Color vision and dentistry

Waletha Wasson* / Norman Schuman**

Color vision is a critical component of restorative and esthetic dentistry, but dentists, as a group, do not have their color vision tested at any time during their careers. A study was undertaken to ascertain the color-vision status of practicing dental personnel at the University of Tennessee, College of Dentistry. One hundred fifty individuals, 75 men and 75 women, were screened. The results corroborated the existing medical data for the general population. It was found that 9.3% of the men and none of the women exhibited color-vision defect. Since most dentists are male, this study demonstrates an area of potential weakness for some practitioners. Once a color-vision problem is found, it is simple to remedy by employing a team approach to shade matching or mechanical means of matching shades (by the practitioner). No ethnic or racial distinctions were detected, although these have been reported in other studies. (Quintessence Int *1992;23:349–353.*)

Introduction

The ability of the dental practitioner to match colors and shades correctly and consistently is a critical component of restorative dentistry, especially when anterior restorations are being prepared.[1] The color-matching ability of the dentist may involve training in color education and awareness of color-vision status. A number of authors have suggested that color-vision screening for dental students and practicing dentists might prevent negative experiences for both the patient and practitioner.[1–4]

Public demand for esthetic dentistry has markedly increased over the last decade because of the development of new esthetic products, simplified techniques, and increased patient-consumer awareness.[5–22] Christensen, in 1987, reported that 92% of 5,000 dentists surveyed in the United States indicated a significant increase in esthetic dentistry procedures (ie, porcelain veneers, tooth-colored inlays and onlays, esthetic crowns, and bonding) as well as an emphasis by the patient on improved appearance coupled with a willingness to pay the cost.[23] The increasing use of new technology in dentistry coupled with patient demand for improved appearance should encourage the dental student and practicing dentist to evaluate their color-matching skills.[1–4,6,24,25] Many industries, such as transportation, commerce, electronics, and telecommunications, use color-vision screening routinely to detect color visual deficiencies in applicants.[26–31]

According to Preston,[32] the "esthetic restorative dentist has the task of trying to ascertain and meet the expectations of patients." The dentist's attempt to meet the patient's needs and provide an acceptable outcome can become a challenging task, depending on the patient's perception of the need[32–34] (ie, enhance beauty[35]). If the dentist is not cognizant of a color-vision defect (mild or moderate), he or she may believe that the patient's dissatisfaction is based on needs that are difficult to meet, when, in fact, the dissatisfaction with the interpretation of the tooth color may be legitimate. Therefore, the dentist becomes an essen-

* Assistant Professor, Division of Operative Dentistry, University of Tennessee, Memphis, College of Dentistry, 875 Union Avenue, Memphis, Tennessee 38163.
** Associate Professor, Division of Operative Dentistry, University of Tennessee, Memphis.

tial player in the stimulus process of esthetic shade matching:[36] *(1)* stimulus (light source); *(2)* object (tooth); *(3)* receptor (patient, dentist, staff); *(4)* interpreter (patient, dentist, staff); *(5)* translator (dentist); and *(6)* performer (dentist or laboratory technician).[1,6,24,36–38]

The light source must be appropriate for shade selection. The spatial, optical, and biological properties[39] of the teeth are known to have a great effect on perception. These properties are important in the stimulus process and if ignored may cause negative restorative outcomes. However, Seghi and others[40] reported that "errors associated with color account for a significant portion of the variability that occurs in the duplication process." Charbeneau[21] stated that "from the patient's point of view, the selection of a shade for the conservative anterior esthetic restoration that will match the color and translucency of the tooth to be restored is probably the most important part of the appointment period." The focus is directed toward the receptor component of the stimulus process.

Individuals with color-vision defects cannot be expected to discern matching colors in a manner comparable with their color-normal cohorts.[1–4,6,24,28,29,41,42] However, dental practitioners (students or practicing dentists) should know their color-vision status. If a color defect exists, the dentist should have staff capable of assisting him or her in color discrimination and matching[1–4,6,24,27,42,43]

