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A Comparative Study of Colour Vision Assessment by Ishihara Charts and Roth 28 Hue Test in Optic Nerve Disorders

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Abstract

Introduction: Colour vision tests that were originally intended for the study of congenital dyschromatopsias produce confusing results when applied to patients with acquired diseases. Ishihara test plates primarily designed for detecting congenital dyschromatopsias, are widely used to detect acquired colour vision defects because of their convenience, apparent simplicity of administration and availability. This study was done to compare the results of Ishihara's test and Roth 28 hue test in identifying and quantification of colour vision abnormalities in Optic Nerve disorders and to establish patterns of colour vision defects in acquired optic Nerve disorders. *Materials and methods:* This was prospective, cross sectional, comparative study done on patients with various optic nerve disorders attending the OPD from January 2016 to December 2018 were included. 71 patients of various optic neuropathies were included. All patients underwent comprehensive ophthalmic examination including visual acuity assessment, slit lamp examination, fundus examination, and IOP measurement. Colour vision was tested mono-ocularly with Ishihara's test and Roth 28 Hue test. All the data was tabulated and statistically analysed. *Results:* The study included 139 eyes of 71 patients with various optic neuropathies. The mean age was 36 years. The causes of optic neuropathies included were papilledema, optic neuritis, optic atrophy, glaucomatous optic neuropathy, and tobacco-alcohol amblyopia. Two patients had Traumatic optic neuropathy and one patient had non-arteritic ischaemic optic neuropathy. On comparing Ishihara and Roth test, there was statistically significant correlation between two tests ($p<0.001$). On comparing BCVA with both the test results, statistically significant correlation was found. (Ishihara: $p=0.001$, Roth: $p<0.001$). *Conclusion:* Even though Ishihara's test was designed to screen congenital colour vision defects, our study shows that it can be still used to detect colour vision abnormalities in acquired colour vision defects such as optic neuropathies because the results are comparable to arrangement test such as Roth test.

Keywords: Colour Vision, Ishihara and Roth Test, Optic Nerve Disorders.

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Introduction

Colour vision helps us to discriminate a light stimulus as a function of its wavelength. The physical effects of light, objects on interaction with each other combined with the physiological response of the eye to light and psychological context of colour perception together produce perception of the surrounding environment [1].

The light-sensitive cone photoreceptor cells in the retina and the neural components that process information about wavelength gathered by the photoreceptors helps in the colour vision. Kollner et al. reported that patients with retinal diseases present with blue - yellow defects, where as optic nerve disorders present with red-green colour blindness and in some cases, there can be nonspecific defects [2].

Acquired colour vision defects occur in toxic, vascular, inflammatory, neoplastic, demyelinating and degenerative disorders of optic nerve, retinal diseases and diseases of visual cortex. The damage caused in these disorders is usually nonselective, and the patterns of defects are usually different

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from those seen in congenital colour vision abnormalities. Hence, tests that are used in the diagnosis of congenital dyschromatopsia produce conflicting results in patients with acquired colour vision defects [3].

Ishihara test plates are widely used to detect colour vision defects because of their ease of administration [4]. The major disadvantages of Ishihara test is that, they do not contain designs for detecting tritan defects, and that good visual acuity is needed for performing the test. Hence Ishihara test is not appropriate for the assessment of a majority of acquired colour vision defects, which are usually associated with tritan type of defects [2].

Other colour vision tests such as Farnsworth Munsell 100 Hue test (FM 100 Hue Test), Roth 28 hue test can be used to estimate both the type and extent of colour vision defects. Error score in Roth 28 hue is comparable to that of 100 hue test and can be used as an alternative to FM100 hue testing to quantitatively assess colour vision, can be performed quickly and useful for follow up also [5].

The present study was done to compare the Ishihara's test and Roth 28 hue test in identifying and quantification of colour vision defects and to establish their patterns in acquired disorders of the optic nerve. A thorough review of literature has shown no studies comparing the two tests in acquired colour vision defects and hence the present study was planned.

