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Examination of Natural Tooth Color Distribution Using Visual and Instrumental Shade Selection Methods

SUMMARY

Aim: *Although visual color determination is the most frequently applied method in dentistry, instrumental color analysis offers advantages like objectivity, measurability and rapidity. The aim of this study was to evaluate the natural teeth color in teeth without any restoration visually, and by using a computerized shade measuring and analyzing system in the population.*

Materials and Methods: *202 patients were inspected. Before instrumental shade matching visual matching was done by the inspector with Vitapan 3D Master Shade Guide in the day light. Images were taken with computerized shade measuring and analyzing system from patients' natural right or left maxillary incisors and canines without any restoration. Then these images were evaluated by the original software of its own.*

Results: *Value differences between visual and instrumental shade matching were statistically significant. Darker value levels were obtained with instrumental measurement. The distribution of hue was more reddish in instrumental examination than visual examination. Significant difference was found at cervical and middle third of the tooth in both visual and instrumental determination of chroma. Chroma of the tooth was higher at these two regions in visual assessment.*

Conclusions: *Teeth colors were distributed more uniform in visual shade matching compared to instrumental matching. However, some teeth shades were more common in instrumental matching. Value scores were found higher with instrumental shade matching. Individual selection of shades for each tooth and different regions of a tooth instead of a single color is considered to be a factor to increase the success of the restoration.*

Key-words: Tooth color, visual, instrumental, shade selection

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Introduction

The esthetics of a restoration depends on shape, surface form, translucency, and color. Color assessment and reproduction remains one of the most challenging aspects of the esthetic dentistry; however, matching of a restoration to existing tooth enamel is not predictable[1].

In recent years, investigators have attempted to utilize color science and color theory to devise a standard that will allow expression of colors numerically; in much the same way length and weight are expressed, for easier and a more precise transfer and communication of color in restorative dentistry[2].

When the color is measured by a visual technique, the considered color is compared with a large set of color tabs[3]. Dental shade guides are commonly used to evaluate tooth color in restorative procedures. A shade guide is composed of a set of shade tabs intended to cover the range of colors present in the human dentition. The successful achievement of a clinically acceptable color match between a given tooth and a shade tab is closely related to the spectral coverage of the shade guide, clinician's experience and the viewing environment[2,4]. Color can be described according to the Munsell color space in terms of hue, value and chroma. Value is determined firstly, followed by chroma that is determined close to the measured value but of increasing saturation of color. Hue is determined last by matching with the color tabs of the already determined value and chroma[3].

Numerous reports have indicated that common shade guides do not provide sufficient spectral coverage of the colors present in the teeth. Moreover, tab colors may not be distributed uniformly throughout the color space of natural teeth, leading to close matches for some shades and gross mismatches for others. The underlying assumption for shade guides is that the difference between the true color and the closest shade tab would not be discernible by the human eye[4].

As a means of extending the effectiveness of the existing guides, Sproull suggested, among other things, that porcelain stain kits include 5 value choices[?] . Five value choices are the starting point for the Vitapan 3-D Master Shade Guide. In 1980, Preston and Bergen published a workbook that identified value as the most important determinant of color[5]. The Vita 3D-Master shade guide features a systematic colorimetric distribution of 26 shade tabs within the tooth color space. The manufacturer reports that this shade guide demonstrates an equidistant distribution in the color space. Vitapan 3D Master represents improvement compared to Vitapan Classical and covers greater natural teeth color range[6]. The color distribution of the Vitapan 3D Master shade guide is more ordered than traditional shade guides[7]. Vitapan 3D Master shade guide also has an improved repeatability when compared to other shade guides[8,9]. The shade guide is organized into 5 primary value levels, with a secondary distribution based on chroma and hue. The first number represents the value, the letter is the hue and the last number is the chroma. Value groups are arranged from lightest (value level 1) to darkest (value level 5), left to right[10]. There are 3 chroma levels, from 1 (the least chromatic) to 3 (the most chromatic) in each group (except in group 1 that has two chroma levels). Intermediate chroma levels (1.5 and 2.5) in groups 2, 3, and 4 are associated with hue variations - L (more yellow) and R (more red)[11].

The spectrophotometric/colorimetric approach is attractive because it allows an objective assessment of tooth color, independent of viewing conditions and examiner experience[2,4]. Currently there are several electronic shade-matching instruments available for clinical use. These devices can be classified as spectrophotometers, colorimeters, digital color analyzers, or combinations of these[12].

