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COLOR EVALUATION OF CENTRAL, LATERAL INCISORS & CANINES OF SOUTH INDIAN POPULATION USING SPECTROPHOTOMETRIC ANALYSIS- A CROSS-SECTIONAL STUDY

Dental Science

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ABSTRACT

Aim: An accurate color reproduction represents the final justification level of an esthetic restoration. The aim of this study was to evaluate the color of permanent maxillary central incisors, lateral incisors and canines, using a clinical spectrophotometer.

Methods: The Vita Easyshade Advance 4.0® intraoral spectrophotometer was used to determine the color of permanent maxillary central incisors, lateral incisors and canines of 351 volunteers aging between 18-35 years. The best matches to Vitapan Classical® and 3D-Master® shade guides were recorded. A one-way analysis of variance and Kruskal-Wallis test were used to compare L*, a*, b*, c* and h* color coordinates among the 3 types of teeth. Differences between the mean values of all color coordinates were evaluated by use of Bonferroni corrections. Color difference (ΔE*) between 3 types of teeth were calculated from ΔL*, Δa* and Δb* data and the results were compared to ΔE*=3.3 acceptability threshold.

Results: The most frequently accepted shades were A1(65%) and 1M1(45%) for central incisors, A2(45%) and 1M2(40%) for lateral incisors and B3(40%) and 2M3(45%) for canines. The highest lightness values were found for incisors (85.65 ± 3.2), while the lowest lightness values were found for canines (81.0 ± 3.02).

Conclusions: Despite the limitations of this study, color differences among maxillary central incisors, lateral incisors and canines were found to be statistically significant, above the clinical acceptability threshold established. In conclusion, successful esthetic restorations of permanent teeth of the same patient need an individual approach for color assessment and reproduction of every type of tooth.

KEYWORDS

Color, Spectrophotometer, Permanent natural teeth, Euclidean distance (ΔE).

Introduction:

'What if the impressionists were dentists' a humorous quote by Woody Allen in his essay, where the whole parody around an impressionist Vincent van Gogh as dentist. Though it is a comic piece but has become the reality in esthetic dentistry[1]. Nowadays dentists are judged more by their artistic talents. Restorative dentistry is a blend of science and art. The success of restorative dentistry is based on the functionality and aesthetic output of the restoration. Achieving esthetics is based on four basic pillars they are; position, contour, texture and color. Color combination not only improves esthetics but also makes the restoration appear natural and attractive and thus becomes a major challenge in the field of esthetic dentistry. When the restoration is aimed to improve the esthetics and does not mimic the optical properties of natural dentition, becomes a source of dissatisfaction for both the patient as well as the clinician.

In the current scenario of dentistry, the most used tooth shade selection methods are subjective. The methods depend on the observer, who has to compare tooth color with selected shade tabs from different shade guides which are prone to error and may vary from one time to the other also among different individuals. The dental shade guides as well do not completely represent natural tooth color, the hue, value and chroma ranges are always deficient[2-5]. All these deficiencies led to the development of new shade guide system, Vitapan 3D Master which was arranged according to L*, C* and h* coordinates in groups of lightness, chroma and hue[6]. This new 3D Master system, with a higher number of shade tabs extended to a wider color range and more uniformly spaced compared to Vitapan Classical shade guide proved to be more accurate but still it is a subjective evaluation method[7-9].

Nowadays, because of the high esthetic demands of the patients and the variability and subjectivity of the human eye has led to the development of new shade taking devices that allows objective choice of shade values. These devices include tristimulus calorimeters, digital cameras, spectrophotometers and spectroradiometers. Spectrophotometers measure the full spectrum of reflected or transmitted light, and later converts them into tristimulus data[10]. Due to its sensitivity, accuracy and reproducibility, spectrophotometers have been used as references for color analysis as it produces more accurate results compared to the visual assessment methods[11,12]. They measure the amount of light energy reflected from an object at 1-25 nm intervals along the visible spectrum[13,14].

