

# Prevalence and awareness levels of color blindness among students of faculty of dentistry and dental prosthesis technology program

## Purpose

The aim of this study was to evaluate the prevalence and awareness levels of color blindness among students in a faculty of dentistry and dental prosthesis technology program in two different universities.

## Materials and Methods

A survey of awareness of color blindness among 710 students (males: n=271; females: n=439) in the faculty of dentistry and dental prosthesis technology program of Gazi University and Ankara Medipol University in 2019–2021 was conducted. The color vision status of 442 of the students (males; n=155; females: n=287) was assessed using an online Ishihara color blindness test. The data obtained were subjected to statistical analysis using SPSS.

## Results

There was no statistically significant difference in the color blindness scores in terms of sex (males:  $0.75 \pm 0.84$ ; females:  $0.64 \pm 0.75$ ) ( $p=0.226$ ). The color blindness scores of the dental prosthesis technology students were statistically higher than those of the faculty of dentistry students ( $p=0.028$ ). Education year was significantly associated with a compromised ability to identify colors properly ( $p=0.040$ ). There was no statistically significant difference in terms of awareness levels of color blindness according to the number of years of education ( $p>0.005$ ).

## Conclusion

In terms of the prevalence of color blindness, 2.2% of faculty of dentistry and dental prosthesis technology students had a moderate-to-high level of color blindness. Students' awareness of their own color vision status was very low. The educational content of faculty of dentistry and dental prosthesis technology programs on color blindness should be enriched.

**Keywords:** Color vision defects, ishihara test, dentistry, dental prosthesis technology, awareness

## Introduction

Esthetics play a critical role in achieving patient satisfaction in prosthetic rehabilitation. Expected esthetic results can be achieved with appropriate morphology and color application in the restoration. One of the most important goals of prosthetic treatment is for the restoration to be compatible with the natural tooth color, especially in fixed and partial teeth or implant-supported prostheses.

Color blindness (color vision defects) can affect color perception and therefore the ability to achieve color matching (1,2). Color blindness is a common color vision anomaly in the population (1,3). Congenital color blindness is the result of genetic mutations, which affect cone pigment expression in the retina. A color vision anomaly may also be an early sign

Ayşe Seda Ataoğlu<sup>1</sup> ,  
Gulfem Ergun<sup>2</sup> 

ORCID IDs of the authors: A.S.A. 0000-0003-3990-179X;  
G.E. 0000-0001-9981-5522

<sup>1</sup>Private Practice, Ankara, Turkiye

<sup>2</sup>Department of Prosthodontics, Faculty of Dentistry,  
Gazi University, Ankara, Turkiye

Corresponding Author: Ayşe Seda Ataoğlu

E-mail: sedaataol@gmail.com

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of eye damage. For example, color vision anomalies may be linked to optic nerve abnormalities in the retina or disorders in the brain. Diseases, such as cone cell dystrophy and acromatopsia, can also cause color blindness (4).

Vision is a psycho-physical phenomenon based on the sensitivity of retinal cones to wavelengths of about 400–700 nm in the electromagnetic spectrum (5). Three types of cones (red, blue and green) are responsible for spectral sensitivity required for color perception in the eye. The absence of any one of these three color-receiving cones makes it impossible to distinguish colors, and color blindness occurs. Protanopia refers to red cone loss and affects the ability to detect long-wavelength light. Deuteranopia refers to color blindness due to the absence of green cones. The visual spectrum in individuals with deuteranopia is almost normal due to the presence of red cones, which detect the color red at long wavelengths. Red-green color blindness is a genetic disorder that occurs almost exclusively in males. Blue-yellow color blindness is called tritanopia, which is extremely rare (1,5,6).

The Ishihara test is the most commonly used conventional method for detecting color blindness. It provides a rapid and accurate assessment of congenital color vision deficiency. This test consists of colored cards, which are usually used to diagnose red-green color deficiency. It is very important to know whether a person is color blind, to identify and inform dental workers (dentists and dental technicians) about color blindness, to obtain the necessary support for the person's profession, and to pursue a successful career (7).

The aim of this study was to evaluate the prevalence and awareness of color blindness among faculty of dentistry and dental prosthesis technology students attending a private and public university, respectively. The null hypothesis of the present study is that faculty of dentistry and dental prosthesis technology students will demonstrate low level of knowledge about color blindness.

## Material and Methods

### *Ethical statement*

This study was approved by the noninterventional clinical research ethics board of Ankara Medipol University (74791132-109/311). Written informed consent was obtained from each participant. All the participants included were informed about the goals of the study.

### *Study questionnaire*

A survey of awareness of color blindness was created using Google Forms. Students in the faculty of dentistry and dental prosthesis technology program were then invited to participate in the survey via a referral link:

([https://www.color-blindness.com/ishihara\\_cvd\\_test/ishihara\\_cvd\\_test.html?iframe=true&width=500&height=428](https://www.color-blindness.com/ishihara_cvd_test/ishihara_cvd_test.html?iframe=true&width=500&height=428)).