The first system to combine digital color imaging with colorimetric analysis was introduced by Cynovad (Saint-Laurent, Canada). The ShadeScan is a hand-held device with a color LCD screen to aid in image location and focus. Through a fiber optic cable, a halogen light source illuminates the tooth surface at a 45° angle and collects the reflected light at 0°. Light intensity and calibration to gray and color standards are continuously monitored and adjusted to provide consistent color reproduction. The image is recorded on a flash card, obviating the need for a computer. The transmitted data can be downloaded to a computer with the ShadeScan software. Shade and translucency mapping can therefore be transmitted to the dental laboratory by e-mail or by including a printout or flashcard with the clinical items required for restoration fabrication. Surface shade mapping with the standard software is in basic Vita Lumin shade designations. Higher-resolution shade mapping, additional shade guide designation conversions, and Hue/Value/Chroma values are optional with additional software for dental laboratories[12-15].

Some studies have compared the electronic devices by visual observation[16-27] or evaluated two or more electronic devices[1,12,28]. Other studies have evaluated color and translucency in relation to the physical properties of porcelains and the color reproduction of porcelains[1]. However, only a few studies have evaluated the tooth color distribution in population.

The aims of this study were to (1) analyze shade distributions, (2) investigate chroma, value and hue differences within maxillary anterior teeth, and differences of value for each site of teeth with visual and instrumental shade matching.

Materials and Methods

Study population

Subjects (n=202, 85 women and 117 men, average age 34.4) were recruited from the dental students and the patients appealed to the Clinics of Gazi University, Faculty of Dentistry, Ankara, Turkey. Informed consent was obtained from all participants included in the study under a protocol reviewed and approved by the ethics committee of Gazi University Faculty of Medicine (No: 209 as of 12th September 2005). The experimental unit of this study were the right or left maxillary central and lateral incisors and canines. To be included in the study, subjects had to present with least one permanent maxillary central and lateral incisors and canine free of caries and restoration and with a reasonable alignment within the arch to facilitate shade measurement. Subjects were excluded if they had tooth discoloration as a result of congenital diseases or side effects of medications, and if they had had tooth bleaching or non-vital teeth.

Visual shade matching

Visual shade matching was done by a research assistant in the Department of Prosthodontics who has not any color perception deficiencies.

For shade matching subjects were upright with the mouth at the observer's eye level. External visual influences, such as lipstick were removed. Upper and lower teeth were apart and the tongue retracted. The shade tab was positioned in the same plane as the tooth to be matched by the observer. Shades were selected from slightly moistened teeth in the day light. The Vita 3D Master shade guide was used as the basis for this study because of its wide distribution and the observer's familiarity with it. The examiner determined the color shades with no time limits for each tooth third (cervical, middle, incisal) using Vitapan 3D Master shade guide (Vita Zahnfabrik, H. Rauter Gmbh&Co. KG, Bad Säckingen, Germany) that was regularly ordered into the five value groups – 1, 2, 3, 4 and 5. Shades were determined for each tooth in its cervical, middle and incisal third, according to the manufacturer's recommendations in the following order: value, then chroma and finally hue.

Instrumental shade measurement

Following visual shade matching, computer aided shade measurements were done (ShadeScan, Cynovad, Montréal, Canada) by the same observer. At the beginning of each session, the instrument allowed to warm up according to manufacturer's instructions. The subjects were instructed to lean their heads against the headrest of the treatment chair during the measurement and to keep their mouth slightly opened. The tongue had to be in a relaxed position since pressing of the tongue against the maxillary front might cause mismeasurements by tissue shining through due to incisal translucency of the tooth. The surgical lamp of the treatment unit remained turned off during measurements.

ShadeScan was calibrated automatically on the docking station prior to measurements. After the handset was taken from the docking station, the instrument was positioned so that the required tooth was in the middle of the highlighted rectangular border shown on the colored liquid crystal display screen. The measuring head was placed on the surface of the teeth as perpendicularly as possible, beginning with the central incisors. At the end of the measurements, the data were transmitted to the computer. The tooth area from which the shade was to be taken was determined using the software of its own, and the output was recorded. Shades were determined for each tooth in its cervical, middle and incisal third.

