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Shade-Matching Abilities of Dental Laboratory Technicians Using a Commercial Light Source

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Abstract

Purpose: The purpose of this study was to evaluate dental laboratory technicians' abilities to match shades using a light-corrective device under conventional laboratory conditions. The variables measured were years experience, gender, and light source.
Materials and Methods: A 14-item shade-matching quiz (SMQ) was field-tested and deemed adequate. Information included age, gender, number of years experience, and Ishihara's Colour-Blindness Assessment. Forty-two dental technicians from five northeast Ohio laboratories were invited to participate. The SMQ was administered twice: under the lighting conditions in the individual laboratories (SMQ-Lab) and with a light-corrective source (SMQ-LC). For each item, the technicians were to select the matching Vita shade tab from five preselected shade tabs. SMQ scores equaled the number of correct matches. Statistical analysis included calculation of means, standard deviations, correlation coefficients, and independent and paired *t*-tests. Significance was set at $p \leq 0.05$.
Results: Twenty male and 20 female technicians participated. None were color-deficient. The SMQ scores were significantly higher with the light-corrective device than under laboratory lighting: 12.0 ± 1.9 and 10.0 ± 2.0, respectively ($p < 0.001$). There were no significant correlations between years experience and SMQ scores, nor were there differences between scores by gender. In general, the Vita C shades were least likely to be matched.
Conclusions: Within the limitations of this study, dental technicians' shade-matching abilities were better with a light-corrective device than under the conventional laboratory lighting conditions. Gender and experience were not factors in matching shades. The Vita C shades were least likely to be matched.

The ability to select acceptable shades for dental restorations is an essential component of esthetic dentistry. Some clinicians may delegate shade selection to laboratory technicians, since technicians fabricate the restorations. Although there are many methods to choose shades, including the use of colorimeters, the most common method is to select matching shade tabs from commercially available shade guides. Since lighting conditions are a critical component of shade selection,[1-4] manufacturers have created lights that purport to simulate ideal lighting conditions. Natural light occurring between mid-day and 3 PM and north sky daylight have been suggested as ideal.[4] The effectiveness of dental students' shade-matching abilities using such a commercial light source was recently investigated by the authors.[1] The shade-matching abilities of students were better with the light-correcting source than under natural light.

Other inconsistencies involve the shape and texture of the tooth to be matched.[2,3] Also, individuals have been found to be inconsistent in their shade matches[5,6] even when the light source is controlled.[5] Although anecdotal evidence suggests that women are superior in discriminating colors, studies comparing shade-matching abilities between men and women have found no differences.[7-11]

The ability to discern shades is also influenced by conditions of the human eye. It has been suggested that shade-matching abilities vary based on the degree of color deficiency of individuals choosing the shade, as well as their age[2] and experience.[4] General experience, however, is not always found to be a factor.[9,12] Color deficiency or color vision confusion can be categorized as either genetic or acquired. Genetic color vision confusion, often referred to as color-blindness, affects

approximately 8% of men and 2% of women.[13] The acquired type of color vision confusion can affect almost everyone, because it can be a result of aging and certain disease processes, as well as environmental and emotional factors.[13] Instruments such as Ishihara's Tests for Colour-Blindness[14] are designed to provide a quick and accurate assessment of color vision deficiency of congenital origin.

An understanding of basic color principles is important for accurate shade selection.[15,16] Color has been described by Munsell as a three-dimensional phenomenon, consisting of hue (color), chroma (saturation), and value (brightness).[17] The Classical VitaShade Guide (Vident, Brea, CA) uses Munsell's terminology. Hue, represented by the letters A, B, C, and D, distinguishes one family of colors from another. Chroma is the amount of saturation, intensity, or strength of the hue. Chroma and value are inversely related. Value, the relative amount of lightness or darkness of the hue, or the scale of white to black/gray, is represented by the numbers 1, 2, 3, and 4. Although achromatic, value is thought to be critical for obtaining acceptable shades.[18] Variations in value are visually apparent even when the shade and chroma of a restoration do not differ from the adjacent teeth.[16] The popular Classical VitaShade Guide has one major limitation when comparing shade tabs: the color changes are not of uniform gradations.[19]

Based on the results of the student shade-matching study,[1] it is of clinical interest to determine if dental laboratory technicians would benefit from light-correcting devices in their respective commercial laboratories. The purpose of the present study was to assess dental technicians' abilities to match shades under the existing lighting of dental laboratories and compare those abilities with shade matching under a light-correcting device. The specific aims were to determine if there were differences in shade-matching scores (1) based on experience (years as a laboratory technician), (2) gender, and (3) light source.

