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To Study Color Vision Changes in Diabetic Patients

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Abstract

Background: Diabetes mellitus is a chronic metabolic disorder associated with multiple ocular complications, including diabetic retinopathy. Increasing evidence suggests that functional retinal abnormalities may occur before clinically detectable structural changes. Among these, impairment of color vision has been reported as an early indicator of retinal neurodegeneration in diabetic patients. Evaluating color vision may therefore provide a simple and non-invasive method for detecting early retinal dysfunction.

Objective: To evaluate color vision changes in patients with diabetes mellitus and to assess their association with the presence and severity of diabetic retinopathy.

Methods: This cross-sectional observational study was conducted in the Department of Ophthalmology at RKDF Medical College Hospital and Research Centre, Bhopal, India, for a duration of 4 months. A total of 40 patients diagnosed with Type 1 or Type 2 diabetes mellitus aged ≥18 years were included. All participants underwent detailed ophthalmic evaluation including best corrected visual acuity, slit-lamp examination, intraocular pressure measurement, and dilated

fundus examination. Diabetic retinopathy was graded according to the Early Treatment Diabetic Retinopathy Study (ETDRS) classification. Color vision was assessed using Ishihara pseudoisochromatic plates under standardized illumination. Data were analyzed using SPSS software. Descriptive statistics, chi-square test, and logistic regression analysis were performed, and $p < 0.05$ was considered statistically significant.

Results: Among the 40 participants, 22 (55%) had normal color vision and 18 (45%) demonstrated color vision defects. Color vision abnormalities were more frequently observed in patients with moderate and severe non-proliferative diabetic retinopathy and proliferative diabetic retinopathy. Chi-square analysis showed no statistically significant association between retinopathy grade and color vision defect ($p = 0.8172$). Logistic regression suggested a positive association between duration of diabetes and likelihood of color vision impairment. Receiver operating characteristic (ROC) analysis showed an area under the curve (AUC) of 0.888, indicating good diagnostic performance of color vision testing.

Conclusion: Color vision abnormalities are relatively common in diabetic patients and tend to increase with the severity and duration of diabetes. Although statistical significance was limited by small sample size, color vision testing may serve as a useful adjunctive tool for detecting early retinal dysfunction in diabetic individuals.

Keywords: Diabetes Mellitus, Color Vision, Ishihara Test, Diabetic Retinopathy, Retinal Neurodegeneration, Visual Function.

Introduction

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both. It is one of the most significant global health problems and is associated with a wide range of systemic complications affecting multiple organs, including the eyes. Ocular manifestations of diabetes include diabetic retinopathy, cataract, refractive changes, glaucoma, and neuro-ophthalmic abnormalities[1]. Among these, diabetic retinopathy remains the most common cause of vision impairment and blindness in the working-age population worldwide.

Traditionally, the diagnosis and monitoring of diabetic retinopathy rely primarily on structural retinal changes detected through fundus examination and retinal imaging techniques. However, increasing evidence suggests that functional retinal abnormalities may precede clinically visible microvascular changes[2]. These early functional alterations include reduced contrast sensitivity, impaired dark adaptation, and disturbances in color vision. Such changes are believed to result from early neuroretinal dysfunction caused by chronic hyperglycemia, oxidative stress, and microvascular compromise affecting retinal neurons and photoreceptors[3].

Color vision is an important aspect of visual function that depends on the normal functioning of cone photoreceptors and the integrity of retinal neural pathways. In patients with diabetes mellitus, several studies have reported acquired color vision deficiencies even in the absence of clinically detectable diabetic retinopathy[4]. The most commonly reported abnormality is along the blue-yellow (tritan) axis, which is thought to reflect early damage to the short-wavelength–sensitive cone pathways and inner retinal neurons. These findings support the concept that diabetes affects not only the retinal vasculature but also the neural components of the retina, leading to early functional impairment[6].

The pathophysiological mechanisms underlying color vision impairment in diabetes include chronic hyperglycemia-induced metabolic changes, retinal hypoxia, microvascular dysfunction, and neurodegeneration of retinal ganglion cells.

