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Repeatability of Electronic Shade Determination and the Influence of Differences in Patient's Sitting Position.

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Abstract - *The aim of the study was to assess the repeatability of shade determination of teeth by a spectrophotometer. Additionally, the influence of different sitting positions on the shade determination was evaluated. Two operators measured the shade of an incisor and a premolar of 24 subjects sitting in three different positions. 18 participants were measured twice. The shade was determined in three areas on each tooth; cervical, central and incisal. Intra- and inter-operator repeatability was calculated and the variance between sitting positions analysed. The results had low to moderate intra- and inter-operator repeatability. The patient's sitting position affected the shade determination.*

KEY WORDS: Electronic colour measuring device, light sources, tooth shade, repeatability.

INTRODUCTION

The technology for electronic determination of shade and colour has now a place in dentistry[1]. Several manufacturers have introduced different electronic instruments for chair-side shade determination of teeth. The reason for using the electronic instruments is to eliminate the errors due to human perceptions of shade and colour and thereby standardize the shade determination procedure. Currently available devices for electronic tooth shade measurements can be classified as spectrophotometers, colorimeters and digital cameras[2-5]. Traditionally the shade determination is done with the support of acrylic or ceramic shade guides which are held up against the tooth for visual comparison. The results depend on the operator's ability to differentiate between shades and the light sources in the room where the shade determination is performed as well as several other factors[6]. This is a difficult and time-consuming operation. Selection of wrong shades will result in either dissatisfied patients or the need to return the mismatched restorations to the dental technician for adjustments or remakes (Figure 1). The available electronic instruments for shade determinations use their own light sources and digitalized determination of shade, based on hue (colour), value (lightness level) and chroma (colour saturation), calibrated against an object of known colour (for instance standard grey). More research is necessary to establish whether these instruments are better at selecting the correct shade of teeth than the combination of the human eye and standard shade guides[7,8].

The aim of the present work was to study whether the sitting position of the patient affects the results of chairside electronic shade determination, as well as to evaluate the intra- and inter-operator repeatability of the equipment used.

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MATERIALS AND METHODS

A spectrophotometer instrument (Vita Easy Shade) was used for the shade determination of vital human teeth. This instrument has its own continuous light source with colour temperature 3350K. The light is transported to the tooth surface through a fibre-optic probe on a hand piece and the reflecting light is returned via the same probe and registered in multiple spectrophotometers which measure the intensity of the light. This information is then processed and the results are displayed as shade codes on a screen on the base unit. The shade codes can be expressed as the traditional A1-D4 shade scale (Vitapan classical shade guide) with 16 shades or as the 3D shade scale (Vitapan 3D-Master) with 26 shades. Additional information of translucency, hue, value and chroma can be obtained.

A random selection of 24 students, dentists and assistants from the dental clinic at the Faculty of Medicine and Dentistry, University of Bergen, were recruited as voluntary participants (Table 1). Mean age of participants was 31 years. Consecutive measurements of 18 participants were performed after one week for intra-operator repeatability assessments. The operators did not know the results of their own measurements. Two clean, healthy, vital teeth (one central upper incisor and one upper second premolar) without substantial restorations were chosen for the measurements on each participant. Tooth number 11 and tooth number 25 were chosen as subjects. If these had been restored, tooth 21 and/or tooth 15 were selected instead. All shade determinations were performed in the same treatment room with the curtains drawn and with identical illumination each day. The operator lamp was switched off. The shades of participants' teeth were determined in three different sitting positions (Figure 2):

- The participant sitting in an upright position in the dental chair with minimal mouth opening.
- The participant sitting in a middle position in the dental chair with the mouth moderately opened.
- The participant in supine position in the dental chair with the mouth maximally opened.