### *Study participants*

All voluntarily students in the faculty of dentistry of Gazi University, Ankara, Turkey and students in faculty of dentistry and dental prosthesis technology program in Ankara Medipol University were included as the source popula-

tions of the study. Presence of known color blindness or any systemic disease in the past were not used as an exclusion criterion. In total, 710 students (males:  $n = 271$ ; females:  $n = 439$ ) in the faculty of dentistry of Gazi University, Ankara, Turkey ( $n=544$ ) and students in faculty of dentistry and dental prosthesis technology program in Ankara Medipol University ( $n=166$ ), Ankara, Turkey in 2019–2021 completed the survey. The survey was completed online to provide a subjective evaluation and to eliminate the directives of the practitioner during survey.

### *Color blindness test*

The color vision status of 442 of the students (males:  $n = 155$ ; females:  $n = 287$ ) was evaluated using an online Ishihara color blindness test. In the test, 38 plates were shown to each of the 442 participants, and the participants were asked to detect the numbers and lines on the color plates. They were asked to email screenshots of their test results to the lead author (A.S.A.). The results of the color blindness test were scored on a scale of 0–4, as follows: 0 = none, 1 = weak, 2 = mild, 3 = moderate, and 4 = high.

### *Statistical analysis*

The data obtained were stratified according to sex, type of institution (private or public university), and education year (first, second, third, fourth, and fifth). The compliance of continuous variables with a normal distribution was tested using the Shapiro–Wilk test. Descriptive statistics were used to define continuous variables (mean, standard deviation (SD), minimum, median, and maximum. For comparisons of two independent variables that were not compatible with a normal distribution, the Mann–Whitney U test was used. For comparisons of more than two independent variables that were not compatible with a normal distribution, the Kruskal–Wallis test was applied. A chi-square or Fisher's exact test, where appropriate was used to examine the relationship between categorical variables. The statistical significance level was set at 0.05. All analyses were performed using IBM SPSS Statistics for Windows, version 24.0 (IBM Corp., Armonk, NY, USA).

## Results

There were 643 (90.6%) faculty of dentistry students and 67 (9.4%) dental prosthesis technology program students in different education years. Among the participants, 544 (76.6%) students were attending Gazi University, and 166 (23.4%) students were attending Ankara Medipol University. According to the survey, 659 (92.8%) students had no systemic diseases, 24 (3.4%) students reported having a systemic disease, and 27 (3.8%) students said they had no knowledge of whether they had a systemic disease.

Among the participants, 0.2%, 2%, 12.4%, and 36.2% had a high, moderate, mild, or weak degree of color blindness, with 1% of females having a moderate-to-high level of color blindness (Table 1). No color blindness was detected in 49.1% of the study population (Table 2). According to the results, 13.3% of the participants who stated they were not color blind had a mild or moderate degree of color blindness (Table 3).

**Table 1: Color blindness score according to gender.**

| Color Blindness | Male |      | Female |      |
|-----------------|------|------|--------|------|
|                 | n    | %    | n      | %    |
| 0               | 71   | 45.8 | 146    | 50.9 |
| 1               | 58   | 37.4 | 102    | 35.5 |
| 2               | 19   | 12.3 | 36     | 12.5 |
| 3               | 7    | 4.5  | 2      | 0.7  |
| 4               | 0    | 0.0  | 1      | 0.3  |

**Table 2: Average of color blindness score and general questions about the color blindness.**

|                       | mean+SD   | Med. (Min.-Max.) |
|-----------------------|-----------|------------------|
| Color Blindness Score | 0.68+0.78 | 1 (0-4)          |

  

|   | n                                     | %        |
|---|---------------------------------------|----------|
| Color Blindness Score   | 0                                     | 217 49.1 |
|   | 1                                     | 160 36.2 |
|   | 2                                     | 55 12.4  |
|   | 3                                     | 9 2.0    |
|   | 4                                     | 1 0.2    |
| Q10. Are You Colorblind?  |                                       |          |
|   | have no information                   | 19 2.7   |
|   | yes                                   | 9 1.3    |
|   | no                                    | 682 96.1 |
| Q11. How did you learn if you are colorblind?   | unanswered                            | 682 96.0 |
|   | my family noticed                     | 3 0.4    |
|   | during my education life              | 7 1.0    |
|   | in traffic                            |          |
|   | other (did not learn)                 | 1 0.1    |
|   | other (during color blindness test)   | 1 0.1    |
|   | other (can not separate close colors) | 1 0.1    |
|   | other (absent)                        | 15 2.1   |
| Q12. Have you had a color blindness test?   |                                       |          |
|   | yes                                   | 283 39.9 |
|   | do not remember                       | 96 13.5  |
|   | no                                    | 331 46.6 |
| Q16. If you have information about the cause of your color blindness, please write the reason | unanswered                            | 692 97.5 |
|   | have no information                   | 2 0.3    |
|   | genetic                               | 4 0.5    |
|   | wonder                                | 1 0.1    |
|   | not color blind                       | 4 0.6    |
|   | color pigment deficiency              | 1 0.1    |
|   | absent                                | 6 0.8    |