A spectrophotometer contains a source of optical radiation, a means of dispersing light, an optical system for measuring, a detector and a means of converting light obtained to a signal that can be analyzed. The values obtained from spectrophotometric reading must be converted into a form useful and understandable for dental professionals. When the tooth surface is to be analyzed with a spectrophotometer, it is illuminated using an inbuilt D-65 illuminant and light is dispersed using fiber optics contained in the probe tip, the reflected light is captured with the help of a detector. The measurements obtained by the instruments are manipulated and converted to tristimulus data/shade tab equivalent. On comparison with the conventional techniques and human eye, spectrophotometers offered an increase in the accuracy by 33% and a more objective match in 93.3% of cases[10]. Spectrophotometers, can provide readings from Commission Internationale de L'Eclairage (CIE) L*, a*, b* color space, where L* represents lightness (the amount of white and black within a color), a* is a measure of redness (positive a*) or greenness (negative a*) and b* represents the position on the blue (negative b*)-yellow (positive b*) axis[15-16]. This color notation system is widely used in dental research for both in vivo and in vitro color measurements[17].

Spectrophotometers have spectral data for the shade tabs of several shade guides incorporated in their database. Therefore, for each measurement they also display the best match of the shade guide chosen.

In color research, the Euclidean distance between two color points (ΔE) remains one of the most important parameter needed in the determination of color differences[18]. After visual determination or instrumental measurement of tooth color coordinates Delta E* is used in dentistry to state the clinical perceptibility acceptability thresholds[19-21].

Tooth color and its optical properties have described in both in-vitro and in-vivo studies but no comparative reports have mentioned about the color parameters of central incisors, lateral incisors and canines The objectives of this study were to determine: (1) L*, a*, b*, C* and h* color parameters of permanent incisors, canines and molars; (2) the most frequently chosen color relying on Vitapan Classical and Vita 3D-Master shade guides; (3) the mean differences of all color parameters among the three groups of teeth; and (4) color differences (ΔE*) among central incisors, lateral incisors and canines. The null hypothesis which was performed in this study assumed that differences in spectrophotometric color coordinates between maxillary central incisors, lateral incisors and canines are not statistically significant.

Materials and methods:

351 volunteers selected for this study ranged between the age of 18-35 years of Tamil ethnicity. All participating subjects received written information and signed an informed consent form which was approved by the Ethical Board of the SRM University. The teeth selected for color measurements were the maxillary right central incisor, lateral incisor and canine. Only natural, unrestored teeth, without pathological discolorations, were included. Teeth with directly/indirectly restoration, teeth that underwent bleaching procedure, teeth with any type of spots in the middle one third of its facial aspect, any type of teeth with developmental disorders, fractured teeth, carious teeth, teeth under orthodontic procedures were excluded. Before measurements, the facial surface of each tooth was cleaned using polishing brushes and paste.

Using a Vita Easyshade spectrophotometer (Vita Easyshade Advance 4.0®; Vita Zahnfabrik) according to the manufacturer's instructions color recordings were performed. This digital shade matching device which uses D-65 illumination for color selection had previously been subjected to a validation test, in order to evaluate its reproducibility and inter-examiner reliability. D-65 is commonly used standard illuminant defined by CIE (Commission of Illumination), it corresponds roughly to the average midday light, hence also known as day light illuminant. Each tooth was measured once, so that a total of all teeth in each group were measured in the end. On the probe tip an infection control shield was placed prior to measurements in every participant. The measurements were obtained from the same position, respectively from the middle third of the labial tooth surface. The "Averaged measurement" operation mode was used to determine the basic color of the 3 types of teeth after calibration on its standard white reflection port and upto 3 measurements were performed on every tooth. Between measurements, the probe tip had to be completely removed from the tooth surface and repositioned. The following measurements were recorded:

1. L*, a*, b*, C* and h* values for all teeth as well as the best matches to Vitapan Classical® and Vita 3D-Master® (Vita Zahnfabrik) shade guides.
2. ΔL*, Δa*, Δb*, ΔC* and Δh* values between the groups of teeth were calculated.
3. Color differences, measured as ΔE* between central incisors lateral incisors & canines were also calculated using the following formula: ΔE*=[(ΔL*)2+(Δa*)2+(Δb*)2]1/2.

