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Shade Determination Using Camouflaged Visual Shade Guides and an Electronic Spectrophotometer

S.F. Kvalheim* and M. Øilo†

Abstract - *The aim of the present study was to compare a camouflaged visual shade guide to a spectrophotometer designed for restorative dentistry. Two operators performed analyses of 66 subjects. One central upper incisor was measured four times by each operator; twice with a camouflaged visual shade guide and twice with a spectrophotometer. Both methods had acceptable repeatability rates, but the electronic shade determination showed higher repeatability. In general, the electronically determined shades were darker than the visually determined shades. The use of a camouflaged visual shade guide seems to be an adequate method to reduce operator bias.*

KEY WORDS: Electronic color measuring devise, light sources, tooth shade, repeatability.

INTRODUCTION

Human teeth come in a variety of different shades, but it is difficult to differentiate between the hues, values and degrees of brightness and to reproduce the correct shade in dental restorations [1, 2]. Some patients have teeth that have shades that are especially hard to determine (Figure 1). Nevertheless, correct shade is an important success factor for dental restorations. Usually, tooth shade determination is performed with the support of acrylic or ceramic shade guides which are held up against the tooth for visual comparison. Human perceptions of colors depends on many different factors such as age, color vision deficiencies, surface structure of the observed object, light sources and presence of daylight in the operation room [3]. The shade determination is also influenced by experience and habits. There is a risk that the operators have a small number of shades that they select in the majority of situations based on the fact that these have been satisfactory in previous cases. The authors' personal clinical experience is that certain shades are more frequently used than others and some are hardly ever used.

Several manufacturers have developed electronic instruments for shade determination of teeth for use in the clinic or at the dental laboratory [4]. The aim of electronic shade determination is to eliminate the human errors and thereby standardize the shade determination procedure [5]. Three categories of devices for electronic tooth color measurements are currently available: spectrophotometers, colorimeters and digital cameras [6-9]. They use a specific light source embedded in the instrument and digitalized determination of color calibrated against an object of known color (for instance standard gray). Several studies have revealed that these instruments can determine tooth shade with a higher degree of repeatability than visual shade determination [10, 11]. These have been compared to standard shade guides where the results can have been distorted by operator bias due to selection of shade by habit. It is not evident whether electronic shade determination instruments are better at selecting the correct shade of teeth than the human eye and standard shade guides.

The aim of the present study was to assess whether camouflaged shade guides for visual shade determination can be used as a method for comparison with instrumental shade determination without operator bias. Additionally the inter- and intra-operator repeatability of visual shade determination to shade determination performed with a spectrophotometer for restorative dentistry was compared.

MATERIALS AND METHODS

The visual measurements were performed with two new classical 16 graded shade guides (Vita Classical shade guide) but with the original shade coding camouflaged (Figure 2). The shades were coded and randomly placed by a person not involved in the measurement procedures. They were thus not organized according to hue as they normally are. The two guides were coded in different ways. This coding was performed in order to reduce operator bias due to selection of commonly used shades. Two operators without color vision deficiencies with respectively 8 and 13 years of clinical practice were calibrated and tested before the onset of the trial. Both operators had a 100 per cent match on the pre-test matching two decoded shade scales (i.e. A1=A1) [10]. When trying to sort the decoded scales according to brightness, they had 43 and 62 per cent match, respectively. The outcome indicates that the operators were well suited to perform shade determinations visually. The dominant shade of the central part of the tooth was to be determined. No additional information was recorded. A spectrophotometer (Vita Easy Shade) was used for the instrumental shade determination. This instrument has its own continuous light source with color temperature 3350K. The light is transported to the tooth surface trough a fiber optic probe on a hand piece and the reflecting light is

* DDS
† PhD, DDS

returned via the same probe and registered in multiple spectrophotometers, which determine the intensity of the light. The processed information is displayed on a screen at the base unit. A classical shade guide scale from A1-D4 was used as the values for the shade registration. The results were recorded by an assistant and the two operators were blinded from the results.