Teeth are neither white nor pure yellow, as most people who are not trained in the field of dentistry believe. They are not a monochromatic organ in the oral cavity, but are, instead, polychromatic with a gradation of chroma from gingival margin to incisal edge.[7,8,10,37,44,45] There are subtle differences that occur in different degrees, varying angles, and portions of the teeth,[46] and these become a perpetual challenge for the clinician trying to address the esthetic concerns of the patient.[47] The basic color range of teeth, according to three studies, placed human teeth into the yellow to yellow-red hue ranges.[7,37,44,48–50] Individuals whose color-vision is red-green defective show a marked depreciation in the yellow hue range (green-yellow to yellow-red) of the visible light spectrum.[4]

The male population has a greater propensity for color-vision anomalies than does the female.[41,51] Among a European, white population, 8% to 10% of males and 0.42% of females had a color anomaly.[41,51] In 1963, Burnham and others[51] reported that in the United States more than 10 million persons were estimated to have a red-green color-vision defect. In 1975, Padgham and Saunders[52] reported that in the United Kingdom, 8% of the male and 0.4% of the female population (2 million males and 100,000 females) have defective color vision. Most students entering dental school are unaware of their color perception, or may be aware of only a slight deficiency that does not affect normal daily visual acuity.[3] Color screening is not a part of the routine eye examination performed by an ophthalmologist or optometrist. Adams and Haegerstrom-Portnoy[29] suggested guidelines for color-vision testing:

1. All children at an early age (before first grade)
2. All patients on their first office visit (optometrist)
3. All patients with an undiagnosed low visual acuity
4. All patients who report recent color disturbances or difference in color vision between the eyes

Many occupations require color-vision screening prior to job placement. Verriest[27] have classified color deficiency into three categories, of which "occupations normally requiring normal color vision but in which instrumentation or the assistance of colleagues can help out with color problems" applies to dentistry.

Color is used as an aid in teaching the basic science laboratory (histology, pathology, embryology) and clinical courses, as well as clinical procedures that rely heavily on color discrimination and matching.[3,30] If a color anomaly is detected early in a dental student's career, the student (as well as students with normal color vision) can be taught color principles and clinical application in restorative procedures. In addition such screening would provide a base of information and guidance in teamwork building in the practice. The team approach includes using a staff member who has normal color vision to assist in color (shade) selection, which may prevent an unpleasant clinical experience for the patient and clinician.[3]

Method and materials

One hundred fifty adult subjects, 75 men and 75 women, were recruited for the study. Informed consent to participate in the study was obtained from all the subjects. The study population included dental students, dentists, dental hygienists, certified dental assistants, faculty, and staff of the University of Tennessee, Memphis, College of Dentistry. Students from the Memphis Area Vocational and Technical School, dental technologists, and dental assistants, were also

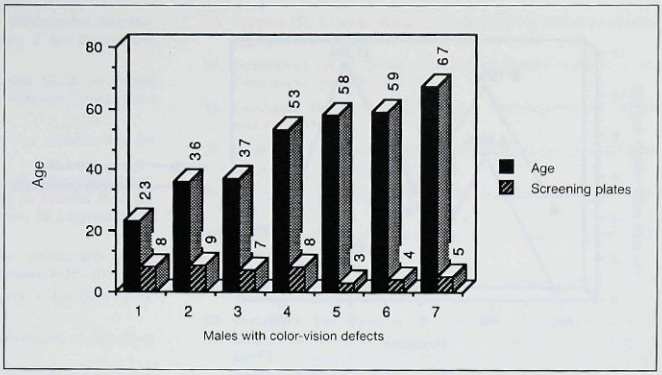

Fig 1 Male subjects identified with a color-vision anomaly.

included. Exclusion criteria consisted of participants who wore tinted lenses.[5] Tinted lenses "alter the spectral properties of the stimuli confounding interpretations of the test results."[28]

The Standard Pseudoisochromatic Plates-Congenital (SPP-C), Part One — Congenital Color Vision Defects (Klingaman R: Personal communication, 1990), was used to detect hereditary color-vision defects (CVDs).[5,26,28,29,53–56] Congenital CVDs were examined, since they have a "stationary nature, present at birth, and usually affect both eyes equally."[26] The SPP-C is a "good test to screen color normals from individuals with any hereditary red-green defects (mild, moderate, severe)."[29] The SPP-C is constructed from uniform-sized dots found on electronically generated numeric displays (eg, pocket calculators).[53,56] The pseudoisochromatic test is the most extensively used test, because it is inexpensive, quick, and easy to use.[26] The screening test is used in manufacturing, transportation, electronics, telecommunications, vocational guidance, military induction and screening, psychophysical and genetic research, and even elementary school settings.[26–31] Each subject viewed nineteen color plates. The screener answered any questions to permit optimal concentration on the color plates. A True Daylight color book stand and illuminator (Richman, Inc) was used to ensure comparability between subjects.