Statistical analysis

Color codes of central incisors, lateral incisors & canines based on the two shade guides (Vitapan Classical and Vita 3D Master), as assessed using an intra-oral spectrophotometer, have been described by computing their frequencies and 95% confidence intervals (95% CI). One-way analyses of variance have been performed to compare L*, a*, b*, C* and h* among the different tooth types (central incisors, lateral incisors & canines).

Post-hoc multiple comparisons using Bonferroni corrections have been performed for pairwise comparisons of these measured color parameters between the three tooth types.

Plots of means and their 95% CI have been used to graphically compare the three tooth types.

The level of statistical significance has been set at α=0.05. Data has been collected using Microsoft Excel 2010 and analyzed using R 3.0.2 - a language and environment for statistical computing.

Results

The mean values of L*, a*, b*, C* and h* color coordinates of the evaluated teeth are presented in Table 1. The highest lightness values were found for incisors (85.65 ± 3.2), while the lowest lightness values were found for canines (81.0 ± 3.02). The most chromatic values (highest a* and b* values) were found in canines (a* = 0.45 ± 1.01; b*= 22.81 ± 2.83). The maxillary incisors were found to have the lowest a* and b* values (a* = -1.25 ± 0.84; b*= 13.58 ± 4.19). Figures 1 to 5 present visual comparisons between incisors, canines, and molars regarding the means and their 95% confidence intervals of L*, a*, b*, C* and h* color coordinates measured for the three tooth types in the studied sample of volunteers.

For the Vitapan Classical® shade guide, the most frequently chosen shades were in order: (1) A1 (65%); (2) B1 (35%) for incisors; (1) A1 (30%); (2) A2 (45%) and (3) B1 (5%) (4) B2 (10%) for lateral incisors; (1) A2 (20%) ; (2) A3.5 (20%) and (3) A3 (15%) (4) B2 (10%) (5) B3 (40%) (6) C2 (5%) for canines (Table 2).

The most frequently chosen shades relying on the Vita 3D-Master® shade guide were in order: (1) 0M2 (5%); (2) 0M2 (5%) (3) 1M1 (45%) (4) 1M2 (30%) and (5) 2M1 (15%) for incisors; (1) 1M1 (5%); (2) 1M2 (40%) and (3) 2L1.5 (5%) (4) 2L2.5 (5%) (5) 2M1 (20%) (6)

Table 1. Mean values, Standard deviation and Confidence Interval for means of Color Coordinates measured in the evaluated teeth.

TOOTH TYPE	COLOR COORDINATES				
	L* ± SD	C* ± SD	h* ± SD	a* ± SD	b* ± SD
CENTRAL INCISORS 95% CI	85.65 ± 3.2 (84.13 – 87.17)	17.78 ± 17.5 (9.56 – 25.99)	97.90 ± 8.11 (94.10 – 101.69)	-1.25 ± 0.84 (-1.62 - -0.83)	13.58 ± 4.19 (11.62 – 15.55)
LATERAL INCISORS 95% CI	83.02 ± 3.4 (81.42 – 84.61)	16.63 ± 4.19 (14.66 – 18.59)	93.89 ± 2.90 (92.53 – 95.25)	-0.93 ± 0.58 (-1.20 - -0.65)	17.39 ± 4.40 (15.33- 19.45)
CANINES 95% CI	81.0 ± 3.02 (80.58 – 83.41)	22.34 ± 10.66 (16.16 – 21.67)	90.35 ± 2.47 (92.51 – 95.59)	0.45 ± 1.01 (- 0.42 - -0.51)	22.81 ± 2.83 (21.48 – 24.13)

2M1.5 (5%) (7) 2M2 (20%) for lateral incisors; (1) 1M2 (5%); (2) 2L1.5 (5%) and (3) 2M1 (5%) (4) 2M2 (25%) (5) 2M3 (45%) (6) 2R1.5 (5%) (7) 2R2.5 (5%) (8) 3M2 (10%) (9) 3M3 (5%) for molars (Table 3).