Figure 1. *Example of an unacceptably mismatched metal-ceramic crown of an upper canine. The patient had been scheduled three times for cementation of the final restoration, but each time the crown had been the wrong shade. The patient had also been twice for additional shade determination at the dental technical laboratory because of the difficulty of determining the correct shade.*

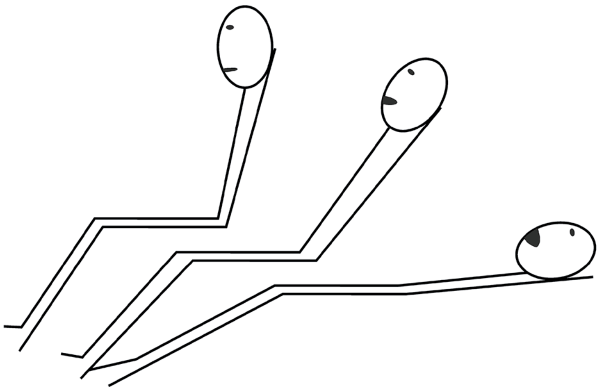

Figure 2. *Illustration of the three sitting positions in which the shade determination of the participants' teeth were performed; sitting upright with minimal mouth opening, sitting in a middle position with moderate mouth opening and supine with the mouth maximally opened.*

Table 1. *Age and sex distribution of the participants.*

Age	*20-30*	*31-40*	*41+*	*Total*	*Per cent*
Male	5	2	2	9	40 %
Female	7	5	3	15	60 %
Total	12	7	5	24	100 %

Table 2. *The classical 16 shades A1-D4 ranged from brightest shade (1) to darkest shade (16) as suggested by the manufacturer.*

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

The measurement procedure was performed as described in the instruction manual with three measurements per tooth (cervical, central and incisal) for shade determination in each area. The probe was calibrated before each new participant after applying the protective shield. The probe was positioned perpendicular to the tooth surface. The A1-D4 shade scale was used for the registrations. Translucency was registered for each tooth in the central region and registered on a scale of 0 to 6, with 0 describing the lowest translucency.

Frequency distributions were computed and differences among variables 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. As the A1-D4 shade scale is grouped by hue, it is not a continuous scale. The shades determined for the central part of the teeth were thus translated into a semi-continuous brightness scale from the brightest (1 = B1) to the darkest (16 = C4) for analytical purposes and analysed with Intraclass correlation coefficient (ICC) for repeatability of brightness as well (Table 2). The statistical analyses were performed with SPSS 15.0, statistical software for Windows.

RESULTS

The intra- and inter-operator calculations showed low to moderate repeatability (Table 3). A statistically significant difference between the operators was found for the shade determinations in the central part of the incisor, both with regard to hue and brightness values ($p = 0.006$, and 0.028, respectively). No other statistically significant differences between operators were found.

Identical shade determination in one tooth area in all three sitting positions for both operators was observed in 6.8 percent of the measurements. The variation in shade between sitting positions does not represent a repeating pattern (Figure 3). However, in the two sitting positions more red/yellow shades such as A1, A2 and B2 were registered compared with more grey shades such as D2 and C1 when the participants were in the supine position with their mouth wide open. Identical shades in all three sitting positions were registered in 47 percent of the subjects for the central incisor and 38 percent for the premolars when the measurements of each operator were evaluated separately. There were statistically significant differences among sitting positions for two of the measuring variables for the incisor: incisal shade ($p = 0.023$) and central shade ($p = 0.016$), but not for the other variables of the incisor or the premolar. The sitting position had no statistically significant effect on the brightness values for either tooth. There were statistically significant differences in shades between centrals and premolars ($p = 0.006$) and among age groups ($p < 0.03$, for both shade and brightness).