A random selection of 66 volunteer patients, students, dentists and assistants were recruited from the Dental clinic at the Faculty of Medicine and Dentistry, University of Bergen (Table I). The participants were from 20 to 64 years of age. Center of tooth number 21 was chosen as measurement point. If this tooth was restored, tooth 11 was measured instead. All measurements were performed in the same treatment room with no windows and with identical lighting. New daylight quality fluorescent tubes had been installed one day prior to the onset of the study. The light was switched on at least ten minutes before shade determinations started. The operator lamp of the dental unit was switched off. The intensity of the light on the region of the participants' head was measured before, one time during and after each session with a luxmeter (Meterman LM631). The intensity varied between 1230 and 1350 Lx which equals the light intensity of a very bright overcast day. The teeth of the participants were measured while the participants were in a sitting position in the dental chair. Each participant was seated for a maximum of 15 minutes.

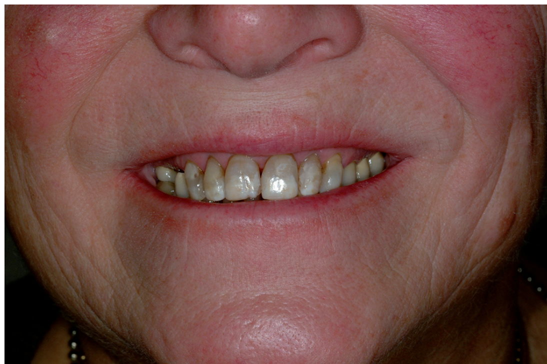

Figure 1. *Patient with teeth that have many different shades in each tooth. This is a particularly difficult case for shade determination.*

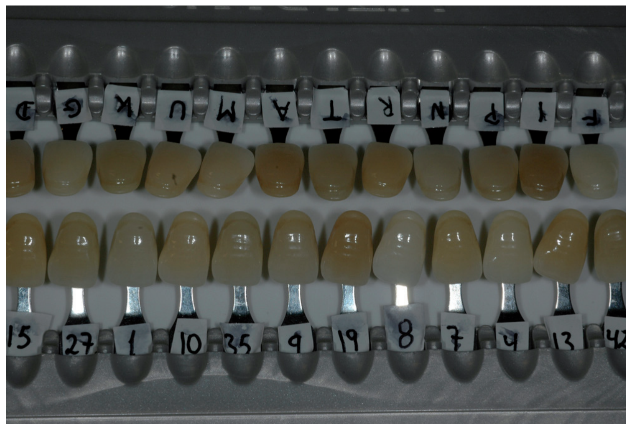

Figure 2. *The camouflaged and coded shade guides used for the visual shade determinations.*

Table 1. Age and gender distribution of the participants.

Age	*20-29*	*30-39*	*40-49*	*50+*
Female	25	9	10	11
Male	3	5	2	1

The participants were told to keep their mouth closed between each measurement and were instructed to take a sip of water if they felt dryness in the mouth. This was done in order to avoid shade alterations due to drying of the tooth surface during the measurements. Each operator performed one visual, one instrumental, a second visual and then a final instrumental measurement on each participant. The instrumental measurement procedure was performed as described in the instruction manual with one central measurement per tooth. The probe was calibrated before each new patient after applying the protective shield. The probe was positioned perpendicularly to the tooth surface.

Frequency distributions were computed and differences among results were calculated using one-way ANOVA. Tests resulting in p-values below 5 percent were considered significant. Intra- and inter-operator repeatability calculations were performed with Cohen's kappa statistics for shade values. Since the classical shade guide is grouped by hue, it is not a continuous scale. The values for the measurements were therefore translated into a semi-continuous brightness scale (Table II) for analytical purposes and analyzed with Intraclass correlation coefficients (ICC) for repeatability on determined shades according to brightness. The statistical analyses were performed with SPSS 15.0, statistical software for Windows.

