ASSESSMENT OF COLOR VISION AND STEREOPSIS IN PATIENTS WITH NORMAL TENSION GLAUCOMA PRESENTING AT AL EHSAN WELFARE EYE HOSPITAL

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***Abstract*- Background:** Glaucoma leads to irreversible vision loss which involves continuous and progressive optic nerve changes and can occur with or without elevated intraocular pressure (IOP). The projection of glaucoma since 2010 was 60 million which reaches 80 million by 2020. Early diagnoses and IOP reduction are important for disease management. This study evaluates the comparative inspection of cup-to-disc ratio and intraocular pressure in patients with standard color vision and those with color vision anomalies, focusing to enhance early diagnostic treatment plans and personalized administrative approaches.

Objective: To find the impact of normal tension glaucoma on color vision and stereopsis. To find which type of color vision deficiency is more frequently affected in young adults with normal tension glaucoma.

Material method: This cross-sectional study involves 93 patients of age group 15 to 35. The patients were examined after fulfilling inclusion and exclusion criteria. Analysis of color vision and stereopsis are done by D-15 color vision test and titmus fly test.

Results: This study includes 93 normal-tension glaucoma patients, 61 males and 32 females. Age distribution ranged from 15-35 years. Mean visual acuity of OD was 0.4153 and visual acuity of OS was 0.4409. Color vision assessment showed 76.3% normal in OD and 67.7% in OS. Stereopsis ranged by 40 to 200 seconds of arc with a mean of 91.61 and a standard-deviation of ± 34.74 seconds of arc.

Conclusion: This study provides important perceptions into color vision and stereopsis in young adults with normal tension glaucoma. Color vision anomalies are present and should be monitored. The changes in stereopsis emphasizes the need for detailed visual assessments in NTG patients. Differentiating the results of this study with the pre-existing literature highlight the significance of age-matched studies and recommends that the impact of NTG on visual functions is although not huge but still significant.

Key words: Color Vision, Glaucoma, Intraocular Pressure, Stereopsis

INTRODUCTION

Glaucoma is categorized as an uniocular or binocular continuous process of optic nerve disfigurement which is further identified by cupping of optic disk, field of vision abnormalities and without or with increased intraocular pressure (IOP) (1). The worldwide presence of glaucoma is roughly calculated to be sixty million in 2010 which further more calculated to increase nearly eighty million in 2020 (2). Glaucoma is classified as one of the major cause of irreversible vision loss on a worldwide level. The foremost risk factor for blindness caused by normal-tension glaucoma is its late diagnosis however focused attention on screening is the potential benefit of early diagnosis and subsequent treatment to reduce its prevalence (3).

Glaucoma has its different types but the most frequent types among them are the AOG (angle open glaucoma) and the CAG (closed angle glaucoma) can be primary (due to an unknown cause) or secondary (due to any other systemic or ocular disease). Primary glaucoma is caused by optic nerve damage occurring with or without elevated intraocular-pressure but the exact cause is unknown. In comparison with open angle glaucoma, secondary glaucoma is characterized by recognizable diseased factors that increase IOP above average levels. In spite

of their dissimilar origination both types of glaucoma share similar characteristics which include dysfunction of the front part of the eye and shows signs such as degradation of ganglion cells of retina and impairment of the optic disk (4, 5).

In the early stages of glaucoma, patients often report poorer vision than expected despite maintaining good visual acuity. This disparity may be attributed to the decline in visual function caused by the disease. Even before the loss of peripheral vision, essential visual abilities such as seeing in low-light conditions, detecting colors, and perceiving depth are diminished. Glaucoma has also been linked to color vision deficiencies, particularly along the blue-yellow axis.(6).