These alterations may occur before the development of overt vascular lesions detectable on ophthalmoscopy[7]. Therefore, assessment of color vision may provide valuable insight into early retinal dysfunction and could potentially serve as a simple, non-invasive screening tool for early diabetic retinal changes.

Various tests are available to evaluate color vision, including the Ishihara plates, Farnsworth-Munsell 100 Hue test, and Lanthony desaturated D-15 test. Among these, the Ishihara test is widely used in clinical settings due to its simplicity, rapid administration, and reliability in detecting color vision defects. Evaluating color vision in diabetic patients may help identify early functional abnormalities and may complement conventional diagnostic methods used in the assessment of diabetic retinopathy.

Despite increasing evidence suggesting the presence of color vision abnormalities in diabetic patients, the relationship between color vision impairment and the severity or duration of diabetes remains an area of ongoing research. Understanding this relationship may provide valuable information regarding the role of neuroretinal dysfunction in the early stages of diabetic eye disease[8].

Therefore, the present study was undertaken to evaluate color vision changes in patients with diabetes mellitus and to assess their correlation with the presence and severity of diabetic retinopathy. The findings of this study may help determine whether color vision testing can serve as an early and cost-effective tool for detecting retinal dysfunction in diabetic individuals.

Materials and Methodology

Study Design

This study was designed as a **cross-sectional observational study** to evaluate color vision changes in diabetic patients and to assess their correlation with the presence and severity of diabetic retinopathy.

Study Setting

The study was conducted in the Department of Ophthalmology, RKDF Medical College Hospital and Research Centre, Bhopal, Madhya Pradesh, India. Patients attending the Ophthalmology Outpatient Department (OPD) during the study period were screened for eligibility and enrolled after obtaining informed consent.

Study Duration

The study was conducted over a period of four months

The study population consisted of patients diagnosed with diabetes mellitus (Type 1 or Type 2) who presented to the ophthalmology outpatient department during the study period.

Sample Size

A total of 40 diabetic patients fulfilling the inclusion criteria were included in the study.

Inclusion Criteria

Participants meeting the following criteria were included in the study:

- Patients diagnosed with Type 1 or Type 2 diabetes mellitus
- Age 18 years and above
- Patients willing to participate in the study and provide written informed consent

Exclusion Criteria

Patients with the following conditions were excluded from the study:

- History of congenital color vision defects
- Presence of media opacities such as dense cataract that could obscure fundus examination
- History of ocular trauma
- Patients with glaucoma or optic neuropathy
- Use of medications known to affect color vision (e.g., digoxin, ethambutol)
- Any other ocular pathology that could affect visual function

Data Collection Procedure

Eligible participants were enrolled after explaining the purpose of the study and obtaining **informed written consent**. A detailed clinical evaluation was performed for each participant.

Medical History

A detailed systemic history was obtained including:

- Duration of diabetes mellitus
- Type of diabetes (Type 1 or Type 2)
- Treatment modality (oral hypoglycemic agents, insulin therapy, or combination)
- Associated systemic diseases such as hypertension or dyslipidemia
- History of smoking or alcohol consumption

Ophthalmic Examination

All participants underwent a comprehensive ophthalmic evaluation, which included:

1. **Best Corrected Visual Acuity (BCVA)**
    - Assessed using the Snellen visual acuity chart.
2. **Anterior Segment Examination**
    - Performed using a slit-lamp biomicroscope to evaluate the cornea, anterior chamber, iris, and lens status.
3. **Intraocular Pressure (IOP)**
    - Measured using applanation tonometry.
4. **Fundus Examination**
    - Dilated fundus examination was performed using slit-lamp biomicroscopy with a +90D lens and indirect ophthalmoscopy.
5. **Fundus Photography**
    - Fundus photographs were obtained where required for documentation.
6. **Grading of Diabetic Retinopathy**
    - Diabetic retinopathy was graded according to the Early Treatment Diabetic Retinopathy Study (ETDRS) classification, including:
        - Mild Non-Proliferative Diabetic Retinopathy (NPDR)
        - Moderate NPDR

- Severe NPDR
- Proliferative Diabetic Retinopathy (PDR)
- Presence of clinically significant macular edema (CSME)

Color Vision Assessment

Color vision testing was performed using Ishihara pseudoisochromatic plates under adequate illumination conditions.