RESULTS

The measured teeth had a distribution of shades across the entire shade guide (Figure 3). All 16 shades on the A1 to D4 scale were detected by the visual method. The instrumental method did not register any teeth in the shades of A3 or B4. Identical shade determination for all eight measurements for one tooth was found in three per cent of the cases. In 12 percent of the cases the measurements revealed a difference of one degree in brightness; for example A1 to B1. When comparing the instrumental shade determinations alone, 48 per cent of the four measurements of each tooth were identical, with an additional 9 percent with a difference of one degree in brightness. In the four visual measurements, 17 percent identical measurement was performed and another 18 per cent with a difference

Table 2. The classical 16 shades A1-D4 ranged from brightest shade (1) to darkest shade (16) as suggested by the manufacturer (Vita Classical Shade Guide, Vident).

B1	*A1*	*B2*	*D2*	*A2*	*C1*	*C2*	*D4*	*A3*	*D3*	*B3*	*A3,5*	*B4*	*C3*	*A4*	*C4*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16

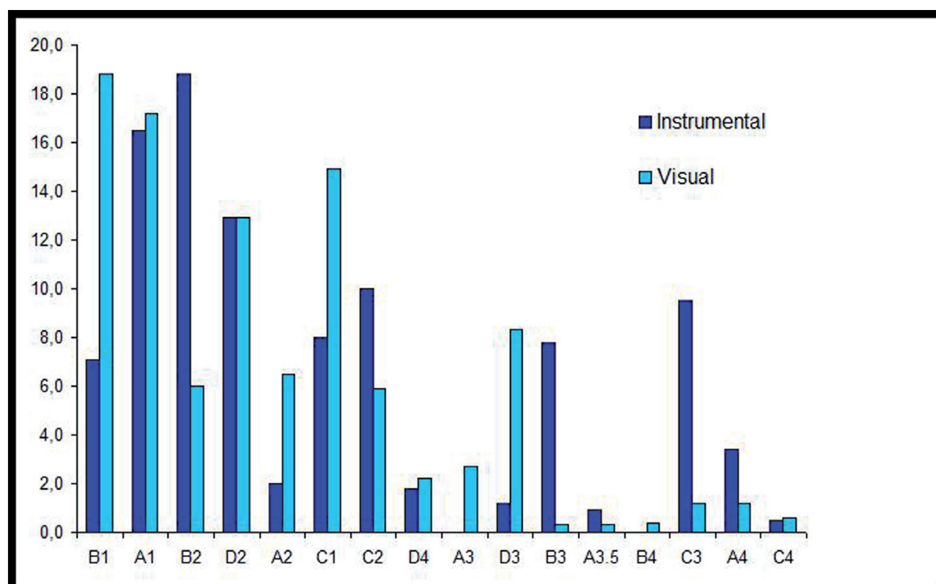

Figure 3. *Distribution of tooth shades for the upper central in per cent as determined by instrumental and visual method.*

Table 3. Intra- and inter-operator repeatability of measurements based on hue (kappa) and brightness (ICC).

	Brightness (ICC)	*Hue (Kappa)*
Visual-visual	0.69	0.66
Instrumental-instrumental	0.88	0.79
Visual-instrumental	0.64	0.20
Operator A-Operator B (Visual)	0.28	0.24
Operator A-Operator B (Instrumental)	0.47	0.59

of one degree of brightness. There was a statistically significant difference between visual and instrumental shade distribution according to both hue and brightness ($p = 0.003$). The visual shade determinations were in general brighter than the instrumental shade determination. There was also a statistically significant difference in the distribution of shades according to brightness between the two operators ($p = 0.014$).