The mean values of ΔL*, Δa*, Δb*, ΔC* and Δh* among the groups of teeth are presented in Table 4. The highest differences for all color coordinates were found among incisors and canines. Differences decreased slightly between the central incisors-lateral incisors groups and were the lowest between lateral incisors and canines. Highly significant mean differences were found for all L*, a*, b*, C* and h* color coordinates between the 3 groups of teeth ($p<0.001$).

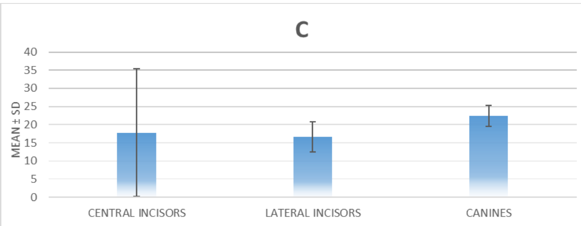

Figure 1. Visual comparison of means and their 95% confidence intervals for L* color coordinates of Central Incisor, Lateral Incisor & Canines measured in the studied sample.

Figure 2. Visual comparison of means and their 95% confidence intervals for C* color coordinates of Central Incisor, Lateral Incisor & Canines measured in the studied sample.

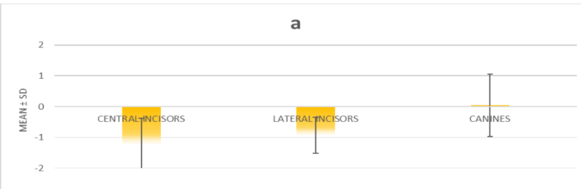

Figure 3. Visual comparison of means and their 95% confidence intervals for h* color coordinates of Central Incisor, Lateral Incisor & Canines measured in the studied sample.

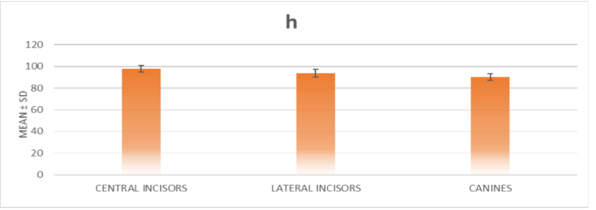

Figure 4. Visual comparison of means and their 95% confidence intervals for a* color coordinates of Central Incisor, Lateral Incisor & Canines measured in the studied sample.

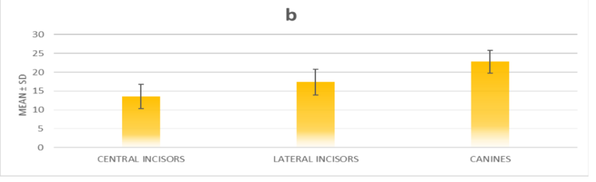

Figure 5. Visual comparison of means and their 95% confidence intervals for b* color coordinates of Central Incisor, Lateral Incisor & Canines measured in the studied sample.

Table 2. Vitapan Classical shade tabs recordings (%) that best matched the examined teeth.

Shade Tab	Central Incisor (%)	Lateral Incisor (%)	Canines (%)
A1	65%	30%	-
A2	-	45%	20%
A3	-	-	15%
A3.5	-	-	20%
A4	-	-	-
B1	35%	5%	-
B2	-	10%	10%
B3	-	-	40%
B4	-	-	-
C2	-	-	5%

Table 3. Vitapan 3D shade tabs recordings (%) that best matched the examined teeth.

Shade Tab	Central Incisor (%)	Lateral Incisor (%)	Canines (%)
0M2	5%	-	-
0M3	5%	-	-
1M1	45%	5%	-
1M2	30%	40%	5%
2L1.5	-	5%	5%
2L2.5	-	5%	-
2M1	15%	20%	5%
2M1.5	-	5%	-
2M2	-	20%	25%
2M3	-	-	45%
2R1.5	-	-	5%
2R2.5	-	-	5%
3M2	-	-	10%
3M3	-	-	5%

Table 4. Mean Differences between the 3 groups of the teeth for all the color coordinates.

