Evaluation of Natural Tooth Color Space of the Indian Population and Its Comparison to Manufacturer's Shade Systems

Abstract

Purpose: This study evaluated the natural tooth color space of the Indian population and compared it with the manufacturer's shade systems. **Materials and Methods:** Maxillary central incisors of individuals aged 18–30 years and shade tabs of Vita Lumin vaccum (VL), Vitapan 3D master (V3D), and Shofu's Vintage Halo (SVH) shade guide were digitally photographed under standardized conditions. L*a*b* values from middle part of tooth and shade tab were attained using Adobe Photoshop 7.0 software. Comparative evaluation between the natural teeth and shade tabs was done, and color differences were noted and analyzed using appropriate software. **Results:** The L*a*b* values of the Indian population displayed a broader range than the shade guides. The mean Δ E* for VL shade guide was 7.22, 7.99 for SVH, and 8.39 for V3D, which was statistically significant. Color space of the Indian population on displayed an elongated cone with an irregular base. The plots of all the three shade guides were narrower and shorter and deficient in the blue–green region as compared to the population. **Conclusions:** Within the limitations of this study, the mean color difference between the Indian population and the three shade guides was above the acceptability thresholds (ΔE* = 2.7–6.8). VL, V3D, and SVH shade guides were deficient in their coverage and therefore can be considered inconsistent.

Keywords: *CIE L*a*b*, color difference, digital photography, shade guide, tooth color space*

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Introduction

Shade selection in restorative dentistry involves accurate understanding of color. A color model is necessary to quantify and describe the color that is visually perceivable to human eyes. The CIELAB (CIE L*a*b*) color model is one of the adopted systems by CIE (Commission Internationale de l'Eclairage) in 1976 that better showed uniform color spacing in their values. It expresses colors in numbers, and the color difference (ΔE*) between the two colors can be calculated. The Δ E* has to approach 3.3 or higher for the human eye to detect a color difference.[1,2] The Adobe Photoshop software (Adobe Systems Incorporated, San Jose, CA, USA) can be conveniently used to achieve the L*a*b* values from the images.[3]

Predominantly, shade selection is done visually comparing with different shade guide tabs, else is done using spectrophotometers and colorimeters.[4-6] The photographic image can also be analyzed using an advanced computer software which determines the true color of whole or part of such tooth image.[3,7-10] Shade selection from a commercially available shade guide should cover the "envelope of color" of the natural tooth of particular population, rather than just being pleasing.

Clark had introduced a custom shade guide based on Munsell's hue, chroma, and value as there were unpredictable color changes in the production of shade tabs.[11,12] Sproull[13] suggested that ideal shade guides should be well distributed and logically arranged. Preston[14] and Miller[15] concluded that the previous shade guides contained limited selection of colors compared to those found in human teeth. Lemire and Burk studied that natural tooth color space was larger compared to shade guides.[16] Yuan defined natural tooth color space within the Greater Buffalo and found that the shade guide was frequently above perceptibility thresholds, but within the range of acceptability.[17] Natural tooth color spaces and CIE L*a*b* values of different populations have been evaluated

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and reported in literature.[17-21] The aim of this study was to evaluate the natural tooth color space of the Indian population and to compare it with available manufacturer's shade systems.

Materials and Methods

The study was carried out among 700 individuals of 18–30 years' age group. The inclusion criteria for individuals were permanent maxillary central incisors with no caries and restorations, with a reasonable alignment within the arch and overall good general health. Individuals were excluded if they had tooth discoloration due to fluorosis, medications, and congenital disease or if they had tooth bleaching within the previous 6 months. The shade selection for them was carried out using commercial shade guides Vita Lumin vaccum (VL), Vitapan 3-D master (VITA Zahnfabrik, Bad Säckingen, Germany) (V3D), and Shofu's Vintage Halo NCC (SVH).

The individuals to be photographed were draped in gray and the entire back ground was kept gray to prevent the reflection and scattering of light. Once the desired natural head position[22] was attained, the photographs of exposed maxillary incisors and all shade tabs were taken under standard daylight source using a digital single-lens reflex camera (NIKON D-300 with NIKON 105-mm macro lens) at a fixed focal length of 105 mm, aperture 14, ISO 200, and at a fixed subject lens distance of 11 inches. All the images including that of shade tabs and individuals were then transferred to the computer. The closest matching shade was selected by visually comparing the images of shade tabs with images of population's middle portion of maxillary central incisors,[23] and the most appropriate match was selected.