Statistical analysis

We used a statistical program software, SPSS version 13 for Windows (SPSS Inc., Chicago, IL, USA), to perform the analysis. We used Wilcoxon Signed Ranks Test to compare the data. We considered a p value < 0.05 to be significant.

Results

This study involved a total of 202 subjects who ranged from 17 to 85 years of age (average age 34.4), and 606 teeth were investigated. Color distribution data of visual and instrumental shade matching is given in figure 1.

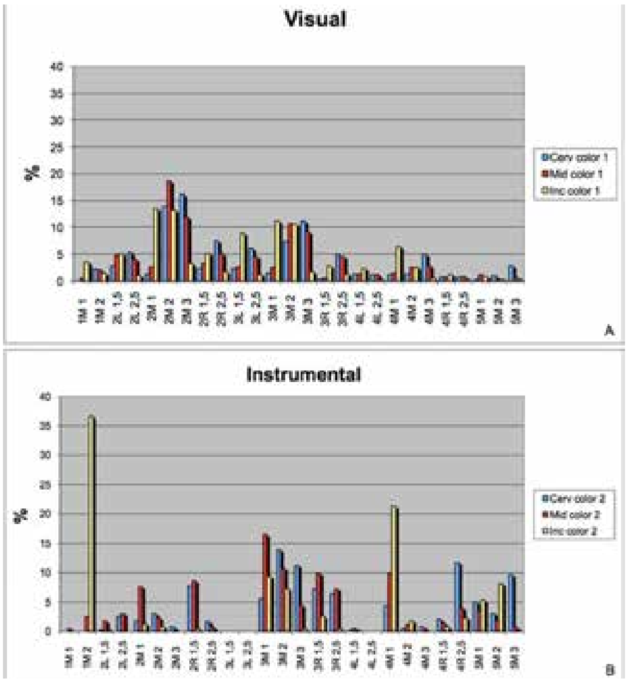

Figure 1: A) Visual shade selection, B) instrumental shade selection

All the tabs in the shade guide were determined at three sites of teeth in visual shade matching but mostly between 2M1 and 3M3 region.

There was not any 1M1 and 1M2 matching at cervical site of teeth in instrumental measurement, and 1M2 was the most common tooth color at incisal site. In our study 3L1.5, 3L2.5, 4L2.5 were not determined at any region of teeth by instrumental measurement.

Value level differences between visual and instrumental shade matching were statistically significant at all sites of teeth (cervical and middle third p=0.0001, Wilcoxon Signed Ranks Test). Darker value levels were obtained with instrumental measurement. At cervical region, level 2 was most common (49.2%) in visual matching, while level 3 was most common (44.4%) in instrumental matching. All results are given in table 1 for different sites of teeth.

In the assessment of the hue, it was observed that the distribution of hue was more reddish in instrumental examination than the visual examination of the teeth color (p = 0.0001, Wilcoxon Signed Ranks Test). M showed higher rates at all three regions of the teeth when L, M and R distributions were examined both instrumentally and visually. In instrument measures, incisal region was found to be 92.6% of the M tone seen. Hue L was seen 19% at cervical region, 18.3% at middle third and 18.6% at incisal respecting visual examination. Ratios obtained from instrumental measurements were 3.1%, 5.4%, 0.5% respectively. The incidence of hue R at cervical and middle third of the teeth was twice higher in instrumental examinations than the examinations made visually. Contrary, data obtained from visual measurements was twice the ratios obtained from the instrumental measurements at the incisal region (Tab. 1).

