and we are recorded.

For the Farnsworth 15 hue test, the participants are classified according to their severity into mild (less than 2 score), moderate (2-9 score), severe (>9 score). The results of the

set of color tests are compared between, before and after wearing Enchroma glasses.

Calculation of sample size

In order to estimate the sample size, we used two-sided testing with the significance at 5% and power at 80% were 35 patients based on data from a previous study.⁴

Statistical analysis

The data was collected in a standardized form and stored in an electronic datasheet (Microsoft excel). Paired T-test was used to compare pre and post test for both the Ishihara and Farnsworth 15 hue tests, A P value of less than 0.05 was considered as statistically

significant. The Satisfaction Questionnaire we used mean and standard deviation for evaluation.

Results

This research to test the efficacy of Enchroma glasses is consisted of 60 participants in total, 57 males (95%) and 3 females (5%) According to Table 1, people with the age between 21-40 years were the largest group, consisting of 40 participants (66.7%) 8 were younger than 20 and 2 were older than 60, which are equivalent to 13.3% and 3.3% respectively according to Table 2. Among 60 participants (Table 3), 17 were employees (28%), 15 were government officials (25%), and 13 were students (21.7%).

Table 1: Patient Demographics

Sex	Frequency(N)	Percent (%)	Cumulative percent (%)
Male	57	95	95
Female	3	5	100
Sex Total	60	100	
Age			
<20	8	13.3	13.3
21-40	40	66.7	80.0
41-60	10	16.7	96.7
>60	2	3.3	100.0

Table 2: Occupation data table

Occupation	Frequency (N)	Percent (%)	Valid percent (%)	Cumulative percent (%)
Government officials	15	25.0	25.0	25.0
Students	13	21.7	21.7	46.7
Merchant	2	3.3	3.3	50.0
Company employee	17	28.3	28.3	78.3
Private business	3	5.0	5.0	83.3
Worker	4	6.7	6.7	90.0
others	6	10.0	10.0	100.0

There are 60 participants diagnosed with green-red color vision deficiency, excluding those with severe red color vision deficiency as there are no specific glasses to that type of disorder. 39 (65%) of those participants are the

green-type, 15 (25%) are the red-type, 6 (10%) are the mild red-green type. The severity of the eyes' color perception are distinguished into 3 categories: mild, moderate, and severe, with 11.7%, 73.3% and 15.0% respectively (Table 3)

Table 3: Categorical distribution of color deficiency in patients in this study

Colour	Severity			Total
	mild	moderate	severe	
Mild red-green deficiency	6(10%)	0 (0%)	0(0%)	6(10%)
Protan deficiency	0(0%)	15(25%)	0(0%)	15(25%)
Deutan deficiency	1(1.7%)	29(48.3%)	9(15%)	39(65%)
Total	7(11.7%)	44(73.3)	9(15%)	60(100%)

Table 4: Paired T-test table compares between before and after wearing Enchroma glasses

Testing	Number Of patients	Mean (Score testing)	ST deviation	P value
Ishihara (Before)	60	1.745	1.027	0.004
Ishihara (After)	59**	2.694	2.731	
Farnworth (Before)	60	6.367	3.014	0.606
Farnworth (After)	60	6.200	3.145	

** Lost data (One patient did not performed the Ishihara test after wearing the glasses)

Ishihara test, before and after wearing the Enchroma glasses, had a P value of 0.004 (significance). Farnsworth test, before and after wearing the Enchroma glasses, had a P value

of 0.606 (no significance). The severity of the color deficiency, before and after wearing the Enchroma glasses had a P value of 0.597 (no significance), During data collection, one patient

Table 5: Subgroup analysis Protan and Deutan

Subgroup Testing			Number of Patients	Mean (Score testing)	ST deviation	P value (Sig 2 tailed)
Ishihara	Deutan	No glasses	39	1.769	0.706	0.000
		Wearing Enchroma	38	2.842	2.995	
	Protan	No glasses	15	1.067	0.258	0.046
		Wearing Enchroma	15	1.267	0.458	
Farnworth	Deutan	No glasses	39	7.384	2.391	0.089
		Wearing Enchroma	39	7.103	2.382	
	Protan	No glasses	15	6.200	1.821	0.313
		Wearing Enchroma	15	6.333	2.743	

** Before and after referred to before and after wearing glasses

did not perform the Ishihara test after wearing the glasses.

Apparently, if divided into subgroups, there are 39 cases of the Deutan and 15 cases of the Protan. From table 5. Non-wearing and wearing

Table 6: Distribution of dominant activity of subjects

Distribution of dominant activity of subjects	Number	Percent
Computer users	47	35.9%
Car drivers	31	23.7%
Outdoor workers	19	14.5%
Indoor workers	29	22.1%
Others	5	3.8%

Table 7: The Satisfaction Questionnaire results

Descriptive statistic	Number	Minimum Satisfaction score	Maximum Satisfaction score	Mean	Std.Deviation
Vision dimming	60	0.00	9.00	4.850	2.622
Distance estimation	60	0.00	10.00	2.550	2.600
Color determination	60	0.00	9.00	2.983	2.561
Visual comfort	60	0.00	9.00	4.467	2.896
Usefulness and practicality	60	0.00	9.00	2.600	2.546
Valid N	60				

Enchroma glasses, both of deutan and protan significantly improve in Ishihara test with the P value 0.000, 0.046 respectively.