Materials and Methods

This was a prospective, cross sectional, comparitive study done in patients with acquired optic nerve disorders attending ophthalmology OPD of tertiary care centre from January 2016 to December 2017. A total of 71 cases with acquired optic nerve disorders like Optic neuritis, Optic atrophy, Traumatic optic neuropathy, Drug induced optic neuropathy, Ischemic Optic Neuropathy were included in the study. Patients with age less than 10 years and more than 65 years, macular disorders, visual acuity less than 6/18 were excluded from the study as these cases have colour vision defects.

Informed written consent was taken from all the patients and ethical committee approval was obtained. Detailed history including demographics, ocular disease, past medical illness, drug history and personal history was taken from all the patients. All patients underwent detailed ophthalmic examination which included best corrected visual acuity by ETDRS Chart, contrast sensitivity by Pelli Robson chart, and dilated funduscopy to assess the condition of the optic nerve. Colour vision was assessed monocularly with Ishihara test plates and Roth 28 hue test with appropriate near vision correction. In Ishihara test, the plates were held at a distance of 75 cm and tilted so that the plane of the paper is at right angles to the line of vision. The numerals which are seen on plates 1-25 are stated and each response was to be given in three seconds. If the subject was unable to read the numerals, plates 26-38 were used and the winding lines between two x's were traced. Each tracing was to be completed within 10 seconds. If more than 17 plates were read normally, the colour vision was recorded as normal. If less than 13 plates were read, colour vision was graded as severe colour vision defect, if 14 to 16 plates were read, as moderate colour vision defect.

Roth 28 Hue test was conducted was conducted on a black background under day light at a distance of 50 cm. The cap number 82 was the reference cap and it was considered as the starting and end point of the test. The patients were instructed to arrange the remaining 27 caps, by selecting a cap closest in colour to the previously arranged cap and placing them in a circular sequence, without any time limit. The score was calculated by reading colour cap numbers on the reverse side of the case and the score sheet was plotted. For each of 28 caps difference of the cap number from numbers of the adjacent caps was calculated (value x). Values x and 84 (= (82-1) +3)-x was then compared and lower was chosen as distance. The shortest distance was then calculated which was taken as corrected x. Values of distance on both sides was added and then 6 was subtracted. The resulting value was noted as local error score sum of which was taken as global error score [6].

Qualitative interpretation of the test was done by plotting the score sheet. The result was considered normal when the lines remained outside the circle. The type of the colour vision defect was determined by comparing the crossover lines to see if they were parallel to protan, deutan and tritan colour confusion axes. In case of multiple crossover lines which were not parallel to any axis, was considered as a nonspecific colour vision defect.

Chi-square test was done to study the correlation between two qualitative variables. The Kruskal-Wallis test was done to study the correlation between quantitative variables and qualitative variables. All tests were done using SPSS version 16 with p value less than 0.05 considered to be significant.

Results

The study included 139 eyes of 71 patients with acquired optic nerve disorders. The age of the patients ranged from 11 years to 64 years with a mean of 36.51±14.79 years. Out of 71 patients in the study, 35 (49.30%) were males and 36 (50.70%) were females. Out of the optic nerve disorders included in the study, papilledema was seen in 47 eyes (34%), optic neuritis in 21 eyes (15%), optic atrophy in 20 eyes (14%), glaucomatous optic neuropathy in 18 eyes (13%), tobacco-alcohol amblyopia in 10 eyes (7%), traumatic optic neuropathy in 2 patients (2%) and one patient had non arteritic ischaemic optic neuropathy. Other conditions included in the study were grade 4 hypertensive retinopathy in 1 patient, diabetic papillopathy in 1 patient, disc edema secondary to orbital pseudotumour in 2 patients and disc edema due to orbital lymphoma in 1 patient.

Out of 71 patients in the study, systemic disease was found in 44 patients. Papilledema due to cerebral venous thrombosis (CVT) was found in 10 patients and Idiopathic Intracranial Hypertension (IIH) was found in 12 patients. Meningitis was found in three patients. Optic neuropathy secondary to intracranial mass lesions were found in 8 patients, one patient had pineal gland tumour and one patient had craniopharyngioma. Optic neuritis due to demyelinating disease was found in 4 patients.