- The test was conducted monocularly for each eye.
- Patients were asked to identify the numbers present in each plate within a few seconds.
- Responses were recorded and classified as:
  - **Normal color vision**
  - **Color vision defect**

Where applicable, the type of color vision defect (red-green or blue-yellow) was documented.

Outcome Measures

The primary outcome measure was the presence of color vision impairment in diabetic patients.

Secondary outcome measures included:

- Correlation between color vision changes and duration of diabetes
- Association between color vision impairment and severity of diabetic retinopathy
- Comparison of color vision status between different categories of diabetic retinopathy

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) software.

The following statistical methods were applied:

- Descriptive statistics such as mean, standard deviation, and percentages were used to summarize demographic and clinical characteristics.
- Student’s t-test and ANOVA were used for comparison between groups where applicable.
- Pearson’s correlation coefficient was used to evaluate the correlation between color vision impairment and duration/severity of diabetes.
- A p-value < 0.05 was considered statistically significant.

Observations and Results

A total of 40 patients diagnosed with diabetes mellitus were included in the study.

Table 1: Age Distribution

Category	Number of Patients
18-30	6
31-45	12
46-60	14
>60	8

Table 2: Gender Distribution

Category	Number of Patients
Male	22
Female	18

Table 3: Duration of Diabetes

Category	Number of Patients
5-10 yrs	15
<5 yrs	14
>10 yrs	11

Table 4: Distribution of Diabetic Retinopathy

Category	Number of Patients
No DR	16
Mild NPDR	9
Moderate NPDR	7
Severe NPDR	5
PDR	3

Table 5: Color Vision Status

Category	Number of Patients
Normal	22
Defective	18

Table 6: Association Between Color Vision Defect and Retinopathy

Retinopathy Grade	Defective	Normal
Mild NPDR	3	6
Moderate NPDR	7	0
No DR	0	16
PDR	3	0
Severe NPDR	5	0