**Table 2: Continue.**

|   | n                               | %        |
|---|---------------------------------|----------|
| Q18. Is there a colorblind in your family?                                  | unanswered                      | 272 38.3 |
|   | have no information             | 40 5.6   |
|   | yes                             | 28 3.9   |
|   | no                              | 370 52.1 |
| Q19. If there is a colorblind in your family, what is the proximity degree? | unanswered                      | 673 94.8 |
|   | 1 <sup>st</sup> degree relative | 1 0.1    |
|   | 3 <sup>rd</sup> degree relative | 3 0.4    |
|   | mother                          | 2 0.3    |
|   | grandmother                     | 1 0.1    |
|   | father                          | 10 1.4   |
|   | grandfather                     | 3 0.4    |
|   | brother                         | 5 0.7    |
|   | cousin                          | 4 0.6    |
| absent  | 8 1.1                           |          |

**Table 3: Correlation between color blind awareness vs color blind score.**

|                          | Mean±SD             | Med. (Min.-Max.) |
|--------------------------|---------------------|------------------|
| Q10. Are You Colorblind? | have no information | 1+1.4 0 (0-4)    |
|                          | yes                 | 2.8+0.45 3 (2-3) |
|                          | no                  | 0.65+0.7 1 (0-3) |

  

| Color Blindness | have no information |      | yes |      | no  |      |
|-----------------|---------------------|------|-----|------|-----|------|
|                 | n                   | %    | n   | %    | n   | %    |
| 0               | 6                   | 54.5 | 0   | 0.0  | 211 | 49.5 |
| 1               | 2                   | 18.2 | 0   | 0.0  | 158 | 37.1 |
| 2               | 1                   | 9.1  | 1   | 11.1 | 53  | 12.4 |
| 3               | 1                   | 9.1  | 4   | 44.4 | 4   | 0.9  |
| 4               | 1                   | 9.1  | 0   | 0.0  | 0   | 0.0  |

There were statistically significant differences in terms of the distribution of color blindness according to the educational institution and education year ( $p = 0.02$  and  $p = 0.040$  respectively). The average score for color blindness among the students in the dental prosthesis technology program was statistically significantly higher than that of the students in the faculty of dentistry ( $p = 0.028$ ).

The color blindness scores among education years were statistically significant only between second and fifth years ( $p = 0.003$ ). A post-hoc multiple comparison of the color blindness scores of other education years revealed no statistically significant difference in those of first-, third-, and fourth-year students. In addition, there was no statistically significant association between color blindness scores and sex or institution type (i.e., private vs. public) (Table 4).

There was no statistically significant difference in the level of knowledge of about the causes of color blindness

**Table 4:** Correlation between Color Blind Score vs gender, the year of education and institution type. Mann-Whitney U test<sup>1</sup>, Kruskal Wallis test<sup>2</sup>

|   |                           | Color Blindness Score |                  |                          |
|---|---------------------------|-----------------------|------------------|--------------------------|
|   |                           | Mean±SD               | Med. (Min.-Max.) | p                        |
| Gender                                      | Male                      | 0.75±0.84             | 1(0-3)           | 0.226 <sup>1</sup>       |
|   | Female                    | 0.64±0.75             | 0(0-4)           |                          |
| Q5. In which higher education do you study? | Faculty                   | 0.66±0.78             | 0(0-4)           | <b>0.028<sup>1</sup></b> |
|   | Collage                   | 0.89±0.79             | 1(0-2)           |                          |
| Q6. What year of your education are you in? | 1                         | 0.7±0.82              | 0.5(0-4)         | <b>0.040<sup>2</sup></b> |
|   | 2                         | 0.48±0.65             | 0(0-3)           |                          |
|   | 3                         | 0.77±0.71             | 1(0-2)           |                          |
|   | 4                         | 0.69±0.8              | 1(0-3)           |                          |
|   | 5                         | 0.9±0.85              | 1(0-3)           |                          |
| Institution                                 | Ankara Medipol University | 0.73±0.76             | 1(0-2)           | 0.354 <sup>1</sup>       |
|   | Gazi University           | 0.67±0.79             | 0.5(0-4)         |                          |

**Post-Hoc two way analyses (p<sup>1</sup>)**

| Education year | Color Blindness Score |
|----------------|-----------------------|
| 1 vs. 2        | 0.041                 |
| 1 vs. 3        | 0.401                 |
| 1 vs. 4        | 0.941                 |
| 1 vs. 5        | 0.125                 |
| 2 vs. 3        | 0.019                 |
| 2 vs. 4        | 0.151                 |
| 2 vs. 5        | <b>0.003</b>          |
| 3 vs. 4        | 0.425                 |
| 3 vs. 5        | 0.571                 |
| 4 vs. 5        | 0.185                 |

between the faculty of dentistry students and dental prosthesis technology program students and no statistically significant difference in the level of knowledge according to education year. 56.5% of the students in faculty of dentistry and 43.3% of the students of collage selected genetic causes and acquired eye diseases as the reasons for color blindness. Both male and female students considered their level of knowledge of color blindness to be “medium” (Table 5).