Table 1: Results of value, hue and chroma analysis of maxillary anterior teeth

			n	Mean Rank	Z	p
COLOR	Cerv Color [2]-Cerv Color [1]	Negative Ranks	77[a]	131,51	-17,173*	0,0001
		Positive Ranks	456[b]	289,88		
		Ties	73[c]			
		Total	606			
	Mid Color [2]- Mid Color [1]	Negative Ranks	157[d]	191,47	-11,864*	0,0001
		Positive Ranks	383[e]	302,89		
		Ties	66[f]			
		Total	606			
	Inc Color [2]- Inc Color [1]	Negative Ranks	235[g]	246,06	-6,161*	0,0001
		Positive Ranks	338[h]	315,46		
		Ties	33[i]			
		Total	606			
VALUE	Cerv Value [2]- Cerv Value [1]	Negative Ranks	32[a]	146,00	-15,779*	0,0001
		Positive Ranks	354[b]	197,79		
		Ties	220[c]			
		Total	606			
	Mid Value [2]- Mid Value [1]	Negative Ranks	69[d]	155,46	-10,896*	0,0001
		Positive Ranks	270[e]	173,71		
		Ties	267[f]			
		Total	606			
	Inc Value [2]- Inc Value [1]	Negative Ranks	215[g]	246,02	-2,618*	0,009
		Positive Ranks	278[h]	247,76		
		Ties	113[i]			
		Total	606			
HUE	Cerv Hue [2]- Cerv Hue [1]	Negative Ranks	67[a]	141,03	-10,316*	0,0001
		Positive Ranks	247[b]	161,97		
		Ties	292[c]			
		Total	606			
	Mid Hue [2] - Mid Hue [1]	Negative Ranks	83[d]	145,85	-8,531*	0,0001
		Positive Ranks	231[e]	161,69		
		Ties	292[f]			
		Total	606			
	Inc Hue [2]- Inc Hue [1]	Negative Ranks	71[g]	103,00	-5,049*	0,0001
		Positive Ranks	141[h]	108,26		
		Ties	394[i]			
		Total	606			
CHROMA	Cerv Chroma [2] - Cerv Chroma [1]	Negative Ranks	298[a]	212,37	-10,047**	0,0001
		Positive Ranks	104[b]	170,37		
		Ties	204[c]			
		Total	606			
	Mid Chroma [2] - Mid Chroma [1]	Negative Ranks	403[d]	237,37	-15,757**	0,0001
		Positive Ranks	53[e]	161,07		
		Ties	150[f]			
		Total	606			
	Inc Chroma [2] - Inc Chroma [1]	Negative Ranks	214[g]	257,13	-,910*	0,363
		Positive Ranks	266[h]	227,12		
		Ties	126[i]			
		Total	606			

[1] Visual shade selection; [2] Instrumental shade selection

[a] Cerv [2] < Cerv [1]; [b]Cerv [2] > Cerv [1] ; [c] Cerv [2] = Cerv [1]; [d] Mid [2] < Mid [1] ; [e] Mid [2] > Mid [1] ; [f] Mid [2] = Mid [1]; [g] Inc [2] < Inc [1] ; [h] Inc [2] > Inc [1] ; [i] Inc [2] = Inc [1]

* Based on negative ranks.

** Wilcoxon Signed Ranks Test

$p<0,05$

Statistically significant difference was found at cervical and middle third of the tooth in both visual and instrumental determination of the chroma. Chroma of the tooth were found higher at these two regions in visual assessment (p = 0.0001, Wilcoxon Signed Ranks Test). Chroma degree, defined with number 3, was detected more common at the cervical part of the teeth in both assessment methods (35% visual and 22.6% instrumental). The most common chroma degree was number 2, respecting visual assessment with 34.2% rate, and number 1.5 respecting instrumental assessment with 22.3% rate at the middle third of the teeth. At the incisal region, No. 1 chroma degree with 35.5% in the visual assessment and No. 2 chroma degree with 54.6% in the instrumental assessment were the most common degrees (Tab. 1).

Discussion

In this study, both visual and instrumental shade selection methods are used together. ShadeScan, which combines digital images with a computer program, was selected as the device to be used. Having an extensive clinical usage, Vitapan 3D Master was utilized as the shade guide.

Spectrophotometers' widespread use in clinical settings and dental research has been hindered by the fact that the equipment was complex, expensive and it was difficult to measure the color of teeth *in vivo* with these machines[23,29,30]. Some of the *in vitro* and *in vivo* dental researches on the color of natural teeth and porcelains, have been conducted with colorimeters[1,14,16,19,29]. Colorimeter measurements have been compared with spectrophotometer readings and deemed reliable and accurate for color difference measurements. In general, colorimeters have shown good repeatability of natural tooth color measurements *in vitro* and *in vivo*[29-31].

The Vitapan 3D Master shade guide was the most suitable one in visual shade selection among the five shade guides that were compared. Clinical experience does have some effect in shade selection and consensus among observers significantly decreased color errors in Vitapan 3D Master and Vintage Halo NCC shade guides[19,32].