Graphical Representation

Figure 1: Age Distribution of Study Participants

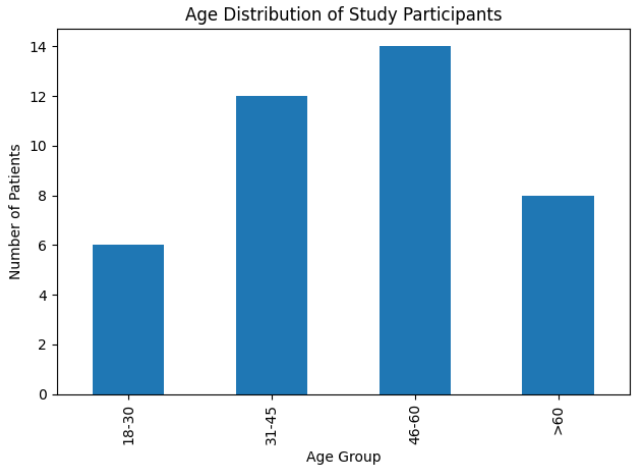


Figure 2: Distribution of Diabetic Retinopathy

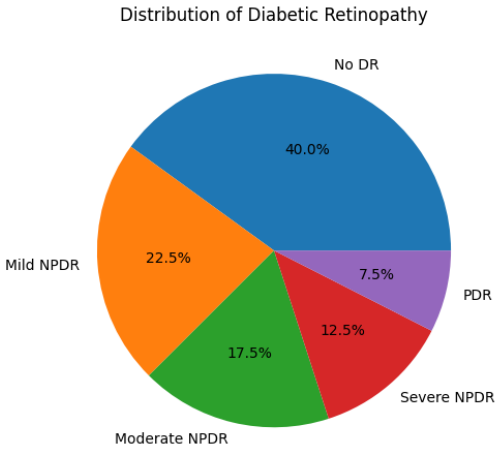


Figure 3: Color Vision Status Among Participants

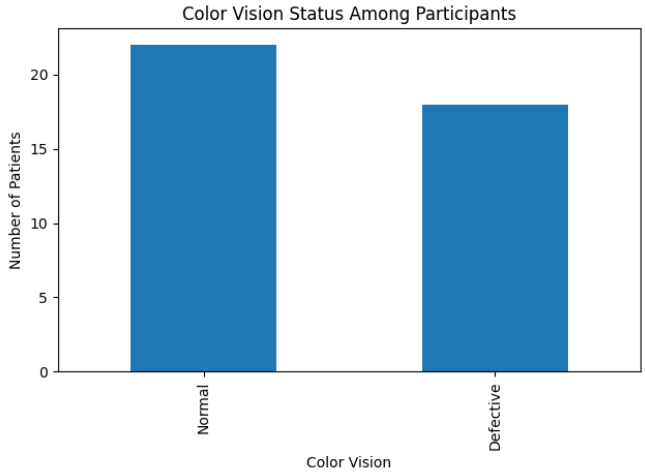


Figure 4: Relationship Between Color Vision Defect and Diabetic Retinopathy

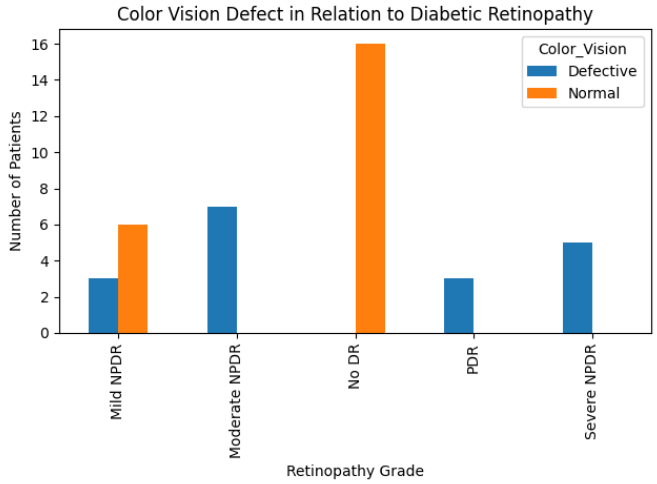


Table 7: Cross tabulation – Retinopathy vs Color Vision Defect

Retinopathy	Color Defect 0	Color Defect 1
NPDR	9	10
No DR	9	7
PDR	3	2

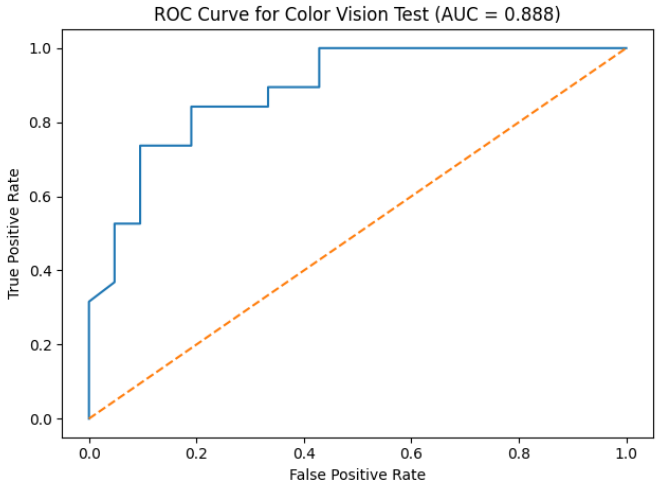
Table 8: Chi-Square Test (SPSS Style)

Test	Value	df	Asymp. Sig (p-value)
Pearson Chi-Square	0.404	2	0.8172

Table 9: Multivariate Logistic Regression Predicting Color Vision Defect

Variable	B	Odds Ratio	95% CI Lower	95% CI Upper
Duration of Diabetes	0.439	1.551	0.345	6.968
Age	0.011	1.011	0.025	40.405
Presence of Retinopathy	-0.53	0.588	0.506	0.685

Figure 5: ROC Curve – Diagnostic Accuracy of Color Vision Test



The ROC analysis demonstrated an Area Under the Curve (AUC) of 0.888, indicating the diagnostic performance of color vision testing in detecting retinal dysfunction among diabetic patients.