Results

One hundred fifty persons took the SPP-C test for color vision. All female subjects tested normal for color vision. Seven male subjects (9.3%) exhibited a color-vision defect, demonstrating the sex-linked nature of this condition (Fig 1). With regard to race of the subjects, no link was evident. However, studies with larger sample populations have noted that the incidence of color-vision defect varies among various ethnic and regional groups.[41,51,52] Of the seven subjects who tested positive, six were white, while one was native American and white (Fig 2). Of those who tested normal, the racial makeup was as follows: 43 black, 95 white, and five Asian. Color-vision defect was also demonstrated to have no relationship with age. The age range of those testing positive was 23 to 67 years. The age range of subjects testing normal was 19 to 66 years.

Discussion

This study corroborated results of past studies.[2,4,41,51,52] Color-vision defect was exclusively a male problem occuring in seven (9.3%) of 75 male subjects. No women tested positive, as might have been expected, because the prevalence of color defect in women is approximately 0.4%. Since most dentists are men, however, it is necessary to concentrate on the male results.

With regard to racial difference, the results were inconclusive. No black subjects tested positive. The same result occurred among Asian subjects. Among whites, about 10% of men tested positive. The single native American and white subject also tested positive. The sample size was large enough to mirror the male-female relationships as they exist in the general popu-

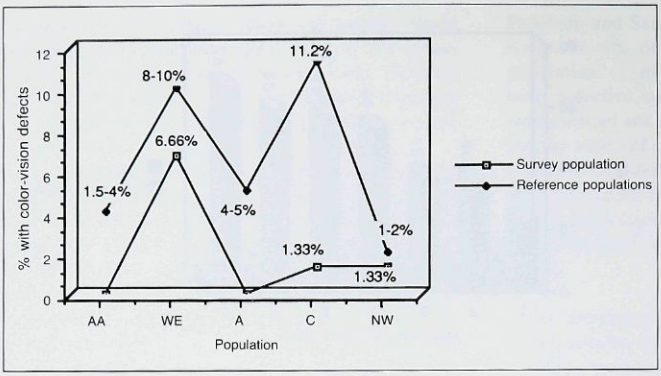

Fig 2 Differences in color-vision defects among survey and reference populations: *(AA)* African American; *(WE)* white European; *(A)* Asian; *(C)* Canadian; *(NW)* native American/white.

lation. Individual racial distinctions, which have been reported previously, could not be duplicated in this study.

Three alternative tracks exist for the individual with color-vision defect: *(1)* a formal course or courses in color education and training for dentists and dental assistants, *(2)* the development of a staff trained in color matching and discrimination of teeth shades, and *(3)* development of colorimetric instruments[25,40,57] that discern small and subtle color differences, including the properties of fluorescence and translucence of teeth (which are just noticeable for the color-vision–normal practitioner, who may vary from day to day with color perception, and for the color-vision–defective individual who may have abnormalities in the red, blue, or green areas). The alternative tracks are adjunctive measures that will provide a cohesive clinical practice environment for the dental clinician, especially those requiring assistance in esthetic shade matching.

Conclusion

Heretofore, the technology was not available, but the development and improvement of esthetic materials and techniques have provided the patient-consumer and dentist with restorative materials and techniques to address their esthetic concerns in shade matching.

The integral part color plays in human vision, particularly in color matching of dental restorative materials for the human dentition, is of tantamount concern for the dentist. A review of the literature revealed that the eyes are the weak link in esthetic shade matching. A significant percentage of dentists and dental students experience color-vision defect (from mild to severe). Among white men, the prevalence approaches 10%. At the present time, few options exist to assist dentists who are color-vision defective. If the alternative tracks are explored further and research is developed, products may be developed that will help the dental community to address some of the color-vision problems associated with esthetic shade matching.

Acknowledgments

The authors would like to thank Dr Roger Klingaman, Assistant Professor at the Southern College of Optometry, for his consultative support on this project. This study was approved by the Institutional Review Board at the University of Tennessee, Memphis.