Normal tensional glaucoma is a type of primary angle-open glaucoma that distinguished from color vision and stereopsis defects along with the characteristic visual field defects, defined as optic disk abnormality associated with alterations in the optic disk parameters and progressive glaucomatous thinning of nerve fiber layer of retina. Gonioscopy reveals a wide angle of anterior chamber, and intra-ocular pressure remains within the normal range, below 21 mmHg. (7). Indications of glaucoma involve narrowing of visual field caused by loss of peripheral vision "tunnel vision", reduced quality of vision, whereas fluctuations in color differentiation and contrast-sensitivity changes take place at initial stage in this condition. Patients may also appear with blurriness, dimness or cloudiness (8).

Color vision is the capability of the eyes to perceive and differentiate between different hues of light by the help of specialized cells known as cones. These cells (cones) allow us to perceive different range of colors as they are reactive to different wavelengths of light. 3 light reflects off it and enters in our eyes When we gaze at an object which are then processed by these cells (cones) to create the conception of color (9). Usually color-vision problems are categorized into congenital and acquired types. Color vision which is due to a secondary cause defects defines that later in life due to several reasons such as eye diseases, neurological conditions or medications the changes in color perception are developed. Whereas congenital defects of color vision refer to defective perception of colors present since birth. It can vary from person to person and is determined by genetic factors. These changes can result in trouble to differentiate between certain hues or seeing colors dissimilar than before. Acquired color-vision anomalies are known to influence as many as in males it is 8% and 0.5% of females with significant changes among populations which has been given considerably less attention than congenital color-vision anomalies (10-12).

In many animals, stereopsis (depth perception) is one of the most accurate sources of information appear from the fact that the both eyes have different visual points. This represents that the images on the both retinae are not exactly the same and it is one of the major problem encountered by the visual system to give information to the visual cortex about a three dimensional (stereoscopic) environment by 2D (depthless) retinal photograps. The difference in the position of matching features on the two retinas is known as binocular disparities and the ability of the eyes to perceive depth from these disparities is called stereopsis (13, 14).

OBJECTIVE OF STUDY

- To find the impact of normal tension glaucoma on color vision and stereopsis.
- To find which type of color vision deficiency is more frequently effected in young adults with normal tension glaucoma.

STUDY STYLE

Cross-sectional statistics style was used.

SAMPLING TECHNIQUE

Non-probability suitable sampling methodology was used.

SETTINGS

Statistics were obtained from the patients presented at Al Ehsan Welfare Eye Hospital Lahore.

DURATION OF STUDY

Study was completed in 4 months from March 15, 2024 to July 15, 2024.

SAMPLE SIZE

Sample size (n) = 93

Inclusion Criteria:

- Age group 15-35
- Both genders male and female

- Participants with normal tension glaucoma

Exclusion criteria:

- Presbyopic patients
- Patients with any other ocular or systemic diseases

DATA COLLECTION PROCEDURE

Data was collected at Al Ehsan Eye Hospital. Patients diagnosed with normal tension glaucoma within the age group of 15-35 were selected. Both male and female participants were included. Exclusion criteria were strictly followed, eliminating diabetic patients, presbyopic patients and those with other ocular or systemic diseases. Each participant was interviewed to gather basic demographic information and medical history. Detailed explanations of the study and procedures were provided. From each participants written consent form is taken and the procedure was explained to participants.

The Snellen visual-acuity chart was used to assess the visual-acuity of each participant. Participants were instructed to read the chart from a standard distance and results were recorded according to log mar value. The D15 color vision test was employed to evaluate color vision. Individuals were asked to arrange colored discs in sequence of similarity and their performance was assessed to identify any color vision deficiencies. The Titmus Fly Test was conducted to measure stereopsis. Participants were asked to wear polarized glasses and identify the three-dimensional image of a fly along with other shapes to determine their depth perception capabilities. Intraocular pressure was measured using applanation tonometer. This test helped confirm the diagnosis of normal tension glaucoma and ruled out elevated intraocular pressure.

All data collected from the tests and interviews were carefully recorded in a structured proforma. Each question and procedure were explained to the participants to ensure clarity and accuracy of the responses.