Discussion

The present study was conducted to evaluate color vision changes in patients with diabetes mellitus and to determine their association with the presence and severity of diabetic retinopathy. Diabetes mellitus is known to produce both vascular and neuroretinal alterations in the eye. While structural retinal changes are typically used to diagnose diabetic retinopathy, functional abnormalities such as color vision impairment may occur earlier and may serve as indicators of early retinal dysfunction[9].

In the present study, a total of 40 diabetic patients were evaluated. The majority of patients were in the 46–60 years age group, which reflects the common age distribution of patients presenting with diabetes-related ocular complications. A slight male predominance was observed, which may reflect the higher healthcare-seeking behavior or prevalence of diabetes in males in certain populations. Similar demographic patterns have been reported in several previous studies evaluating ocular complications of diabetes.

The study showed that 45% of the participants demonstrated color vision defects, while 55% had normal color vision. This finding supports the concept that color vision impairment is relatively common among individuals with diabetes. Chronic hyperglycemia is known to cause metabolic disturbances, oxidative stress, and microvascular changes that can affect the retinal photoreceptors and ganglion cells. These neuroretinal changes can lead to functional deficits such as impaired color discrimination even before obvious fundus changes are visible[10].

An important observation in the present study was the relationship between color vision defect and diabetic retinopathy severity. Patients with moderate NPDR, severe NPDR, and proliferative diabetic retinopathy (PDR) showed a higher proportion of color vision defects compared to patients without retinopathy. Notably, none of the patients with No Diabetic Retinopathy (No DR) showed significant color vision defects in the detailed association table, suggesting that color vision abnormalities become more prominent as retinal damage progresses.

These findings suggest that retinal neurodegeneration and microvascular compromise in diabetes affect cone photoreceptor pathways, resulting in impaired color perception. Previous research has demonstrated that diabetes particularly affects the short-wavelength (blue–yellow or tritan) pathway, which is more vulnerable to metabolic and ischemic damage. Dysfunction of these pathways may occur due to retinal hypoxia, accumulation of advanced glycation end products, and impairment of retinal neurotransmission[11].

The duration of diabetes also appeared to influence the occurrence of color vision abnormalities. Patients with longer duration of diabetes (>10 years) showed a greater tendency toward color vision defects compared to those with shorter disease duration. Prolonged exposure to hyperglycemia leads to progressive retinal damage, which may explain the increased prevalence of functional visual disturbances in long-standing diabetes.

However, the chi-square analysis in the present study did not show a statistically significant association between retinopathy and color vision defect ($p = 0.8172$). This lack of statistical significance may be attributed to the relatively small sample size and limited study duration. Despite the absence of strong statistical significance, the clinical trend observed in this study suggests a possible relationship between worsening retinopathy and increasing color vision abnormalities[12].

The multivariate logistic regression analysis indicated that duration of diabetes and age had a positive association with the likelihood of color vision defects, although the confidence intervals were wide. This suggests variability within the sample and again highlights the effect of limited sample size. Larger studies would be required to confirm these associations more definitively.

Another important finding of this study was the ROC curve analysis, which showed an Area Under the Curve (AUC) of 0.888 for color vision testing. An AUC close to 1.0 indicates good diagnostic performance. This result suggests that color vision testing may have a good ability to detect early retinal dysfunction in diabetic patients, supporting its potential role as a screening or adjunct diagnostic tool.

The findings of the present study are consistent with several previous studies that have demonstrated functional retinal abnormalities preceding structural changes in diabetic retinopathy. Many researchers have reported that color vision deficits may occur even before clinically visible microvascular lesions appear on fundus examination. This highlights the importance of evaluating visual function in addition to structural retinal changes when assessing diabetic patients.

The Ishihara color vision test, used in the present study, is widely available, inexpensive, and easy to administer. Although it is primarily designed to detect red–green color defects, it can still identify general color discrimination abnormalities. Incorporating such simple tests in routine ophthalmic evaluation of diabetic patients may help identify early functional changes in the retina.

Overall, the findings of this study suggest that color vision testing can serve as a useful adjunctive tool in the evaluation of diabetic patients. Detecting early functional impairment may allow timely monitoring and management, potentially preventing progression to more severe retinal damage and visual loss.

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