A statistically significantly higher number of faculty of dentistry students than students in the dental prosthesis technology program considered that color blindness was permanent ( $p = 0.022$ ). More students in the faculty of dentistry than in the dental prosthesis technology program responded positively to the statement “If I had learned that I was color blind before choosing dentistry, it would have affected my choice of profession” ( $p = 0.001$ ) (Table 5). The vast majority of students, especially third-year students, thought that color blindness had important implications for professional practice as dentists and dental prosthesis technicians, (Table 6).

The majority of the students were undecided about whether increased use of digital technology in dentistry would have a positive or negative impact on professional skills among practitioners with color vision defects (Table 6).

**Discussion**

The null hypothesis of the present study was accepted that faculty of dentistry and dental prosthesis technology students demonstrated low level of knowledge about color blindness. Color blindness among dental practitioners in clinical or laboratory settings has implications for job performance. Previous studies showed that individuals who were color blind made significantly more errors in terms of hue and chroma selection in X test than those with normal vision (5,8). Knowledge about the underlying causes and consequences of color blindness can aid career decision making. For example, an individual who is color blind and wishes to pursue a career in dentistry can select to work as part of a team in a clinical or laboratory setting where aesthetic prostheses are expected. In addition, the availability of electronic shade matching devices, such as like colorimeters, spectrophotometers, and digital color analyzers, may make it feasible for color blind individuals to practice dentistry (5).

There are many tests for color blindness. Different color blindness test eg. Pseudoisochromatic plates like Ishihara test and Dvorine, Bostrom, AO HRR, Farnsworth-Munsell 100 Hue Test can be used. However, these tests are not common because of its expense and need for performing by a by a specialist (5). So, in our study, the Ishihara test were used to screen for color blindness. Both the survey and Ishihara color

**Table 5:** Questions about knowledge level of color blindness.

|   |   | Faculty |      | College |      | p     |
|---|---|---------|------|---------|------|-------|
|   |   | n       | %    | n       | %    |       |
| Q9. Do you have any information about what is color blindness?  | have no information   | 17      | 2.6  | 2       | 3.0  | 0.224 |
|   | yes   | 607     | 94.4 | 60      | 89.6 |       |
|   | no  | 19      | 3.0  | 5       | 7.5  |       |
| Q12. Have you had a color blindness test?   | yes   | 255     | 39.7 | 28      | 41.8 | 0.309 |
|   | do not remember   | 91      | 14.2 | 5       | 7.5  |       |
|   | no  | 297     | 46.2 | 34      | 50.7 |       |
| Q13. Indicate your level of knowledge about the reasons of color blindness                                  | very low  | 38      | 5.9  | 3       | 4.5  | 0.765 |
|   | very high   | 8       | 1.2  | 0       | 0.0  |       |
|   | low   | 119     | 18.5 | 15      | 22.4 |       |
|   | medium  | 378     | 58.8 | 37      | 55.2 |       |
|   | absent  | 23      | 3.6  | 4       | 6.0  |       |
|   | high  | 77      | 12.0 | 8       | 11.9 |       |
| Q14. What are the causes of color blindness?  | brain injuries  | 5       | 0.8  | 0       | 0.0  | 0.055 |
|   | have no information   | 2       | 0.3  | 0       | 0.0  |       |
|   | have no information maybe genetic   | 1       | 0.2  | 0       | 0.0  |       |
|   | genetic   | 467     | 72.6 | 37      | 55.2 |       |
|   | know it's related to the receptors in the eye   | 1       | 0.2  | 0       | 0.0  |       |
|   | all of them   | 1       | 0.2  | 0       | 0.0  |       |
|   | acquired eye diseases   | 162     | 25.2 | 29      | 43.3 |       |
|   | color blindness can occur due to the lack of pigment in photoreceptor cells and the failure of these cells to function properly | 1       | 0.2  | 0       | 0.0  |       |
|   | there is no reason  | 0       | 0.0  | 1       | 1.5  |       |
|   | age   | 3       | 0.5  | 0       | 0.0  |       |
| Q15. If you know you are color blind do you have any information about the cause of color blindness of you? | unanswered  | 239     | 37.2 | 33      | 49.3 | 0.151 |
|   | have information  | 52      | 8.1  | 4       | 6.0  |       |
|   | have no information   | 352     | 54.7 | 30      | 44.8 |       |
| Q17. Is color blindness genetic?  | unanswered  | 239     | 37.2 | 33      | 49.3 | 0.192 |
|   | yes   | 288     | 44.8 | 19      | 28.4 |       |
|   | no  | 4       | 0.6  | 1       | 1.5  |       |
|   | indecisive  | 36      | 5.6  | 4       | 6.0  |       |
|   | definitely yes  | 75      | 11.7 | 10      | 14.9 |       |
|   | definitely no   | 1       | 0.2  | 0       | 0.0  |       |
| Q20. Is color blindness permanent or temporary?   | unanswered  | 239     | 37.2 | 33      | 49.3 | 0.022 |
|   | it is temporary   | 1       | 0.2  | 1       | 1.5  |       |
|   | it is permanent   | 288     | 44.8 | 18      | 26.9 |       |
|   | indecisive  | 57      | 8.9  | 8       | 11.9 |       |
|   | it is absolutely permanent  | 58      | 9.0  | 7       | 10.4 |       |
| Q21. Do you think color blindness has professional importance for dentists / dental prosthetic technicians? | unanswered  | 239     | 37.2 | 33      | 49.3 | 0.464 |
|   | yes   | 199     | 30.9 | 17      | 25.4 |       |
|   | no  | 24      | 3.7  | 2       | 3.0  |       |
|   | indecisive  | 71      | 11.0 | 4       | 6.0  |       |
|   | definitely yes  | 109     | 17.0 | 11      | 16.4 |       |
|   | definitely no   | 1       | 0.2  | 0       | 0.0  |       |