DISCUSSION

The results showed that the shade determination with the spectrophotometer tested had low to moderate repeatability both between sessions and between operators. The inter-operator repeatability was good when shades were assessed according to a semi-continuous brightness scale rather than a scale grouped by hue. This indicates that the tested spectrophotometer is more accurate in determination of brightness than hue. The discrepancy may to some extent be explained by the grouping of the shades according to hue in traditional shade guide systems, which are not systematically graded or continuous scales. The A1-D4 scale is divided into four groups according to hues and each group has an internal range according to brightness. The red/yellow hue contains five shades ranged from bright to dark as A1 to A4, the yellow hue is B1 to B4, the grey/brown hue is C1 to C4, while the D2 to D4 are the shades with a grey hue. The difference in brightness between A1 and D2 is very small whereas on the A1-D4 scale A1 and D2 are almost on either end of the scale. This will affect the repeatability calculations.

The measurements were to some extent affected by the patient's sitting position. This was most apparent for incisal and central measurements of the incisors where the shades were statistically significantly more D2 in the supine position than in the sitting positions. The sitting position as well as the mouth opening will affect the amount of light from the surroundings that shine into the oral cavity during measurements. Incisors have less tooth substance in the

Table 3. *Intra- and inter-operator repeatability of shade determinations of teeth based on hue (kappa), brightness (ICC), and translucency (ICC). The intra-operator registrations were made with a one week interval and the operators did not know the results of their previous measurements.*

	Intra-operator repeatability (n = 18)	*Inter-operator repeatability (n = 24)*
Shade (Cervical)	0.51	0.42
Shade (Central)	0.51	0.46
Shade (Incisal)	0.43	0.42
Brightness	0.81	0.85
Translucency incisor	0.05	0.29
Translucency premolar	0.02	0.15

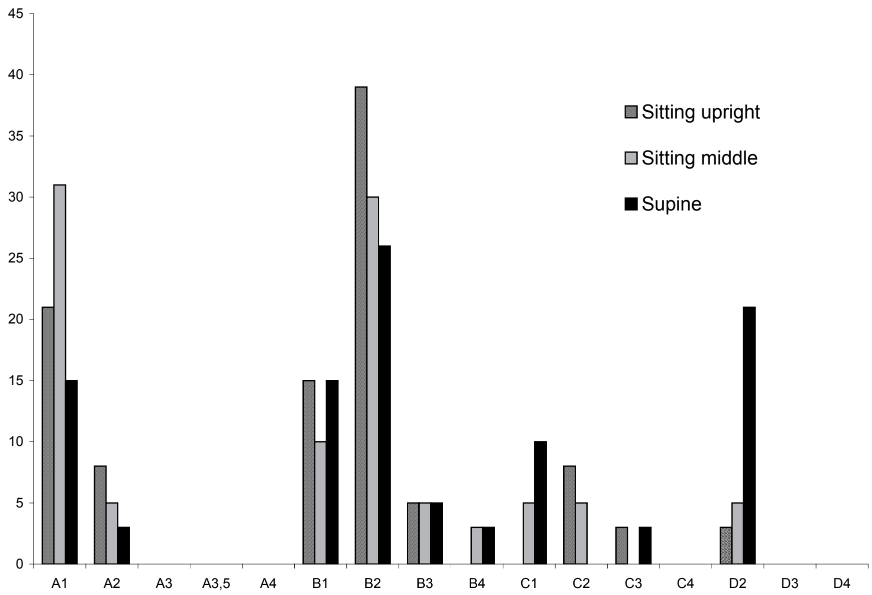

Figure 3. *Shade distribution, in per cent, in the middle of the maxillary central as determined with a chairside spectrophotometer instrument on 24 subjects. The shade determinations were performed with the participants in three positions: sitting upright with minimal mouth opening, sitting in a middle position with moderate mouth opening and supine with the mouth maximally opened.*

bucco-lingual direction than the premolars and are thus more sensitive to surrounding light shining through the tooth substances. An incisor observed with a light source inside the oral cavity appears brighter than when observed when the oral cavity is completely dark. Additionally, the wavelength of light that shines through a translucent object is longer than the wavelength of reflected light. This phenomenon affects the visual perception of tooth shades and may also affect the shade determination of the instrument tested. The present results indicate that supine position where the ceiling light enters the mouth, can camouflage the warmer red and yellow hues of the front teeth. The finding that translucency measurements had the lowest intra- and inter-operator repeatability further implies that the tested device could not fully counterbalance the surrounding light, although the influence of sitting position was not strong in the present study. The low to moderate repeatability of the measurements in general may have confounded a possible stronger influence of the sitting position and light in the oral cavity. Further studies are necessary to establish whether the instrument is affected by background illumination. The illumination of the room and the potential of light entering the oral cavity and thus affecting the shade of the teeth, should, however, be considered in clinical situations when determining shades for restorative therapy of anterior teeth.