References

1. Sproull RC: Color matching in dentistry. Part III. Color control. *J Prosthet Dent* 1974;31:146–154.
2. Barna GJ, et al: The influence of selected light intensities on color perception with color range of natural teeth. *J Prosthet Dent* 1981;46:450–453.
3. Preston JD: Color in dental ceramics, in Schärer P, Rinn LA, Kopp FR (eds): *Esthetic Guidelines for Restorative Dentistry*, Koehler HM (trans). Chicago, Quintessence Publ Co, 1982, pp 13–25.
4. Moser JB, et al: Color vision in dentistry: a survey. *J Am Dent Assoc* 1985;110:509–510.
5. *Insights to Esthetic Dentistry*, 1989. Savannah, Ga, Brasseler USA, Inc, 1988, pp 1–12.
6. Lemire PA, Burk B: *Color in Dentistry*. Hartford, Conn, JM Ney Co, 1975.

7. Larson TD: Technique for achieving realistic color distribution in large composite resin restorations. *J Am Dent Assoc* 1987;(special issue):26E–40E.
8. Fergenbaum N, Mopper KW: *A Complete Guide to Dental Bonding.* East Windsor, NJ, Johnson & Johnson Dental Care Co, 1984.
9. Ramfjord SP: Dentistry in the 21st century. *Quintessence Int* 1989;20:167–171.
10. Williams HA, Caughman WF: Principles of esthetic dentistry: practical guidelines for the practitioner, in Hardin JF (ed): *Clark's Clinical Dentistry,* vol 4. Philadelphia, JB Lippincott Co, 1989, pp 1–20.
11. Sheets CG: Modern dentistry and the esthetically aware patient. *J Am Dent Assoc* 1987;(special issue):103E–105E.
12. Hunt PR: The future of esthetic dentistry. *J Am Dent Assoc* 1987;(special issue):106E–112E.
13. Faunce F: Esthetic dentistry: a new direction. *J Am Dent Assoc* 1987;(special issue):5E.
14. Phillips RW: Eras of new biomaterials in esthetic dentistry. *J Am Dent Assoc* 1987;(special issue):7E–12E.
15. Christensen GJ: Tooth-colored inlays and onlays. *J Am Dent Assoc* 1987;(special issue):12E–17E.
16. Weinstein AR: Anterior composite resins and veneers: treatment planning, preparation, and finishing. *J Am Dent Assoc* 1988;(special issue):38E–45E.
17. Jordan RE: *Esthetic Composite Bonding: Techniques and Materials.* Philadelphia, BC Decker, 1988.
18. Garber DA, Goldstein RE, Feinman RA: *Porcelain Laminate Veneers.* Chicago, Quintessence Publ Co, 1988.
19. Goldstein RE: *Change Your Smile,* ed 2. Chicago, Quintessence Publ Co, 1988.
20. Brightbill T: Cosmetic dentistry. *AGD Impact* 1989;17(11): 10–13.
21. Charbeneau GT: Direct esthetic restorations, in Charbeneau GT (ed): *Principles and Practice of Operative Dentistry,* ed 3. Philadelphia, Lea & Febiger, 1988, pp 267–272.
22. Freedman GA, McLaughlin GL: Color and the porcelain laminate, in Hacke G (ed): *Color Atlas of Porcelain Laminate Veneers.* St Louis, Ishiyaku Euro America, 1990, pp 135–137.
23. The promising future of dentistry. A report. Six clinicians discuss the future of dentistry. *Dent Management* 1987;Jan.
24. Preston JD, Bergen SF: *Color Science and Dental Art: A Self-Teaching Program.* St Louis, CV Mosby Co, 1980.
25. Freedman GA, McLaughlin GL: The demand for cosmetic dentistry, in Hacke G (ed): *Color Atlas of Porcelain Laminate Veneers.* St Louis, Ishiyaku Euro America, 1990, pp 1–6.
26. Birch J: A practical guide for colour-vision examination. Report of the standardization committee of the international research group on colour-vision deficiency. *Ophthalmic Physiol Opt* 1985; 5:265–285.
27. Verriest G: Vocational and practical implications of defective color vision, in Pokorny J, Smith VC, Verriest G, et al (eds): *Congenital and Acquired Color Vision Defect.* New York, Grune and Stratton, 1979, pp 349–357.
28. Swanson WH: Color vision: assessment and clinical relevance. *Ophthalmic Clin North Am* 1989;2:391–413.