**Table 5:** *Continue.*

|  |                | Faculty |      | College |      | p      |
|--|----------------|---------|------|---------|------|--------|
|  |                | n       | %    | n       | %    |        |
| <b>Q22. If you are color blind do you think it will affect your professional success?</b>  | unanswered     | 239     | 37.2 | 33      | 49.3 | 0.213  |
|  | yes            | 189     | 29.4 | 16      | 23.9 |        |
|  | no             | 50      | 7.8  | 3       | 4.5  |        |
|  | indecisive     | 105     | 16.3 | 6       | 9.0  |        |
|  | definitely yes | 55      | 8.6  | 8       | 11.9 |        |
|  | definitely no  | 5       | 0.8  | 1       | 1.5  |        |
| <b>Q23. Do you think the increasing use of digital dentistry will increase the effect of color blindness on professional skills in a negative way?</b> | unanswered     | 239     | 37.2 | 33      | 49.3 | 0.117  |
|  | yes            | 147     | 22.9 | 11      | 16.4 |        |
|  | no             | 68      | 10.6 | 3       | 4.5  |        |
|  | indecisive     | 154     | 24.0 | 13      | 19.4 |        |
|  | definitely yes | 30      | 4.7  | 6       | 9.0  |        |
|  | definitely no  | 5       | 0.8  | 1       | 1.5  |        |
| <b>Q24. If you had learned that you are colorblind before choosing your profession, would it affect your choice of profession?</b>                     | unanswered     | 239     | 37.2 | 33      | 49.3 | <0.001 |
|  | yes            | 113     | 17.6 | 11      | 16.4 |        |
|  | no             | 114     | 17.7 | 6       | 9.0  |        |
|  | indecisive     | 132     | 20.5 | 6       | 9.0  |        |
|  | definitely yes | 26      | 4.0  | 10      | 14.9 |        |
|  | definitely no  | 19      | 3.0  | 1       | 1.5  |        |

**Table 6:** *Questions about the effect of color blindness on profession.*

|   |   | 1 <sup>st</sup> class |      | 2 <sup>nd</sup> class |      | 3 <sup>rd</sup> class |      | 4 <sup>th</sup> class |      | 5 <sup>th</sup> class |      | p     |
|---|---|-----------------------|------|-----------------------|------|-----------------------|------|-----------------------|------|-----------------------|------|-------|
|   |   | n                     | %    | n                     | %    | n                     | %    | n                     | %    | n                     | %    |       |
| <b>Q9. Do you have any information about what is color blindness?</b>             | have no information                           | 9                     | 2.9  | 5                     | 3.8  | 2                     | 2.5  | 2                     | 1.7  | 1                     | 1.3  | 0.554 |
|   | yes   | 290                   | 94.8 | 122                   | 91.7 | 74                    | 93.7 | 107                   | 92.2 | 74                    | 97.4 |       |
|   | no  | 7                     | 2.3  | 6                     | 4.5  | 3                     | 3.8  | 7                     | 6.0  | 1                     | 1.3  |       |
| <b>Q12. Have you had a color blindness test?</b>                                  | yes   | 117                   | 38.2 | 51                    | 38.3 | 35                    | 44.3 | 46                    | 39.7 | 34                    | 44.7 | 0.878 |
|   | do not remember                               | 47                    | 15.4 | 15                    | 11.3 | 11                    | 13.9 | 14                    | 12.1 | 9                     | 11.8 |       |
|   | no  | 142                   | 46.4 | 67                    | 50.4 | 33                    | 41.8 | 56                    | 48.3 | 33                    | 43.4 |       |
| <b>Q13. Indicate your level of knowledge about the reasons of color blindness</b> | very low                                      | 16                    | 5.2  | 7                     | 5.3  | 2                     | 2.5  | 8                     | 6.9  | 8                     | 10.5 | 0.466 |
|   | very high                                     | 4                     | 1.3  | 0                     | 0.0  | 1                     | 1.3  | 2                     | 1.7  | 1                     | 1.3  |       |
|   | low   | 53                    | 17.3 | 25                    | 18.8 | 22                    | 27.8 | 23                    | 19.8 | 11                    | 14.5 |       |
|   | medium  | 180                   | 58.8 | 78                    | 58.6 | 41                    | 51.9 | 68                    | 58.6 | 48                    | 63.2 |       |
|   | absent  | 14                    | 4.6  | 3                     | 2.3  | 4                     | 5.1  | 2                     | 1.7  | 4                     | 5.3  |       |
|   | high  | 39                    | 12.7 | 20                    | 15.0 | 9                     | 11.4 | 13                    | 11.2 | 4                     | 5.3  |       |
| <b>Q14. What are the causes of color blindness?</b>                               | brain injuries                                | 5                     | 1.6  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 0.417 |
|   | have no information                           | 1                     | 0.3  | 0                     | 0.0  | 1                     | 1.3  | 0                     | 0.0  | 0                     | 0.0  |       |
|   | have no information maybe genetic             | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 1                     | 1.3  |       |
|   | genetic                                       | 217                   | 70.9 | 103                   | 77.4 | 53                    | 67.1 | 77                    | 66.4 | 54                    | 71.1 |       |
|   | know it's related to the receptors in the eye | 1                     | 0.3  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  |       |
|   | all of them                                   | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 1                     | 0.9  | 0                     | 0.0  |       |
|   | acquired eye diseases                         | 80                    | 26.1 | 29                    | 21.8 | 25                    | 31.6 | 36                    | 31.0 | 21                    | 27.6 |       |