On Roth 28 hue test, out of 139 eyes, 91 (65.46%) eyes had normal colour vision and 48 (34.53%) eyes had colour vision defects. Out of 48 eyes, 2 eyes (1.43%) had protan defects, 6 eyes (4.31%) had duetan defects and 22 eyes (15.82%) had tritan defects and 18 eyes (12.94%) had diffuse nonspecific chromatic loss. On Ishihara test, normal colour vision was found in 91 (65.46%)eyes and 48 (34.53%) eyes had colour vision defects. Out of 48 eyes, 16 eyes (11.51%) had moderate colour vision defect, 15 eyes (10.79%) had severe colour vision defects, 17 eyes (12.23%) were not able to read any of the plates.

Ishihara Vs Roth 28 Hue Qualitative analysis (Table 1)

On comparing results of Roth 28 Hue test and Ishihara test, 74 eyes had normal colour vision by both the tests and the correlation between the two tests was statistically significant (p<0.001). On Ishihara's test, 91 eyes had normal colour vision. Of these 91 eyes, on Roth testing, only 74 eyes showed normal colour vision and 17 eyes had colour vision defects. Out of 17 eyes with colour vision defects, 9 had severe colour vision defect and 8 eyes showed colour pattern defects. On the other hand, on Roth test 91 eyes showed normal colour vision out of which only 74 eyes showed normal colour vision by Ishihara's test. Remaining 14 eyes showed severe colour vision defect and 3 showed moderate defects by Ishihara's test. Severe colour vision defect was detected in 32 eyes by Ishihara's test. Of these 32 eyes on Roth test, only 4 eyes were detected to have nonspecific colour vision defect (severe); 14 eyes had normal colour vision and 14 eyes showed a pattern abnormality. Roth test showed a tendency towards detecting more pattern abnormalities, with 30/139 showing different colour patterns.

Table 1: Roth 28 Hue Test Vs Ishihara test-Cross tabulation (Qualitative)

		Ishihara			Total	Pearson- Chi square value 36.10 p<0.001
		Severe CV defect	Moderate CV defect	Normal C V		36.10 P<0.001
Roth	Nonspecific	4	5	9	18	
	Patterns	14	8	8	30	
	Normal	14	3	74	91	
Total		32	16	91	139	

Table 2: Correlation of colour vision using Ishihara's test and Global error score on Roth 28-hue test.

		Roth 28 Hue test-Global Error Score		
		Median	Inter quartile distance	
Ishihara Test	Severe CV defect	282	630	Pearson-Chi square Value 14.81
	Moderate CV defect	264	582	
	normal	0	120	p<0.001

Ishihara Vs Roth 28 hue Quantitative analysis (Table 2)

Increased Global error score was associated with severe colour vision defect by Ishihara test and this correlation was statistically significant (p<0.001). The median global error score was 282 (680) with severe color vision defects, with moderate colour vision defect was 264 (582), and in normal colour vision the score was 0 (120)

Comparison of BCVA with Roth 28 hue test (Fig. 1)

Severe colour vision defect by Roth test was correlated with the least median Log MAR BCVA of 0.20 (0.30), moderate colour vision defect was correlated with median Logmar BCVA of 0.20 (0.50) and normal colour vision by Roth test with a median Logmar BCVA of 0 (0.20).