By following this systematic procedure comprehensive data on visual acuity, color vision, stereopsis, and intraocular pressure were collected providing a solid foundation for analyzing the impact of normal tension glaucoma on these visual functions.

Data Collection Tools

- Snellen acuity chart
- Applanation tonometer
- Ophthalmoscope
- D15 color vision test
- Titmus fly test
- Proforma

DATA ANALYSIS

The data analysis was performed using two statistical software programs: Microsoft Excel and SPSS version 21. These tools offer robust features for statistical analysis and data visualization. Descriptive statistics were used to summarize and describe the data's characteristics. For categorical variables, such as gender, frequencies and percentages were calculated to understand the distribution of each category within the sample, offering a clear snapshot of how the data are distributed across different groups.

For quantitative variables, such as age, the mean (average) and standard deviation were calculated. The mean serves as a measure of central tendency, representing the average value of the variable within the sample. The standard deviation reflects the dispersion or variability of the data points around the mean, providing insight into the data's spread.

After calculating the descriptive statistics, associations between risk factors and outcomes were analyzed.

RESULTS

In this study we observed 93 patients with normal tension glaucoma. In which 61 participants were males and 32 were females. For the variable VAOD the values from minimum of 0 to maximum of 1 with a mean-deviation of 0.4153 & SD of 0.34944. Similarly, for the variable VAOS the values also ranged from a minimum of 0 to a maximum of 1 with a mean-deviation of 0.4409 and a standard-deviation of 0.33207. 6 participants were of 15-20 years of age group, 11 participants were of 21-25 years of age-group, 31 participants were of 26-30 years of age group and 45 were of 31-35 years of age-group. The assessment of color vision in right eye among participants revealed 71 (76.3%) individuals exhibited normal color vision. Deutan color-vision deficiency was observed in 15(16.1%) participants. Protan color-vision deficiency was found in 5(5.4%) participants. Tritan color-vision anomaly was the least common with 2(2.2%) participants. In total 93 participants were assessed. Whereas the detection of color-vision in left eye among participants revealed 63 (67.7%) individuals exhibited normal color-vision. Deutan color-vision anomaly was observed in 18 (19.4%) participants. Protan color vision deficiency was found in 11(11.8%) participants. Tritan color vision deficiency was the least common with 1(1.1%) participant. In total 93 participants were assessed. While the minimum stereopsis was 40 sec of arc while the maximum stereopsis was 200 sec of arc. The 29.0% (n=27) of the participants shows the most frequent stereopsis of 80 sec of arc. 24.7% (n=23) individuals show stereopsis of 100 sec of arc. 19.3% (n=18) individual shows stereopsis of 60 sec of arc while 16.1% (n=15) shows stereopsis of 140 sec of arc. 7.5% (n=7) individuals show stereopsis of 40 sec of and the 3.2% (n=3) individuals shows the least stereopsis of 200 sec of arc. The Mean stereopsis was 91.61 seconds of arc with a SD of ± 34.74.

Table 1: Age of participants

Age of patients	Frequency	Percent
15-20 years	6	6.5
21-25 years	11	11.8
26-30 years	31	33.3
31-35 years	45	48.4
Total	93	100

Table 1 shows that 6 (6.5%) participants were of 15 to 20 years of age-group, 11 (11.8%) participants were of 21 to 25 years of age-group, 31 (33.3%) participants were of 26 to 30 years of age-group and 45 (48.4%) were of 31 to 35 years of age-group.

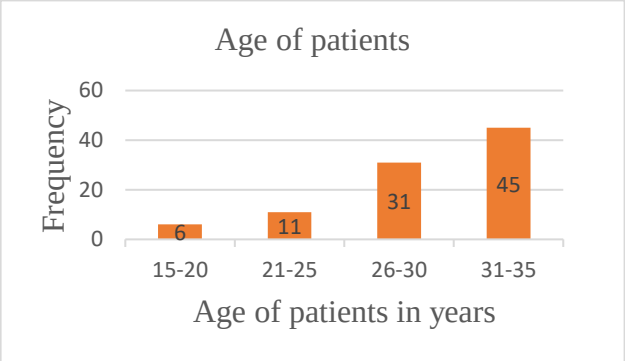

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Table 2: Gender of participants

Gender	Frequency	Percent
Male	61	65.6
Female	32	34.4
Total	93	100

Table 2 shows that statistics for gender were 61 (65.6%) participants were males and 32 (34.4%) were females.