The finding that the inter-operator repeatability was lower than the intra-operator repeatability and the statistically significant differences between operators, indicate that the tested instrument is affected by the measuring technique. Both operators, one third-year dental student and one experienced dentist, had read the instruction manuals thoroughly and practised the shade determination technique before onset of study. The instrument tested also had an option to register the mean of ten consecutive measurements. This may possibly give more repeatable results, but was not used in the present study because this option is only available for single measurements of each tooth and not for three separate regions on each tooth. Previous studies have demonstrated differing repeatability rates, but almost all studies comparing instrumental and visual shade determination demonstrate better repeatability for the instrumental shade determination than for the visual shade determination[4,7-11]. Comparison of the results from the different studies is not straight-forward however, since different variables or statistical methods are used.

The maxillary central was chosen for its visual and easily accessed position. The second premolar was chosen because the localization is partly shadowed by the lip. According to the instruction manual, the probe should be placed perpendicular to the tooth surface. Deviations of less than 30 degrees from this could be accepted without inferring with the measurements. For some of the premolars this was difficult to achieve as the buccal surfaces curved both horizontally and vertically. Additionally, some of the premolars were too short to make three separate measurements for the incisal, central and cervical positions as the probe has a relatively large diameter. Despite these potential problems with electronic shade determination on premolars, the results indicate that premolars seem to be less affected by sitting position and operator technique than the incisors.

Due to the relatively young participants, the shade distribution among the participants is, as expected, in the brighter end of the shade scale[12,13]. More A-shades and less B-shades had been expected from clinical experience with traditional shade guides and assumptions based on personal communications with dental material providers and dental technicians. The fact that the participants were in the dental society may have affected the shade distribution. It is probable that some of the participants had previously undergone bleaching procedures and thus had brighter teeth than the general public, but all participants had most certainly well maintained dentitions. The participants were also younger than the patients who are most often in need of crowns and bridges. Thus the reports from dental technicians and material providers that they use and sell more A and C shades may well be the appropriate shades that suit the people who need such restorations. The observed differences among age groups and between the incisors and premolars are in accordance with previous studies of shade distribution in populations[12,13]. Teeth darken with age and premolars are usually darker than incisors.

Further studies are necessary to assess whether the spectrophotometer instrument tested or any other electrical shade determination instrument determines tooth shade more correctly than the human eye, even though the instruments seem to be more consistent than human vision [3,4,7-10,14-20]. With the knowledge available today, it seems that a spectrophotometer instrument can be a supplement to, but not a substitute for visual shade matching. The instrument does not give information of all the factors affecting the appearance of natural teeth in addition to shade, such as surface smoothness, translucency, cracks, and localized discolorations. This information must be obtained by other methods, visually and/or by photographs.

CONCLUSION

The spectrophotometer tested worked with low to moderate intra- and inter-operator repeatability and the measurements were affected by the patient's sitting position. The repeatability was best when a scale based on brightness rather than hues was used. It is not evident whether the tested instrument determines the tooth shade more correctly than other methods, but it may be a useful supplement to visual shade matching in difficult cases.

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MANUFACTURER'S DETAILS

- Vita Easy Shade, Vita Zahnfabrik, Bad Säckingen, Germany.
- Vitapan shade guides, Vita Zahnfabrik, Bad Säckingen, Germany.
- SPSS 15.0, statistical software for Windows, Chicago, IL, USA.

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