In 1998, Okubo et al[16] tested recognition of Vita Lumin shade tabs using another identical shade guide and, at that time, a new colorimeter. The colorimeter was successful in 50%, and the visual examiners in 48% of the cases. Tung et al[29] reported that when using Vita Lumin shade guide, experienced clinicians reached 55-64% agreement with a colorimeter. On the contrary, in their study the repeatability of colorimeter measurements was at the level of 82%. The clinicians showed 73% of agreement with each other. Based on their study Paul et al[17] reported only 27% reproducibility among three human observers who determined the shade for the maxillary central incisors of 30 subjects.

Dozic et al[1] indicated that there was no difference between performances of spectrophotometer and digital camera in shade matching under standard conditions. It was concluded that ShadeScan is the most accurate device in terms of repeatability when used for the same patient. Furthermore, ShadeScan, Ikam and Easyshade were found to be the most reliable devices *in vitro*[1]. For devices that detect tooth color from a small area, how accurately measurements can reflect the tooth color is a controversial issue[33]. ShadeScan, used in our study, seems to be advantageous since it presents tooth colors in different regions on the photo of the tooth as a map.

Hugo et al[18] reported that computer-aided color shade determination of natural teeth does not seem to reflect human perception. On the contrary, Paul et al[17] found that spectrophotometric color analysis (83%) was more accurate and repeatable when compared to visual shade selection (26.6%; $p<0.0001$). This research is similar to our study, since significant difference was observed between visual and instrumental measurements.

In a study conducted on extracted teeth by Analoi et al[4], 3 different shade guides were compared and Vitapan 3D Master was concluded to have the best shade content for extracted teeth. Because of the fact that the study was performed on extracted teeth, the results cannot provide accurate information about the shade guides' clinical performance. Shade difference between extracted and not extracted teeth is mainly based on the pulp content and blood circulation of the tooth besides of the population, age and nutrition.

The maxillary central incisor has frequently been used in evaluations of tooth color[10,17,21,29,32,34-37]. Since color differences have been recorded among different teeth of some patients[38], it appears that maxillary central incisors do not represent overall tooth color. Therefore, left or right maxillary central, lateral incisors and canines were chosen for this study, similar to previous studies[18,22]. The value, the amount of lightness or darkness of a color, is of a great importance to the restorative process; if the value is correct, the restoration can be successful even if the wrong hue and chroma have been selected[39].

The range of color and distribution of color in different regions of the tooth have been described by a number of investigators. It was indicated that there were statistically significant color differences between the regions, and these differences were also clinically significant[34,37,40].

In this study, shades of 606 natural teeth in 202 subjects (85 females, 117 males; mean age: 43.4 years) were examined. In visual shade selection, it is observed that the shades in the range of 2M-1 to 3M-3 were selected commonly and shade selections were distributed in the population uniformly. The most selected shades were; 2M-3 for cervical area (16.2%), 2M-2 for middle third (18.6%) and 2M-1 for incisal area (13.5%). Shade distribution observed in instrumental examination was not homogeneous. In the cervical area of the tooth light shades in the guide like 1M-1 and 1M-2 were not selected. The most selected shade was 3M-2 (13.9%). The most selected shade in the middle third was 3M-1 (16.5%). The most selected shades in the incisal area were 1M-2 (36.6%) and 4M-1 (21.3%), respectively. In instrumental shade selection 3L-1.5; 3L-2.5 and 4L-2.5 were not detected in any area of the tooth.

In a study including *in vivo* color measurements of 2830 anterior teeth, measurements were made in cervical, middle and incisal sites of the coronal portions of the teeth by a colorimeter. The incisal mean hues were more yellow than those of the middle site. For value, the means were similar for all three sites although some higher values were found for some incisal sites. For chroma, the means for incisal and middle sites were almost identical but the cervical sites appeared more saturated similar to our results[38].

In terms of restorative procedure, the lightness and darkness of the teeth have a great importance. It is emphasized that if the value is correct, restoration can be successful even if wrong hue and chroma were selected[39].

Conclusion

Within the limitations of this study, the following conclusions were drawn:

In visual shade selection lower value was selected when compared to instrumental method;

Tooth color was not uniform and it was not composed of a single color;

Shades of the cervical regions were darker and had higher chroma.

Based on the results obtained, individual selection of shades for each tooth and different regions of a tooth instead of a single color is considered to be a factor to increase the success of the restoration.

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