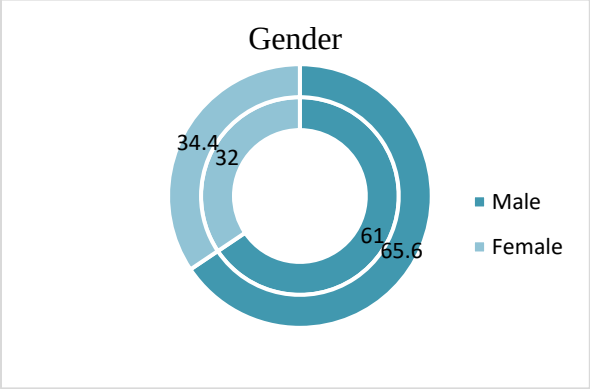

Figure 2: Gender of participants

Figure 2 shows that statistics for gender were 61 (65.6%) participants were males and 32 (34.4%) were females.

Table 3: Color vision right eye

CVOD	Frequency	Percent
Normal	71	76.3
Deutan	15	16.1
Protan	5	5.4
Tritan	2	2.2
Total	93	100

Table 3 shows that the assessment of color vision among participants revealed 71 (76.3%) individuals exhibited normal color vision. Deutan color vision deficiency was observed in 15(16.1%) participants. Protan color vision deficiency was found in 5(5.4%) participants. Tritan color vision deficiency was the least common with 2(2.2%) participants. In total 93 participants were assessed.

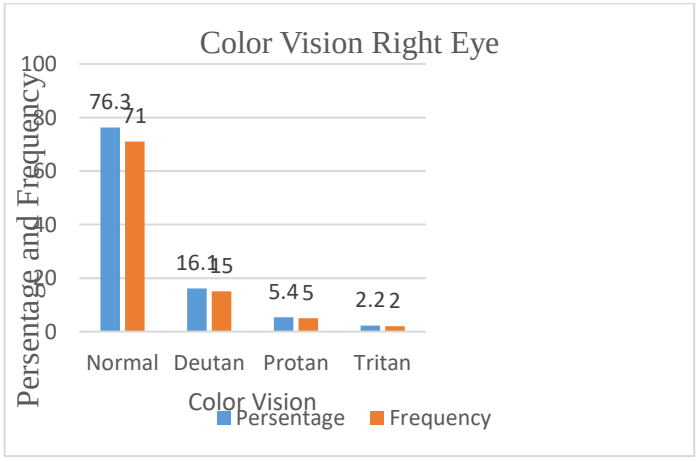

Figure .3: Color vision right eye

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Table 4: Color vision left eye

CVOS	Frequency	Percent
Normal	63	67.7
Deutan	18	19.4
Protan	11	11.8
Tritan	1	1.1
Total	93	100

Table 4 shows that the assessment of color vision among participants revealed 63 (67.7%) individuals exhibited normal color vision. Deutan color vision deficiency was observed in 18 (19.4%) participants. Protan color vision deficiency was found in 11(11.8%) participants. Tritan color vision deficiency was the least common with 1(1.1%) participants. In total 93 participants were assessed.