Table III shows the inter- and intra-operator repeatability results for all the measurements. The intra-operator repeatability calculated in kappa for determined shades according to hue was 0.7 for operator A and 0.6 for operator B for the visual shade determinations. For the instrumental determinations the kappa was 0.8 for both operators. Operator A had 66 per cent identical visual shade determinations and operator B had 56 per cent. For instrumental shade determinations identical shade in both measurements was found in 79 and 80 percent of the cases for operator A and B, respectively.

DISCUSSION

The results show that the distribution of shades was slightly different between the two test methods. The use of a camouflaged visual shade guide resulted in brighter shades than the instrumental method although the differences were not large. The spectrophotometer had a higher percentage of identical measurements for single teeth than the visual determination method. The intra-operator repeatability was at an acceptable level for both methods while the inter-operator repeatability was low for the visual shade determination. Previous studies generally report lower intra-operator repeatability for visual shade determination than the present study, but comparisons are not straightforward due to differences in techniques [11-13]. The use of the camouflaged shade guides forced the operators to spend more time and effort to distinguish between hues, degrees of brightness and values since the shades were organized randomly and the coding was unfamiliar. They did not, however, spend more time than what can normally be spent in a busy clinical situation. The results indicate that a camouflaged shade guide may be a good method to reduce the operator bias in shade determination studies. A camouflaged shade guide may also be a helpful instrument in clinical situations where shade determination is particularly difficult or in order to reduce the use of shades by habit.

Due to the blinding of the registrations in this study the eight different shade determinations could be performed in the same session in contrast to many of the other similar studies where there have been days or weeks between sessions to avoid that the operators remember their previous measurements. This may have made it easier to measure the exact same point of the teeth for each of the eight measurements in the present study. The shade was to be determined centrally on each tooth, but many teeth have variations in shade over the tooth area which may affect

the results of shade determination (Figure 1). This may explain the differences between the two operators. Even though the operators had calibrated the testing technique before onset of the study, one operator may have chosen a slightly different area for the measurement than the other, for instance more cervically on the tooth. Previous studies reveal that the repeatability of instrumental shade determination may be affected by both operation technique and surrounding light [14]. Studies comparing several different electronic shade determination devices found higher inter-operator repeatability for visual shade determination than among the different instrumental ones [15]. Other studies conclude that instrumental shade determinations is more repeatable than visual [1, 11, 13, 16, 17]. The repeatability found in this study is comparable to other studies performed with the same spectrophotometer [17]The present study found that the spectrophotometer generally registered darker shades than the human eyes. This is in contrast to another study where another type of spectrophotometer was tested. This difference indicate variations among instruments [13]. Our detection of brighter colors in visual determinations may be explained by the relatively young age of the participants. Tooth color comes from the dentine shining through the almost translucent enamel. The thickness of the enamel decreases with age, which gives young teeth a longer distance from tooth surface to dentine. This decrease is accompanied with a reduction in surface roughness. Young teeth are thus less shiny than older teeth and appear brighter due to the dispersion of the reflecting light [1]. Some of the participants also informed us that they had undergone a tooth bleaching therapy in recent years, which will further affect the reflection of the light [18]. These phenomena may not be registered by the instrument since the spectrophotometer will only measure the light that is reflected back into the measuring probe. People who have bleached their teeth and want their dental restorations to match their white teeth exactly, which may represent a clinical problem. Additionally, young people usually have a higher degree of fluorescence in their teeth, making them appear brighter than they actually are in UV-light. The fluorescence may not be registered the same way by the instrument and the human eye. The results indicate that a shade determined by the spectrophotometer should be supplemented by visual determination as well.