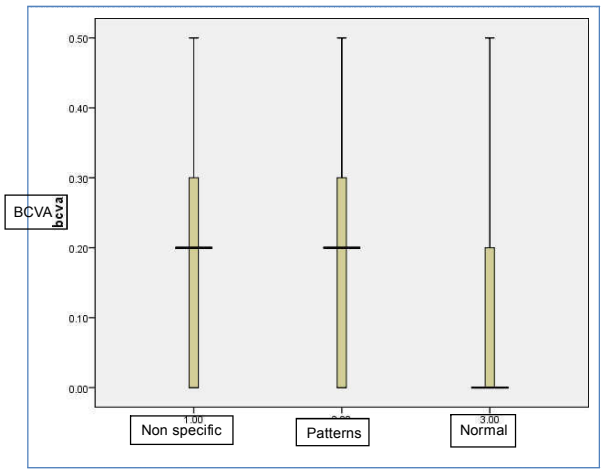

Fig. 1: Comparison of BCVA with Roth 28 hue test

Comparison of BCVA with Ishihara test (Fig. 2)

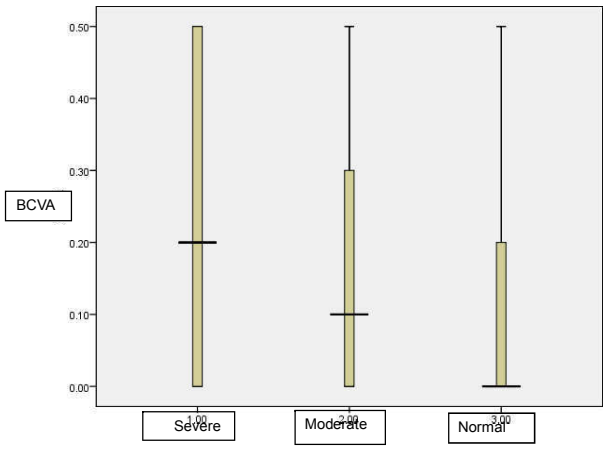

Fig. 2: Comparison of BCVA with Ishihara test

Statistically significant correlation was found between BCVA and severity of colour vision defects (p=0.001). Severe colour vision defect was associated with the poorest BCVA, with median BCVA of 0.20 (0.05), while moderate colour vision defect had a median BCVA of 0.10 (0.03) and normal colour vision had a median BCVA of zero (0.20)

Comparison of Colour Vision Test Results and Presence of RAPD

Statistically significant correlation was found between RAPD and severity of colour vision defect on both Ishihara (p=0.001) and Roth 28 hue tests (p< 0.001)

Patterns of Colour Vision Defects in Optic Neuritis

In the present study, 34% of the eyes with optic neuritis had tritan defects and 6% had Deutan defects. 30 % of the eyes showed nonspecific colour vision loss. 30% of the cases of optic neuritis showed normal colour vision and good visual acuity on resolution.

Patterns of Colour Vision Defects in Papilledema

80% of the eyes with papilledema had normal colour vision whereas 11% eyes had tritan defects, 5% had deutan defects, 4% had nonspecific colour vision defects.

Patterns of Colour Vision Defects in Optic Atrophy

44% of the eyes with optic atrophy had normal colour vision and had good visual acuity. Other colour vision defects noted in these patients were tritan defects (28%), deutan (11%) and nonspecific colour vision defects (17%).

Discussion

Most of the patients in the study were in age group of 20-60 years. Papilledema due to cerebral venous thrombosis (CVT) was found in 10 patients and Idiopathic Intracranial Hypertension (IIH) was found in 12 patients. Infections like pyogenic meningitis were found in one patient and rickettsial meningitis was found in one patient. Pituitary adenoma was found in 8 patients, one patient had pineal gland tumour and one patient had craniopharyngioma. Optic neuritis secondary to demyelinating disease was found in 4 patients.

On correlation of BCVA with Ishihara test results, severe colour vision defect was associated with the poorest BCVA, with median Log MAR BCVA

of 0.20 (0.05), while moderate colour vision defect by Ishihara test had a median LogMAR BCVA of 0.10 (0.03) and normal colour vision by Ishihara test had a median Log MAR BCVA of zero (0.20). The correlation between BCVA and severity of colour vision defects was statistically significant (p=0.001). The study also found that Ishihara's test requires better acuity for good resolution. The results were in accordance with a study by Almog Y et al., who correlated visual acuity with colour vision on Isihara's test and found that colour vision defects correlates well with best corrected visual acuity. They also concluded that for the same degree of vision loss, patients with optic neuropathy are most likely and patients with amblyopia are least likely to have a significant colour vision defect [7].