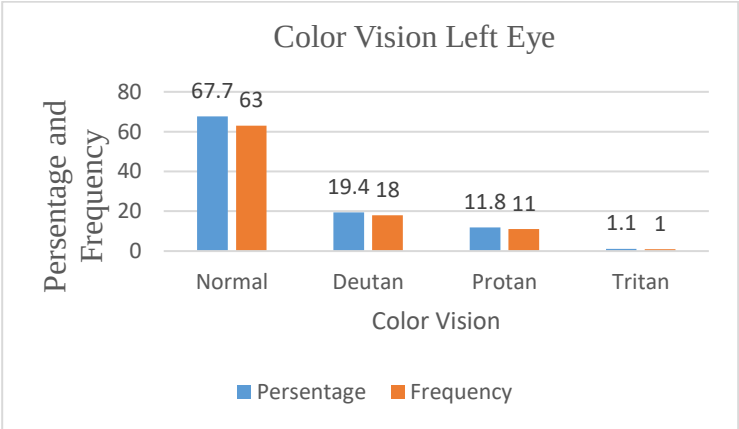

Figure 4: Color vision left eye

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Table 5: Visual Acuity of participants

Visual Acuity	N	Minimum	Maximum	Mean	Std. Deviation
VAOD	93	1	0	0.4153	0.34944
VAOS	93	1	0	0.4409	0.33207

Table 5 shows that this study included 93 participants. For the variable VAOD the values ranged from a minimum of 0 to a maximum of 1 with a mean deviation of 0.4153 and a standard

deviation of 0.34944. Similarly, for the variable VAOS the values also ranged from a minimum of 0 to a maximum of 1 with a mean value of 0.4409 and a standard deviation of 0.33207.

Table 6: Stereopsis of the participants

Stereopsis Value	N	Minimum (seconds of arc)	Maximum (seconds of arc)	Mean	Std. Deviation
STVALUE	93	40	200	91.61	34.74

Table 6 shows that the stereopsis values of 93 participants were analyzed. The minimum stereopsis value recorded was 40 seconds of arc while the maximum value was 200 seconds of arc. The mean stereopsis value was found to be 91.61 with a standard deviation of 34.74.

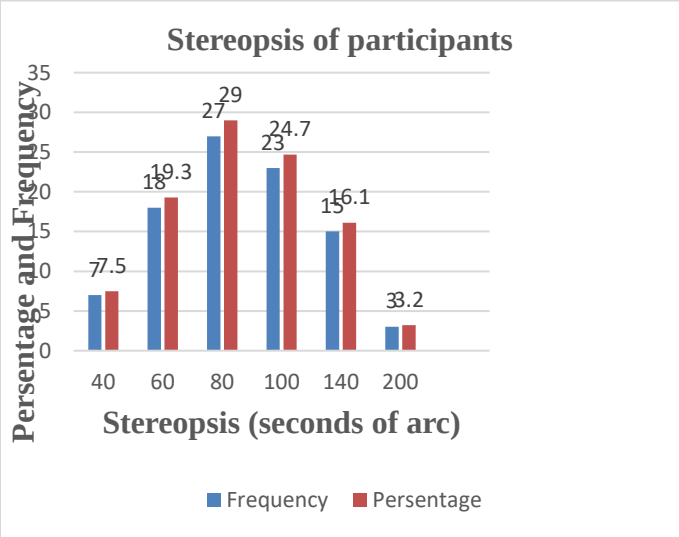

Figure 5: Stereopsis of the participants

Figure 5 shows that the distribution of stereopsis measured in seconds of arc among the participants. The 29.0% (n=27) of the participants shows the most frequent stereopsis of 80 sec of arc. 24.7% (n=23) individuals shows stereopsis of 100 sec of arc. 19.3% (n=18) individual shows stereopsis of 60 sec of arc while 16.1% (n=15) shows stereopsis of 140 sec of arc. 7.5% (n=7) individuals show stereopsis of 40 sec of and the 3.2% (n=3) individuals shows the least stereopsis of 200 sec of arc.