29. Adams AJ, Haegerstrom-Portnoy G: Color deficiency, in Amos JF (ed): *Diagnosis and Management in Vision Care.* Stoneham, Mass, Butterworths, 1987, pp 671–711.
30. Coren S, Hakstian AR: Color vision without the use of technical equipment: scale development and cross-validation. *Perception Psychophysics* 1988;43:115–120.
31. Aarnisalo E: Testing of color vision for vocational purposes. *Acta Opthamol [Suppl] (Copenh)* 1984;161:135–138.
32. Preston JD: Current status of shade selection and color matching. *Quintessence Int* 1985;16:47–58.
33. Neumann L, et al: Dental esthetic satisfaction in adults. *J Am Dent Assoc* 1989;118:565–570.
34. Goldstein RE: *Esthetics in Dentistry.* Philadelphia, JB Lippincott Co, 1976, pp 3–16.
35. Nash DA: Professional ethics and esthetic dentistry. *J Am Dent Assoc* 1988;(special issue):7E–9E.
36. Swepston JH, Miller AW: Esthetic matching. *J Prosthet Dent* 1985;54:623–625.
37. Clark EB: Tooth color selection. *J Am Dent Assoc* 1933;20: 1065–1073.
38. Saleski CG: Color, light, and shade matching. *J Prosthet Dent* 1972;72:263–268.
39. Preston J: The elements of esthetics – application of color science, in McLean JW (ed): *Dental Ceramics: Proceedings of the First International Symposium on Ceramics.* Chicago, Quintessence Publ Co, 1983, pp 491–520.
40. Seghi RR, et al: Visual and instrumental colorimetric assessments of small color differences on translucent dental porcelain. *J Dent Res* 1989;68:1760–1764.
41. Pokorny J, et al: Congenital color defects, in Pokorny J, Smith VC, Verriest G, et al (eds): *Congenital and Acquired Color Vision Defect.* New York, Grune and Stratton, 1979, pp 183–241.
42. Davison SP, Myslinski NR: Shade selection by color vision-defective dental personnel. *J Prosthet Dent* 1990;63:97–101.
43. Miller L: Organizing color in dentistry. *J Am Dent Assoc* 1987; (special issue):26E–40E.
44. Matthews TG: A method for shade selection. II. *Quintessence Int* 1980;11(3):67–70.
45. Matthews TG: A method for shade selection. I. *Quintessence Int* 1980;11(2):101–105.
46. Goldstein RE: *Esthetics in Dentistry.* Philadelphia, JB Lippincott Co, 1976, pp 79–81.
47. Sproull RC: Understanding color, in Goldstein RE: *Esthetics in Dentistry.* Philadelphia, JB Lippincott Co, 1976, pp 404–410.
48. Sproull RS: Color matching in dentistry. Part II. Practical applications of the organization of color. *J Prosthet Dent* 1973;29: 556–566.
49. Clark BE: An analysis of tooth color. *J Am Dent Assoc* 1931: 2093–2103.
50. Best D: Hue, value, and chroma: Dental color terminology and the world of art. *Trends Technique Contempory Dent Lab* 1984;1 (5):31–34.
51. Burnham RW, et al: *Color: A Guide to Facts and Concepts.* New York, John Wiley and Sons, 1963, p 103.
52. Padgham CA, Saunders JE: *The Perception of Light and Colour.* London, G Bell and Sons Ltd, 1975, p 154.
53. Ichikawa H, Hukami K, Tanabe S, et al: *Standard Pseudoisochromatic Plates. Part One. For Congenital Color Vision Defects.* New York, Igaku-Shoin, 1978.
54. Honson VJ, Dain SJ: Performance of the standard pseudoisochromatic plate test. *Am J Optom Physiol Opt* 1988;65:561–570.
55. Long GM, et al: Color vision screening and viewing conditions: The problem of misdiagnosis. *Nurs Res* 1985:35(1):52–55.
56. Birch J, et al: Clinical testing methods, in Pokorny J, Smith VC, Verriest G, et al (eds): *Congenital and Acquired Color Vision Defect.* New York, Grune and Stratton, 1979, p 90.
57. Seghi RR, et al: Performance assessment of colorimetric devices on dental porcelains. *J Dent Res* 1989;68;1755–1759. □