On comparing BCVA with Roth test results, severe colour vision defect by Roth test was associated with the least median Log MAR BCVA of 0.20 (0.30), moderate colour vision defect with median Log MAR BCVA of 0.20 (0.50) and normal colour vision with a median Log MAR BCVA of 0 (0.20). Statistically significant correlation was found between severity of colour vision defects detected by Roth test and BCVA (p= <0.002)

Mc Culley et al in their study compared colour vision results of Ishihara, Farnsworth D-15 panel and HRR plates with visual acuity in 12 normal individuals and found that the results with Ishihara test were most dependent and Farnsworth D-15 test were least dependent on visual acuity. The differences between the results of the two tests are multi-factorial. Ishihara test has 21 characters to be recognized where as arrangement tests are based on identifying a given object. The size of test object also correlates with visual acuity, as Ishihara characters differ in width with the thinnest portions being less than 0.5cm and caps of arrangement tests having a diameter of 1 cm [8].

In our study, 34% of the eyes with optic neuritis showed tritan defects and 6% had deutan defects and 30% of the eyes showed nonspecific defects. 30% of the resolved cases had normal colour vision and had good visual acuity. Our findings were in concurrence with the findings of Optic Neuritis Treatment Trial which detected mixed red- green defects in 29.6% patients and tritan defects in 40.8% patients. The study found that blue- yellow defects were more common in acute phase and red- green defects were seen at 6 months followup. The study also concluded that optic neuritis always will not always result in selective red- green deficits and the type of the defect cannot be used in the diagnosis of optic neuritis [9].

In our study, 80% of eyes with papilledema had normal colour vision, 11% had tritan defects, 5% had nonspecific colour vision loss and 4% had deutan defects. Hart W M et al in their study had similar findings and concluded that chronic papilledema causes mild to moderate confusion of blue-yellow hues with a lesser degree of impairment of red green discrimination [9].

In the present study, 44% of eyes with optic atrophy showed normal colour vision and also had good visual acuity. Tritan defects were found in 28% of the eyes, 11% had deutan defects and 17% had nonspecific colour vision loss. According to Hart W M et al optic nerve disorders especially those involving papillo-macular bundle are most frequently associated with central scotomas that impair visual acuity and are associated with red-green defects. Optic nerve disorders resulting in arcuate or peripheral field defects are associated with relatively good visual acuity and result in selective blue- yellow defects [9].

RAPD was found in 15 eyes (10.79%) in the study. Out of them, 10 eyes had pattern abnormalities on Roth test and 5 eyes had normal colour perception. On Ishihara's testing, 9 eyes had severe colour vision defect, 2 eyes had moderate colour vision defect and 4 eyes had normal colour vision.

On comparision of Roth 28 Hue test and Ishihara tests, 91 eyes were found to have normal colour vision by both the tests. However, only in 74 eyes there was concordance between the two tests. The concordance between the two tests was higher when visual acuity was normal. There was statistically significant correlation between the two tests (p<0.001).

On Ishihara's test 91 eyes showed normal colour vision. Of these 91 eyes on Roth testing, only 74 eyes showed normal colour vision and 17 eyes had abnormal colour vision; 9 had severe colour vision defect and 8 eyes showed patterns. On the other hand, 91 out 139 eyes showed normal colour vision by Roth test, out of which only 74 eyes showed normal colour vision by Ishihara's test. Remaining 14 eyes showed severe colour vision defect and 3 showed moderate defects by Ishihara's test.

Severe colour vision defect was detected in 32 eyes by Ishihara's test. Of these 32 eyes, only 4 eyes were detected to have nonspecific colour vision defect (severe) by Roth test; 14 eyes had normal colour vision and 14 eyes showed a pattern abnormality. Roth test showed a tendency towards detecting more pattern abnormalities, with 30/139 showing different colour pattern abnormality. This

implies that Ishihara test overestimates defects of colour vision and also more severe colour vision defect is more likely to be detected by Ishihara's test as it requires finer visual acuity.