According to the participants' eye-usage data queries Table 6., 35.9% were computer users, 23.7% were car drivers, 14.5% were outdoor workers, 22.1% were indoor workers.

The Satisfaction Questionnaire has a maximal score of 10 points. Averaging the score from the 60 participants, vision dimming received a mean score of 4.85, with a standard deviation of 2.622. Distance estimation received a mean score of 2.55, with a standard deviation of 2.600. Color determination received a mean score of 2.983, with a standard deviation of 2.561. Visual comfort received a mean score of 4.467, with a standard deviation of 2.896. Usefulness and practicality received a score of 2.6, with a standard deviation of 2.546.

Discussion

There was a large increase in the initial plan for the sample size, with 60 participants which tested the efficacy of the Enchroma glasses. However, all participants were diagnosed with green-red color blindness, not severe red-type patients because the glasses do not support that type. Although there are many types of Enchroma glasses, the selected type in this research was to be used indoor. Only 3 of the participants were female, while 57 were male, indicating that the color blindness is more common in males than females. This is because color blindness is inherited through a recessive gene on the X chromosome. Comparing the results of before and after wearing the glasses to perform the Ishihara test, it is revealed that the glasses assist in the ability in performing the Ishihara test, with a P value of 0.004. However,

when comparing the results of before and after wearing Enchroma glasses to perform the Farnsworth test, no significant difference was found, with a P value of 0.606.

From Farnsworth testing, The results can be divided into mild, moderate, severe, (mild severity 0-2 slitting line, moderate severity 2-9 slitting line, severe more than 10 slitting line)

comparing the severity of the chromatic aberration before and after wearing the glasses also revealed no significant difference, with a P value of 0.597.

In conclusion, Enchroma glasses help improve the ability to perform the Ishihara test, but do not make any significant difference for the Farnsworth test or the severity of chromatic aberration. Compared with the previous study of Gomez-Robledo et al.³ that does not improve both Ishihara and Farnsworth.

From the independent T-test in Table 8, comparing protan and deutan from the sig-2-tailed value, no significant difference was shown between both groups in regards to reducing the severity of color deficiency.

The satisfaction questionnaire shows that after wearing the glasses, issues such as darkened vision, distance estimation, color determining, comfort, and practical benefits still persisted if they were to be used in daily life.

While collecting data from the participants in this research for the effectiveness of the Enchroma glasses, two participants with color vision of severe red type were identified. The authors had explained to these participants and persuaded them to withdraw from the study, however, they insisted on trying the Enchroma glasses. It was found that the Enchroma glasses can help reduce the severity of red color deficiency in these patients as well.

The use of enchroma in Thailand may require further studies in the future, Enchroma has many different types and each may not be

suitable for some people, therefore further studies are necessary.

Limitations

There are no recommendations on the specific duration of wearing Enchroma glasses before significant results are shown. This may influence the outcome of the study, which explains why the glasses created an effect for some patients but not the others. There are also other factors affecting whether the Enchroma glasses improve color-vision or not, such as inconsistencies in environment and lighting.

Conclusions

The Ishihara test results during which Enchroma glasses are worn revealed a higher score in comparison to when the glasses are not worn, with a P value of 0.004. However, no difference between before and after wearing the glasses was found in the Farnsworth test, with a P value of 0.606. There was also no difference found in the severity of the chromatic aberration when comparing between before and after wearing the glasses, with a P value of 0.597.

Acknowledgements

The authors would like to thank Dr. Tayakorn Kupakanjana, BMBS for reviewing the manuscript.

References

1. M.P. Simunovic, "Colour vision deficiency," *Eye (Lond.)* 24(5),747-755 (2010).
2. Matsumoto ER, Johnson CA, Post RB. Effect of X-Chrom Lens Wear on Chromatic Discrimination and Stereopsis in Color-Deficient Observers. *Optometry and Vision Science.*1983;60(4):297-302.
3. Swarbrick H, Nguyen P, Nguyen T, Pham P. The ChromaGen contact lens system: colour vision test results and subjective

- responses. *Ophthalmic and Physiological Optics*. 2001;21(3):182-196.
4. Gomez-Robledo L, Valero EM, Huertas R, Martinez-Dominga MA, Hernandez-Andres J. Do EnChroma glasses improve color vision for colorblind subjects?. *Optics Express*. 2018;26(22):28693-28703.
 5. Martínez-Domingo MA, Gómez-Robledo L, Valero EM, Huertas R, Hernández-Andrés J, Ezpeleta S, et al. Assessment of VINO filters for correcting red-green Color Vision Deficiency, *Optics Express*. 2019;17(13):17954-17967.
 6. Popleteev A, Louveton N, McCall R. Colorizer: Smart Glasses Aid for the Colorblind. *Colorizer*. 2015;1:7-8