Table 6: Continue.

|   |   | 1 <sup>st</sup> class |      | 2 <sup>nd</sup> class |      | 3 <sup>rd</sup> class |      | 4 <sup>th</sup> class |      | 5 <sup>th</sup> class |      | p     |
|---|---|-----------------------|------|-----------------------|------|-----------------------|------|-----------------------|------|-----------------------|------|-------|
|   |   | n                     | %    | n                     | %    | n                     | %    | n                     | %    | n                     | %    |       |
| Q14. What are the causes of color blindness?  | color blindness can occur due to the lack of pigment in photoreceptor cells and the failure of these cells to function properly | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 1                     | 0.9  | 0                     | 0.0  | 0.417 |
|   | there is no reason  | 1                     | 0.3  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  |       |
|   | age   | 1                     | 0.3  | 1                     | 0.8  | 0                     | 0.0  | 1                     | 0.9  | 0                     | 0.0  |       |
| Q15. If you know you are color blind do you have any information about the cause of color blindness of you?                                     | unanswered  | 109                   | 35.6 | 45                    | 33.8 | 34                    | 43.0 | 50                    | 43.1 | 34                    | 44.7 | 0.258 |
|   | have information  | 22                    | 7.2  | 11                    | 8.3  | 5                     | 6.3  | 14                    | 12.1 | 4                     | 5.3  |       |
|   | have no information   | 175                   | 57.2 | 77                    | 57.9 | 40                    | 50.6 | 52                    | 44.8 | 38                    | 50.0 |       |
| Q17. Is color blindness genetic?  | unanswered  | 109                   | 35.6 | 45                    | 33.8 | 34                    | 43.0 | 50                    | 43.1 | 34                    | 44.7 | 0.811 |
|   | yes   | 135                   | 44.1 | 66                    | 49.6 | 33                    | 41.8 | 45                    | 38.8 | 28                    | 36.8 |       |
|   | no  | 2                     | 0.7  | 0                     | 0.0  | 0                     | 0.0  | 2                     | 1.7  | 1                     | 1.3  |       |
|   | indecisive  | 17                    | 5.6  | 5                     | 3.8  | 5                     | 6.3  | 8                     | 6.9  | 5                     | 6.6  |       |
|   | definitely yes  | 42                    | 13.7 | 17                    | 12.8 | 7                     | 8.9  | 11                    | 9.5  | 8                     | 10.5 |       |
|   | definitely no   | 1                     | 0.3  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  |       |
| Q20. Is color blindness permanent or temporary?   | unanswered  | 109                   | 35.6 | 45                    | 33.8 | 34                    | 43.0 | 50                    | 43.1 | 34                    | 44.7 | 0.799 |
|   | it is temporary   | 2                     | 0.7  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  |       |
|   | it is permanent   | 133                   | 43.5 | 63                    | 47.4 | 32                    | 40.5 | 50                    | 43.1 | 28                    | 36.8 |       |
|   | indecisive  | 34                    | 11.1 | 12                    | 9.0  | 7                     | 8.9  | 6                     | 5.2  | 6                     | 7.9  |       |
| Q21. Do you think color blindness has professional importance for dentists / dental prosthetic technicians?                                     | it is absolutely permanent  | 28                    | 9.2  | 13                    | 9.8  | 6                     | 7.6  | 10                    | 8.6  | 8                     | 10.5 | 0.013 |
|   | unanswered  | 109                   | 35.6 | 45                    | 33.8 | 34                    | 43.0 | 50                    | 43.1 | 34                    | 44.7 |       |
|   | yes   | 101                   | 33.0 | 34                    | 25.6 | 28                    | 35.4 | 35                    | 30.2 | 18                    | 23.7 |       |
|   | no  | 7                     | 2.3  | 5                     | 3.8  | 2                     | 2.5  | 7                     | 6.0  | 5                     | 6.6  |       |
|   | indecisive  | 46                    | 15.0 | 13                    | 9.8  | 4                     | 5.1  | 8                     | 6.9  | 4                     | 5.3  |       |
|   | definitely yes  | 42                    | 13.7 | 36                    | 27.1 | 11                    | 13.9 | 16                    | 13.8 | 15                    | 19.7 |       |
| Q22. If you are color blind do you think it will affect your professional success?  | definitely no   | 1                     | 0.3  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 0                     | 0.0  | 0.181 |
|   | unanswered  | 109                   | 35.6 | 45                    | 33.8 | 34                    | 43.0 | 50                    | 43.1 | 34                    | 44.7 |       |
|   | yes   | 93                    | 30.4 | 35                    | 26.3 | 23                    | 29.1 | 31                    | 26.7 | 23                    | 30.3 |       |
|   | no  | 20                    | 6.5  | 8                     | 6.0  | 5                     | 6.3  | 14                    | 12.1 | 6                     | 7.9  |       |
|   | indecisive  | 58                    | 19.0 | 22                    | 16.5 | 12                    | 15.2 | 12                    | 10.3 | 7                     | 9.2  |       |
|   | definitely yes  | 23                    | 7.5  | 21                    | 15.8 | 5                     | 6.3  | 8                     | 6.9  | 6                     | 7.9  |       |
| Q23. Do you think the increasing use of digital dentistry will increase the effect of color blindness on professional skills in a negative way? | definitely no   | 3                     | 1.0  | 2                     | 1.5  | 0                     | 0.0  | 1                     | 0.9  | 0                     | 0.0  | 0.002 |
|   | unanswered  | 109                   | 35.6 | 45                    | 33.8 | 34                    | 43.0 | 50                    | 43.1 | 34                    | 44.7 |       |
|   | yes   | 91                    | 29.7 | 22                    | 16.5 | 13                    | 16.5 | 24                    | 20.7 | 8                     | 10.5 |       |
|   | no  | 21                    | 6.9  | 13                    | 9.8  | 11                    | 13.9 | 13                    | 11.2 | 13                    | 17.1 |       |
|   | indecisive  | 69                    | 22.5 | 41                    | 30.8 | 15                    | 19.0 | 25                    | 21.6 | 17                    | 22.4 |       |
|   | definitely yes  | 15                    | 4.9  | 11                    | 8.3  | 4                     | 5.1  | 4                     | 3.4  | 2                     | 2.6  |       |
| Q24. If you had learned that you are colorblind before choosing your profession, would it affect your choice of profession?                     | definitely no   | 1                     | 0.3  | 1                     | 0.8  | 2                     | 2.5  | 0                     | 0.0  | 2                     | 2.6  | 0.691 |
|   | unanswered  | 109                   | 35.6 | 45                    | 33.8 | 34                    | 43.0 | 50                    | 43.1 | 34                    | 44.7 |       |
|   | yes   | 58                    | 19.0 | 25                    | 18.8 | 10                    | 12.7 | 16                    | 13.8 | 15                    | 19.7 |       |
|   | no  | 53                    | 17.3 | 23                    | 17.3 | 13                    | 16.5 | 20                    | 17.2 | 11                    | 14.5 |       |
|   | indecisive  | 56                    | 18.3 | 31                    | 23.3 | 18                    | 22.8 | 23                    | 19.8 | 10                    | 13.2 |       |
|   | definitely yes  | 20                    | 6.5  | 8                     | 6.0  | 2                     | 2.5  | 3                     | 2.6  | 3                     | 3.9  |       |
|   | definitely no   | 10                    | 3.3  | 1                     | 0.8  | 2                     | 2.5  | 4                     | 3.4  | 3                     | 3.9  |       |