Global error score determined by Roth 28 Hue test was compared with Ishihara test and increasing values of global error score was associated with severe colour vision defect by Ishihara test and this correlation was statistically significant ($p<0.001$).

A thorough review of literature showed no studies comparing Roth 28 hue test with Ishihara's test in detecting colour vision defects in optic nerve disorders. However, there are studies which have compared colour vision abnormalities detected by different plate tests (such as HRR plates versus Ishihara's test) or by arrangement test (such as FM 100 hue test versus the shorter versions) .

Baron et al compared colour vision defects detected by HRR plates and Ishihara plates in patients of optic neuropathy and found that the receiver operating characteristics (ROC) curve was statistically significantly better on HRR test than for the Ishihara test ($p=0.0006$). The best specificity-sensitivity balance for the HRR was 100% and 79% respectively, and for the Ishihara test was 100% and 48% respectively. They concluded that the HRR test was superior to the Ishihara test in detecting acquired dyschromatopsia due to optic neuropathy which correlated with the present study [10].

Neitz M et al. found that nearly half of the people with normal colour vision tend to make errors on the Ishihara Plates. Most patients with colour vision defects fail to see the correct symbol in almost all the test plates and thus it is not possible to grade the severity of colour vision deficiency [5]. Hardy L G et al showed that, Ishihara test is rough screening method for red green defect. It is a gross test, fails to classify type of colour vision defect and cannot be used to give satisfactory evaluation of extent and degree of defect [3]. However, our study has shown that the two test results are comparable statistically ($p< 0.001$) and in 61.8% of eyes there was complete agreement in the test results obtained by two study tests. Hence, Ishihara's test can be used to detect acquired colour vision abnormalities when arrangement tests are not available.

Amos J F et al. concluded that Roth 28 Hue test is a good compromise between the ease and speed of D-15 and quantification of the 100 hue, because this test is based on established principles of FM 100 hue test. 11 According to Erb C et al., FM 100 hue test is too time consuming and difficult for both patient and ophthalmologist. On the other hand, screening tests such as Ishihara plates are quick and simple to use but colour discrimination cannot be quantitatively evaluated. Roth 28 hue test is reliable, sensitive and quick colour arrangement test. By presenting more colour caps than D -15 it allows greater expression of colour confusion and hence it is a good compromise between D-15 and 100-Hue test [5].

Nichols B E et al. evaluated significantly shorter version of FM 100 hue test in patients with optic neuritis, IIH and Grave's ophthalmopathy and found that a test consisting of chips 22-42 had nearly the same sensitivity and specificity as the entire test. This minimizes the time to one fourth of the original examination time [10].

In this study we have compared Ishihara's test with Roth test and found that it can be still used to detect acquired colour vision abnormalities although the test was designed for congenital colour vision defects. The results are also comparable to arrangement test such as Roth test.

Even though Ishihara's test was designed to screen congenital colour vision defects, our study shows that it can be still used to detect colour vision abnormalities in acquired colour vision defects because the results are comparable to arrangement test such as Roth test. Our study also showed that visual acuity correlates well with results of both the tests. Ishihara test showed a tendency to pick up severe colour vision loss while Roth test showed different pattern abnormalities. This difference among two tests may be because of the size of test types. We also found that, in contrary to common clinical belief, optic neuropathies do not always result in red-green colour vision defects. Patients with optic neuritis showed a greater tendency towards blue –yellow defect in the present study and resolved cases of optic neuritis had normal colour perception. Most of the patients with papilledema showed normal colour vision.

Conclusion

From this study we can conclude that Ishihara's test can still be used as an important clinical tool for evaluation of colour vision. Even though Ishihara's test was designed to screen congenital colour vision defects, our study shows that it can be still used to detect colour vision abnormalities in acquired colour vision defects such as optic neuropathies because the results are comparable to arrangement test such as Roth test.

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