Table 7: Cup to disk ratio of the participant's eyes

C/D Ratio	N	Minimum	Maximum	Mean	Std. Deviation
OD	93	0.2	0.8	0.531	0.1011
OS	93	0.4	0.7	0.613	0.6743

Table 7 shows that the cup to disk ratio of 93 participants were analyzed. The minimum cup to disk ratio recorded was 0.2 while the maximum was 0.8, the mean cup to disk ratio was found to be 0.531 with a standard deviation of 0.1011 in right eye. The minimum cup to disk ratio recorded was 0.4 while the maximum was 0.7, the mean cup to disk ratio was found to be 0.613 with a standard deviation of 0.6743 in left eye.

Table 8: Intraocular pressure of participants

IOP	N	Minimum	Maximum	Mean	Std. Deviation
OD	93	12	21	15.305	2.5446
OS	93	11.4	21.3	15.687	2.9338

Table 8 shows the intraocular pressure (IOP) measurements for the right eye (OD) of 93 patients ranged from a minimum of 12 to a maximum of 21 with a mean of 15.305 and a standard deviation of 2.5446. For the left eye (OS) of the same 93 patients, the IOP ranged from a minimum of 11.4 to a maximum of 21.3 with a mean of 15.687 and a standard deviation of 2.9338.

Table 9: Comparative analysis of cup-to-disk ratio and intraocular pressure in right eye of normal and color vision deficient individuals

CVRE		N	Minimum	Maximum	Mean	Std. Deviation
Normal	IOP R	71	12	19.8	14.423	1.8734
	CD Ratio OD	71	0.2	0.7	0.506	0.0939
Deutan	IOP R	15	12.7	21	17.733	2.6278
	CD Ratio OD	15	0.5	0.7	0.593	0.0704
Protan	IOP R	5	18	20	19.1	0.8124
	CD Ratio OD	5	0.6	0.7	0.64	0.0548
Tritan	IOP R	2	16.9	21	18.95	2.8991
	CD Ratio OD	2	0.6	0.8	0.7	0.1414

Table 9 provides a comparative analysis of the cup-to-disc (CD) ratio and intraocular pressure (IOP) in participants with normal

color-vision and those with various types of color-vision deficiencies (CVD).

In individuals with normal color vision the IOP (OD) ranged from 12 to 19.8 mmHg with a mean of 14.423 mmHg and a standard deviation of 1.8734. The CD ratio in the right eye (OD) for these individuals ranged from 0.2 to 0.7 with a mean of 0.506 and a standard deviation of 0.0939.

For those with deutan color vision deficiency the IOP (OD) ranged from 12.7 to 21 mmHg with a mean of 17.733 mmHg and a standard deviation of 2.6278. The CD ratio OD ranged from 0.5 to 0.7 with a mean of 0.593 and a standard deviation of 0.0704.

Individuals with protan color vision deficiency had an IOP (OD) ranging from 18 to 20 mmHg with a mean of 19.1 mmHg and a standard deviation of 0.8124. The CD ratio OD in these individuals ranged from 0.6 to 0.7 with a mean of 0.64 and a standard deviation of 0.0548.

In those with tritan color vision deficiency the IOP (OD) ranged from 16.9 to 21 mmHg with a mean of 18.95 mmHg and a standard deviation of 2.8991. The CD ratio OD ranged from 0.6 to 0.8 with a mean of 0.7 and a standard deviation of 0.1414.

Table 10: Comparative analysis of cup-to-disc ratio and intraocular pressure in left eye of normal and color vision deficient individuals

CVLE		N	Minimum	Maximum	Mean	Std. Deviation
Normal	CD Ratio OS	63	0.4	0.6	0.514	0.0564
	IOP L	63	11.4	21	14.586	2.3188
Deutan	CD Ratio OS	18	0.5	0.7	0.572	0.0826
	IOPL	18	12	20.4	16.878	2.597
Protan	CD Ratio OS	11	0.6	0.7	1.245	1.9096
	IOP L	11	13.4	21.3	19.673	2.2419
Tritan	CD Ratio OS	1	0.6	0.6	0.6	.
	IOP L	1	19.8	19.8	19.8	.