Materials and methods

The materials and methods were the same as described by Curd et al.[1] Vita shade guides with the same batch number (#G68-903) were used to construct the quiz items. In addition, the authors assessed the shade tabs to be matched. The shade-matching quiz was based on hue, value, and chroma. Vita shade tabs (A1, A2, A3, A4, B1, B2, B3, C1, C2, and C3) were used to construct the 14-item shade-matching quiz (SMQ). The format was such that the participants matched a selected quiz item, a shade tab with the identifying code concealed, to one of five choices of shade tabs. One of the five choices was the same shade. Three of the distracters were of the same Vita value and/or hue and varied by only one value number or were only one hue different from the correct answer. The fourth distracter was an outlier, differing in two of the following: hue, value, and/or chroma. For example, the choices for Vita A1 were A1, B1, C1, and D2. Although the Vita lettering and numbering system does not actually represent incremental differences, the Classical Vita system was chosen because it is commonly used by dentists. The correcting-light source used in the present study was a Demetron Shade Light (Kerr Corporation, Orange, CA). Approval for the study was obtained from Case Western Reserve University Institutional Review Board.

Because color vision confusion can adversely affect shade selection, participants were tested for color deficiency using the 14-Plate Concise Edition of Ishihara's Tests for Colour-Blindness.[14]

During the spring and summer of 2005, 42 dental laboratory technicians from five commercial dental laboratories in Cuyahoga, OH, were recruited to participate in the study. The inclusion criteria for participation were that the dental technicians work in the prosthodontic department/section of their respective laboratories, and that shade selection was part of their job descriptions. Although all the dental technicians agreed to participate, two technicians from two of the larger laboratories were unable to participate during the times scheduled for the study.

The SMQ was administered twice to each technician: under the lighting conditions in the laboratory or work area (SMQ-Lab) used for shade selection, and using a commercially available light source (SMQ-LC), the Demetron Shade Light. To reduce the possibility that improvement in scores was related to familiarity of the quiz format and items, the lighting source first used was arbitrarily chosen. For the same reason, the quiz items were presented in an arbitrary order, one quiz item at a time. SMQ scores were calculated by adding the number of correct matches for the 14 items, with 14 the highest score attainable.

Statistical analysis

Data analysis included computation of descriptive statistics, that is, means, standard deviations, and frequencies. Paired *t*-tests were applied to determine differences between SMQ-Lab and SMQ-LC. Independent *t*-tests were used to determine if there were differences in SMQ scores by gender. Pearson correlation coefficients were used to determine if there was a relationship between the scores and years experience and age. All computations were performed using SSPS Statistical Software for Windows (SPSS 10 for Windows, SPSS, Chicago, IL); significance was assessed at $p \leq 0.05$.

Results

There was an equal distribution of male (n = 20) and female (n = 20) laboratory technicians. Age range of the participants was from 18 to 61 years (mean, 38.9 ± 10.2); the number of years of experience as dental technicians ranged from 1 to 44 years (mean, 13.8 ± 11.1). None were color-deficient according to Ishihara's Tests for Colour-Blindness.

The SMQ-LC scores were significantly higher than SMQ-Lab scores. Table 1 shows SMQ-Lab and SMQ-LC scores for the total group and by gender. Independent *t*-tests revealed no differences between the SMQ-Lab scores of the men and women ($p = 0.940$), nor between SMQ-LC scores of the men and women ($p = 0.118$). More than 75% of the participants (31/40) scored higher on the SMQ-LC than the SMQ-Lab, eight had the same score or one point lower on the SMQ-LC than on the SMQ-Lab, and only one participant's SMQ-LC score was more than one point lower than their SMQ-Lab score (11 and

Table 1 Comparison of Shade-Matching Quiz (SMQ) score under the conditions in the laboratory (Lab) and with commercially available light* (LC) for total sample and by gender

	Total N = 40	Male n = 20	Female n = 20
SMQ-Lab	9.98 ± 2.0	9.95 ± 2.3	10.00 ± 1.9
SMQ-LC	12.03 ± 1.9	12.50 ± 1.7	11.55 ± 2.1
Paired *t*-test, *p* =	<0.001	<0.001	0.002

*Demetron ShadeLight (Kerr Corporation, Orange, CA).