	ΔL*	ΔC*	Δh*	Δa*	Δb*
CI – LI 95% CI	2.63 (1.18 – 5.15)	1.15 (-7.08 – 9.3)	4.00 (-0.3 – 8.04)	-0.29 (-0.94 – 0.35)	-3.81 (-6.83 - - 0.78)
LI – C 95% CI	1.02 (-1.49 – 3.53)	-5.71 (-13.9 – 2.52)	3.53 (-0.5 – 7.57)	-0.97 (-1.62 – 0.3)	-5.41 (-8.43 - - 2.39)
CI – C 95% CI	3.65 (1.13 – 6.17)	-4.56 (-3.67 – 12.79)	7.54 (3.50 – 11.5)	-1.27 (-1.9 - - 0.62)	-9.22 (-12.2 - - 6.20)

Regarding color variations, the greatest color difference was found again between incisors and canines (ΔE=9.99). The color differences between the other two groups of teeth were: central incisors- lateral incisors (ΔE=4.63); lateral incisors-canines (ΔE=5.58).

Discussion

A clinically valid restoration bio mimics the natural appreance of an individual's teeth. Bio mimicking the restoration requires proper color matching approach and reproducing it to the permanent natural teeth. Several previous studied have documented data regarding the range of colors in permanent and primary dentition[5,22]. But there is only handful of data regarding all the five color coordinates which have been published.

The null hypothesis that no significant color difference can be detected between the spectrophotometric color coordinates of maxillary central incisors, lateral incisors and canines has been rejected in our study. The L* values were found higher for the central incisors than lateral incisors and canines which resembled the previous studies[5]. Canines were darker than lateral incisors, which in turn were darker than central incisors. According to a* and b* values obtained canines were more chromatic than lateral and central incisors, with central incisors having the lowest chromatic values. Vitapan Classical® and Vita3D-Master® shade guides confirmed these results. 65% of central incisors corresponded to A1 shade and 85% to lightness group 1 from the 3D Master shade guide, while B3 was the best match for 40% of canines and 90% belonged to the second group of lightness from the Vita 3D Master® shade guide. Among Vitapan Classical® shade tabs the widest range of color distribution was recorded for canines, where 6 different shade tabs constituted the best match. In the case of incisors only 2 shade tabs were found to be the best match (Table 2). On the other hand, for the Vita3D-Master® shade guide the widest ranges of shade tabs found as best match were recorded in order: for central incisors (5 shade tabs), lateral incisors (7 shade tabs) and canines (9 shade tabs) (Table 3). These findings not only confirmed the previous studies [22-23], but also confirmed that Vitapan Classical® does not match the tooth color of permanent teeth adequately due to presence of fewer shade tabs[2-3].

Human eye is capable to detect a limited range of color difference. Threshold for acceptance and perceptibility of color difference are a debatable subject in cosmetic dentistry. Clinical acceptable threshold of 3.3 was established by Ruyter et al[24-25]. i.e, color difference ΔE* less than or approximating 3.3 are clinically acceptable and ΔE* 3.4 will be rejected[26]. In the present study, all the ΔE* values among the three groups were more than 3.3 making them clinically perceptible and therefore unacceptable color difference between central incisors, lateral incisors and canines. This fact was also confirmed by post-hoc multiple comparisons using Bonferroni corrections between the color parameters of these 3 types of teeth.

For clinically objective shade selection of natural teeth and prosthetic restorations the Vita Easyshade® spectrophotometer was specially designed for. The CIE L*, C* and h* color coordinates and the Vita 3D-Master® corresponding shades provided by this objective device were considered to be very similar to those chosen by experienced clinicians[27]. Being clinically efficient the device still encounters problems in cases of measuring curved regions of the teeth and translucent surfaces elucidating edge loss errors leading to reduced L* values[28], therefore creating a measurement bias and hence an acknowledged limitation of this study.

Conclusion:

Within the limitation of this study, significant color differences were observed between the central incisors, lateral incisors and canines using spectrophotometric measurements. The most frequently accepted shades were A1 and 1M1 for central incisors, A2 and 1M2 for lateral incisors and B3 and 2M3 for canines. These differences can be transposed into clinically observable color variation and thus can aid the clinician to provide more esthetically sound and precise restoration with patient satisfaction.

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