blindness test were completed online in order to evaluate the data on color blindness subjectively, without the influence of the practitioner. In the current study, most of the students selected 'genetic causes and acquired eye diseases' as the reasons for color blindness. Thus, the possible mechanism of color blindness generally might be congenital. Similar findings were reported by other studies (9,10).

We included students from two different university settings (private and state) to evaluate the level of awareness of color blindness according to the institution type and the prevalence of color blindness among students in private and state universities. There was no significant difference in terms of the knowledge level of the reasons for color blindness among the students attending the private versus the state university, with the students attending both institutions stating that they had a "medium" level of knowledge.

According to previous research, the incidence of color blindness among dentistry professionals varied from 2.8–9.99%, with an incidence of 8% in males and 0.5% in females (1,3,6,11). In our study, as shown by the color blindness scores stratified according to gender (Table 1), 2.2% (males: 4.5%; females: 1%) of the study population had a moderate-to-high level of color blindness, similar to that reported in several previous studies (9,12). In common with the findings of the present study, previous studies reported a higher prevalence of color blindness among males. The prevalence of color blindness among males can be attributed to a gene defect in the X chromosome in the Xq28 band (13,14). The relatively low prevalence of color blindness among the males in our study may be due to the low number of males in our study population relative to that of females.

Previous studies highlighted the need for awareness of dentists and dental technicians of color blindness and its effect on clinical success (3,15). According to previous studies, many dentists have no knowledge of their color vision status, and others who are aware have of no knowledge of the degree of color blindness (15,16). According to the results of the color blindness test in the present study, 13.3% of participants who were unaware that they were color blind had a mild or moderate degree of color blindness. This result emphasizes the importance of individuals who wish to pursue a career in esthetic dentistry in clinic or laboratory settings undergoing the Ishihara test during their education and training.