Table 10 presents a comparative analysis of the cup-to-disc (CD) ratio and intraocular pressure (IOP) in the left eye (OS) for individuals with normal color vision and those with various types of color vision deficiencies (CVD).

In individuals with normal color vision the CD ratio OS ranged from 0.4 to 0.6 with a mean of 0.514 and a standard deviation of 0.0564. The IOP in the left eye (OS) for these individuals ranged from 11.4 to 21 mmHg with a mean of 14.586 mmHg and a standard deviation of 2.3188.

For those with deutan color vision deficiency the CD ratio OS ranged from 0.5 to 0.7 with a mean of 0.572 and a standard deviation of 0.0826. The IOP (OS) ranged from 12 to 20.4 mmHg with a mean of 16.878 mmHg and a standard deviation of 2.597.

Individuals with protan color vision deficiency had a CD ratio OS ranging from 0.6 to 0.7 with a mean of 1.245 and a standard deviation of 1.9096. The IOP L in these individuals ranged from 13.4 to 21.3 mmHg, with a mean of 19.673 mmHg and a standard deviation of 2.2419.

For those with tritan color vision deficiency both the CD ratio OS and IOP (OS) were constant at 0.6 and 19.8 mmHg respectively with no standard deviation as only one individual was assessed.

CONCLUSION

In conclusion this study offers important insights into color vision and stereopsis in young adults with NTG. Although many participants retain normal color vision some do show deficiencies that need monitoring. The variability in stereopsis emphasizes the need for thorough visual assessments in NTG patients. Comparing the consequences of this study with existing research highlights the need for age-matched studies and suggests that NTG has a noticeable but not major impact on visual functions.

RECOMMENDATIONS

- Implement routine screening for color vision deficiencies and stereopsis in young adults diagnosed with normal tension glaucoma (NTG) to enable early detection and intervention.
- Include these tests in standard ophthalmic examinations to provide a comprehensive assessment of visual functions.
- Increase awareness among healthcare providers and the general public about the importance of regular eye examinations particularly for young adults who may be at risk of NTG.
- Educate patients on the potential impact of NTG on color vision and depth perception emphasizing the significance of early diagnosis and management.
- Invest in the development and utilization of advanced diagnostic tools and techniques for more accurate assessment of visual functions in NTG patients.
- Develop personalized treatment plans that address the specific visual impairments of NTG patients including targeted therapies for those with identified color vision deficiencies or stereopsis issues.
- Provide additional support and resources for patients with significant visual impairments to enhance their quality of life.

LIMITATIONS

- The study has a fixed sample size that can affect relevancy of the observations. Research in future should aim for greater and diverse participant groups.
- The study was observed at a single location (Al Ehsan Eye Hospital) that may restrict the applicability of results to some other regions/populations with different kind of demographic abilities.
- Excluding patients with diabetes, presbyopia, or other ocular/systemic diseases might limit the understanding of NTG's impact in individuals with coexisting conditions.
- The dependence on self-collected data and patient interviews may have recall bias or subjective interpretation affecting the accuracy of the collected information.
- The study used specific tools like the Snellen chart, D15 color vision test, and Titmus Fly Test, which may have inherent limitations in sensitivity and specificity. Exploring additional or alternative diagnostic tools could provide a more comprehensive evaluation.
- Variations in testing environments such as lighting conditions could impact the results of visual acuity, color vision and stereopsis tests. Standardizing these conditions in future studies is crucial for consistency.

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Data availability statement:

Due to the privacy issues data is not available to show. Corresponding author should be directed for the availability of data.

Competing Interest declaration: No

Ethical statement: This study was conducted in accordance with ethical guidelines and principles.

Funding Declaration: No

Author Contribution Statement:

Kiran Shakeel Alvi.: Conceptualization, - original draft. Data curation, Software

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Nimra Khalid: Investigation, Writing

Amna Shakeel Alvi: Writing - review & editing.

Salman Amjad: Statistic

Saif Ahsan: Drafting

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

This article is not published anywhere else.