The traditional A1-D4 scale was chosen for the determination even though this scale has some limitations. Other scales may better match the actual shade distribution of human teeth. The traditional A1-D4 scale is, however, still frequently used by both dentist and dental technicians. The disadvantage of this scale is that it is organized by hue and thus not graded which complicates statistical analyses. The restructuring of the scale according to brightness as used in this study and in many other similar studies is not ideal, because the scale is not continuous. There are differences in the degrees of brightness distinguishing the shades on the scale. This reduces the significance of the statistical analyses. Neither calculations on hue nor brightness are ideal and must be analyzed with caution. For some teeth the differences among the shade determination was 7 degrees according to brightness but only one degree according to hue, i.e. C2 and C3. The repeatability for both instrumental and visual shade determination was best when brightness was assessed, which is in accordance with previous findings [14]. Comparison with previous studies is not straightforward, since many studies report either brightness, hue or calculated values for lightness, degree of red-green and degree of yellow-blue.

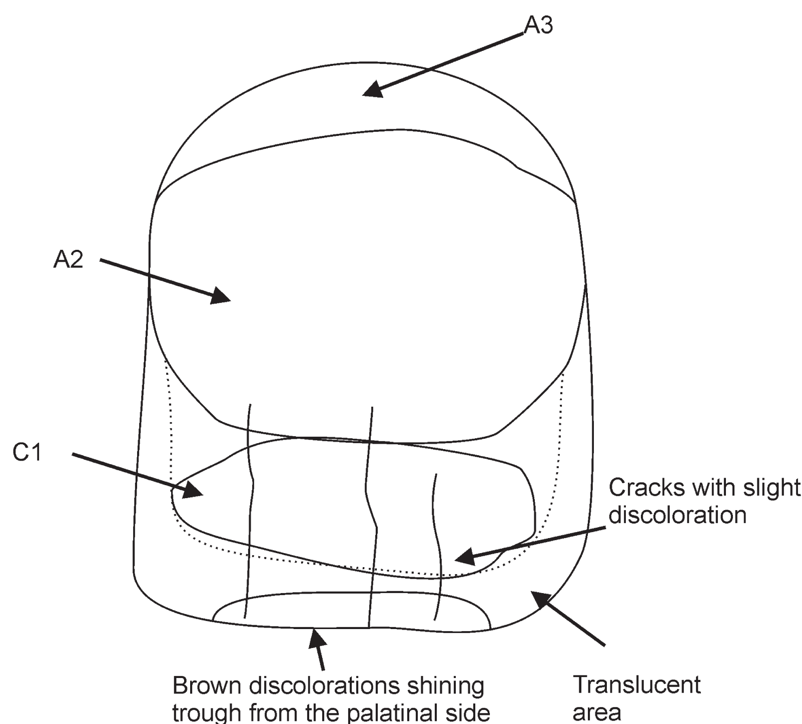

Figure 4. *Illustration of a shade map for additional communication with a dental technician.*

The shade distribution is as expected in the brighter end of the shade guide due to the relatively young age of participants, although more A-shade colors and fewer B-shade colors had been expected from clinical experience [1, 19]. Further studies are necessary to assess whether the spectrophotometer tested or any other electrical shade determination instrument measures tooth shade more correctly than the human eye, even though they seem to be more consistent [7, 8, 10, 11, 15, 20-27]. The instrumental shade guides can, anyhow, not completely substitute visual assessment when designing a dental restoration, since there are many other factors that determine the appearance of teeth than shade alone (Figure 1 and 4).

CONCLUSION

The use of a camouflaged visual shade guide seems to be an adequate method to avoid operator bias. The spectrophotometer tested worked with a higher degree of repeatability than visual shade determination. It is not evident, from this study, whether the instrument determines the tooth shade more correctly than other methods. A camouflaged shade guide may be a good instrument to use in clinical situations to avoid selections of shades by habit.

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MANUFACTURERS' DETAILS

- Vita Classical shade guide, Vita Zahnfabrik, Bad Säckingen, Germany
- Vita Easy Shade, Vita Zahnfabrik, Bad Säckingen, Germany

ADDRESS FOR CORRESPONDENCE

Marit Øilo, Department of Clinical Dentistry, Faculty of Medicine and Dentistry, Postboks 7804, N-5020 Bergen, Norway. E-mail: marit.oilo@iko.uib.no

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