In the present study, most of the students who were aware of their color blind status had become aware of this issue during their training. This result shows that faculty of dentistry and dental prosthesis technology curricula can have a direct impact on raising awareness among future dentists and dental technicians about color blindness (3).

In our study, there were statistically significant differences in terms of the color blindness distribution according to the educational institution and year of education ( $p = 0.028$  and  $p = 0.040$ , respectively). The average score for color blindness among the students in the dental prosthesis technology program was statistically significantly higher than that of the students in the faculty of dentistry ( $p = 0.028$ ). These results are supported by that of a previous study, which reported a higher percentage of color blindness in regions with lower education levels (16). However, there was no sig-

nificant difference in the color blindness scores stratified by education year, except for second and fifth years ( $p = 0.003$ ). Most of the participants thought that color blindness was important for a profession as a dentist or dental prosthesis technician. Most also stated that knowledge of color perception ability would affect their choice of profession. These findings demonstrate the necessity of performing color blindness tests at high-school level prior to students selecting a career path.

The present study had some limitations. One limitation was the small number of dental prosthesis technology students relative to the number of faculty of dentistry students. In addition, the rate of participation in the color blindness awareness survey between the different institutions was different. An additional limitation was that the color blindness test was performed online in the students' homes/classrooms. Thus, the conditions under which the tests were performed were not uniform.

## Conclusion

The students in both the faculty of dentistry and dental prosthesis technology programme demonstrated medium levels of knowledge about color blindness. The prevalence of color vision deficiency among the faculty of dentistry and dental prosthesis technology students was 2.2%, with these students having a moderate-to-high level of color blindness. Awareness of color vision status was very low among the students attending both institutions. Our findings highlight the necessity of enriching the education of students of faculty of dentistry and dental prosthesis technology programs on color blindness. To eliminate the negative effects of color blindness on professional skills, practitioners should be advised to use electronic shade-matching devices or ask for assistance during shade selection/matching. The data in the present study can be expanded by increasing the number of institutions and the number of participants in order to reflect the awareness level of color blindness more comprehensively.

**Türkçe özet:** *Diş hekimliği fakültesi ve diş protezi teknolojisi programı öğrencilerinde renk körlüğü yaygınlığı ve farkındalık düzeyleri. Amaç: Bu çalışmanın amacı, iki farklı üniversitede diş hekimliği fakültesi ve diş protez teknolojisi programında okuyan öğrencilerde renk körlüğü yaygınlık ve farkındalık düzeylerinin değerlendirilmesidir. Gereç ve Yöntem: Gazi Üniversitesi ve Ankara Medipol Üniversitesi Diş Hekimliği Fakültesi ve Diş Protez Teknolojisi Programında 710 öğrenciye (erkek: n = 271; kadın: n = 439) 2019-2021 yıllarında renk körlüğü farkındalığı anketi yapıldı. Öğrencilerin 442'sinin (erkek; n = 155; kadın: n = 287) renk görme durumu, çevrimiçi bir Ishihara renk körlüğü testi kullanılarak değerlendirildi. Elde edilen veriler SPSS, versiyon 24.0 kullanılarak istatistiksel analize tabi tutuldu. Bulgular: Renk körlüğü skorlarında cinsiyete göre istatistiksel olarak anlamlı fark bulunmadı (erkekler:  $0.75 \pm 0.84$ ; kadınlar:  $0.64 \pm 0.75$ ) ( $p = 0.226$ ). Diş protez teknolojisi öğrencilerinin renk körlüğü skorları diş hekimliği fakültesi öğrencilerine göre istatistiksel olarak daha yüksekti ( $p = 0.028$ ). Eğitim yılı, renkleri sınırlı şekilde doğru tanımlama yeteneği ile önemli ölçüde ilişkilendirildi ( $p = 0.040$ ). Eğitim alınan yıl sayısına göre renk körlüğü farkındalık düzeyleri açısından istatistiksel olarak anlamlı bir fark bulunmadı. Sonuç: Renk körlüğü yaygınlığı açısından, diş hekimliği fakültesi ve diş protez teknolojisi programı öğrencilerinin %2,2'si orta-yüksek düzeyde renk körlüğüne sahipti. Öğrencilerin kendi renk görme durumlarının farkındalığı çok düşüktü. Diş hekimliği fakültesi ve diş protez teknolojisi programlarının renk körlüğü ile ilgili eğitim içeriği zenginleştirilmelidir. Anahtar Kelimeler: renk görme kusurları, ishahara testi, diş hekimliği, diş protez teknolojisi, farkındalık*



**Ethics Committee Approval:** This study was approved by the non-interventional clinical research ethics board of Ankara Medipol University (74791132-109/311).

**Informed Consent:** Participants provided informed consent.

**Peer-review:** Externally peer-reviewed.

**Author contributions:** ASA, GE participated in designing the study. ASA, GE participated in generating the data for the study. ASA, GE participated in gathering the data for the study. ASA, GE participated in the analysis of the data. ASA wrote the majority of the original draft of the paper. GE participated in writing the paper. ASA, GE have had access to all of the raw data of the study. ASA, GE have reviewed the pertinent raw data on which the results and conclusions of this study are based. ASA, GE have approved the final version of this paper. ASA guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

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