Table 2 Results of Shade-Matching Quiz by item

ITEM no	SMQ-Lab					SMQ-LC				
B1	B1	C1	B2	C4	D2	B1	C1	B2	D2	C4
	92.3	7.7				100				
B3	B3	A3	C3	D3	A1	B3	A3	C3	A1	D3
	85	10	5			97.5	2.5			
B2	B2	A2	C2	A3.5	D2	B2	A2	C2	D2	A3.5
	82.5	12.5	2.5	2.5		90	7.5	2.5		
B1	B1	C1	B2	C4	D2	B1	C1	B2	D2	C4
	82.5	10	5	2.5		92.5	7.5			
A3	A3	B3	A3.5	C3	C4	A3	B3	A3.5	C3	C4
	82.5	10	7.5	0		95	5			
A3	A3	B3	A3.5	C3	C4	A3	A3.5	B3	C3	C4
	77.5	17.5	5			92.5	7.5			
B3	B3	A3	D3	A1	C3	B3	A3	C3	D3	A1
	72.5	25	2.5			75	25			
A2	A2	B2	A1	D4	C2	A2	B2	A1	D4	C2
	72.5	17.5	7.5	2.5		92.5	5	2.5		
A2	A2	A1	C2	D4	B2	A2	B2	A1	D4	C2
	72.5	22.5	2.5	2.5		90	5	5		
A1	A1	C1	B1	D2	A4	A1	C1	B1	D2	A4
	67.5	20	10	2.5		85	10	5		
C3	C3	A3	D3	B3	B1	C3	A3	D3	B3	B1
	62.5	20	17.5			82.5	12.5	5		
C2	C2	B2	D2	A2	A4	C2	B2	A2	D2	A4
	57.5	25	12.5	5		80	7.5	5	5	2.5
C1	C1	A1	B1	D1	D4	C1	A1	B1	D1	D4
	50	25	20	5		62.5	27.5	10		
A4	A4	A3.5	C4	B4	D4	A4	A3.5	C4	B4	D4
	45	27.5	15	12.5		70	30			

Numbers represent percentage (from highest to lowest) of participants choosing each shade tab by item under lighting in the laboratory (SMQ-Lab) and commercially available light (SMQ-LC).

14, respectively). The Pearson correlation coefficients between years of experience and SMQ-Lab and SMQ-LC scores were low and insignificant, r = 0.149 ($p = 0.367$) and r = −0.089 ($p = 0.589$), respectively. Nor was there a relationship between age and SMQ-Lab or SMQ-LC score, r = 0.251 ($p = 0.118$) and r = −0.070 ($p = 0.666$), respectively.

Table 2 shows the results of SMQ-Lab and SMQ-LC by item. Shade-matching performance on all items was better with the commercial light source than under the lighting conditions of the laboratories. In general, the Vita C shades were least likely to be matched.

Discussion

Although shade matching is subjective, it is a procedure dental technicians are asked to perform routinely. The present study showed that the shade-matching abilities of dental laboratory technicians were better with the commercial correcting-light source than under the usual lighting conditions in the dental laboratories of this study. Previous studies have ascertained that dental personnel are inconsistent in their shade-matching abilities, with some changing their shade selection from day to day.[5] Therefore, methods that improve the process, such as using a consistent light source, should improve shade selection.

The results of the present study using experienced dental technicians are congruent with the dental student study.[1] In general, the laboratory technicians were able to most closely match the B shades, followed by the A shades. The C shades were the most often missed. A limitation of the present study was that the sample was one of convenience; although each of the technicians selected shades as part of their jobs, their training and degree of experience varied. Nevertheless, systems that improve the accuracy of shade selection should benefit dental teams and patients.

Similar to the results of the student study,[1] when an incorrect shade tab was chosen by the technicians in the present study, the incorrect choice often had the same value (number) as the correct tab, but was of a different hue (letter). For example, the shade tab most often confused for C1 was A1 and for shade tab B3 was A3. Also of interest was the most mismatched item under the laboratory lighting conditions, A3.5 shade tab, which was often mistaken for A4. This is inconsistent with color science, because the hue is the same and the value differs only slightly (4 vs. 3.5). Yet in the present study, under the corrective-light source there was a major improvement in the shade selections for shade tab A4; however, since the gradations of the Vita classical system are not uniform, additional studies are needed. Nevertheless, clinical observations of others[16] were similar in that they found that slight differences in shade or chroma were less perceptible than were differences in value.

Based on one study that showed that aging can negatively affect vision,[2] it was anticipated that older technicians, those with more years of experience, would have lower scores. This, however, was not the case; the SMQ scores were not related to age nor were they related to years of experience as a dental technician.

Although daylight has been suggested to be the most appropriate type of lighting for matching shades, it is not always possible to choose shades during the day, nor is the quality of daylight consistent throughout a given day. In the present study, the light sources at the dental laboratories also varied. The types of lighting included fluorescent and incandescent, as well as natural light. Ascertaining the specifications of each light source was not feasible; therefore, one of the limitations of the study was not categorizing the types of lighting of the laboratories. Nevertheless, because only one participant's score under the corrective light was lower by more than two points, and more than 75% of the participants scored higher using the corrective-light source, it is clear that the shade-matching scores were better using the corrective-light source.

To summarize, the results of this study are congruent with the shade-matching selection of novice dental students,[1] that is, the color-correcting light source improved shade selection. Also consistent with other studies, there were no differences in shade-matching scores based on experience or gender of the technicians or dental students.[7-12]

Conclusion

Under the testing conditions of this study, which involved attempts to match shade tabs with one another, dental laboratory technicians' shade-matching abilities were better with a corrective-light source than under laboratory light sources; gender was not a factor in matching shades; neither age nor years of experience as a dental technician affected shade-matching scores; and the Vita C shades were least likely to be matched. Additional research is needed to determine the effectiveness of corrective lighting when matching shade tabs to patients' natural teeth.

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