Visually matching on the computer eliminates the influence of external factors such as light and surrounding tissue metamerism. All images were opened individually in Adobe Photoshop 7.0 and Lab sliders were set in Palette well then eyedropper tool was moved to the middle portion of all images displaying the L*a*b* values in the Lab sliders. Three readings for all images were recorded and averaged. Then, those values were converted into L* (luminance), C* (chroma), and H * (hue) values using $C = \sqrt{a^2 + b^2}$ and $H = \tan^{-1} b/a$. The ΔE* was computed between the L*a*b* values of the Indian population and of closest matching shade using $\Delta E^* = \sqrt{"L^2 + "a^2 + "b^2}$.

The L*, C* and a* and b* of all three shade guides were compared with the Indian population. Linear regression analysis and one sample *t*-test for ΔE*between L*a*b* values of population and shade guides were analyzed. The ANOVA test for comparison of ΔE* between the shade guides was also calculated using statistics. All statistical analyses were carried out using Windostat version 8.6. from indostat services, Hyderabad.

Results

It is seen that L* and C* values of the Indian population displayed a broader range than those of shade guides [Figures 1-3]. The chromaticity coordinate a* and b* values of VL shade guide were plotted with a* and b* values of the Indian population, showing that its values extended only in the positive directions toward red (+a*) and toward yellow (+b*), except for B1 shade
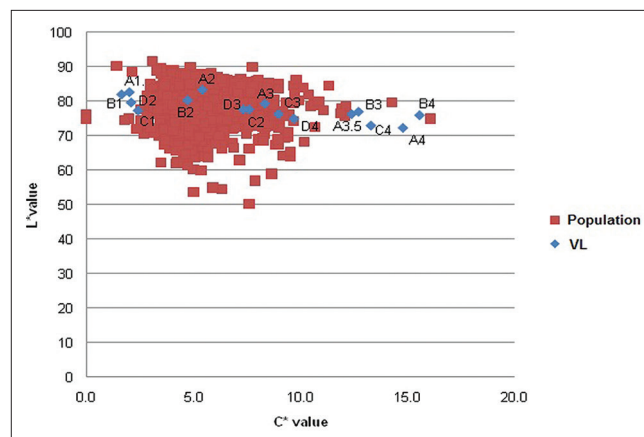

Figure 1: L* and C* plot of population and VITA Lumin vaccum shade guide
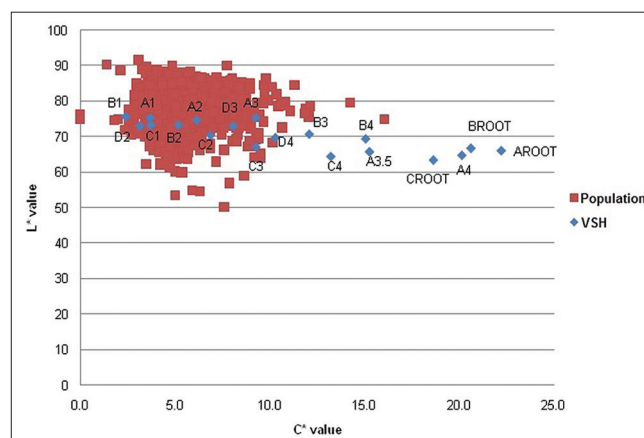

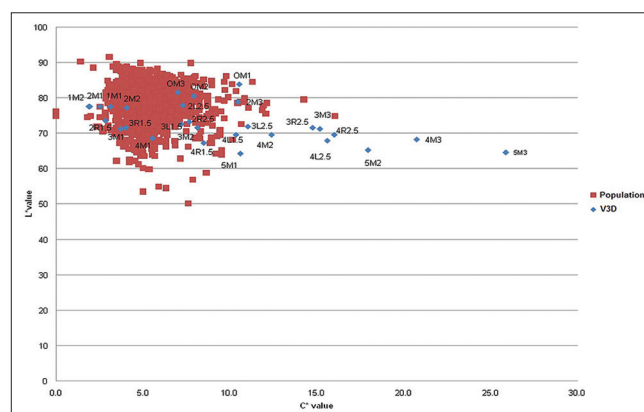Figure 2: L* and C* plot of population and Shofu's Vintage Halo NCC shade guide

Figure 3: L* and C* plot of population and Vitapan 3-D master shade guide

which shifts toward blue (–b*) [Figure 4], and for SVH shade guide, a* and b* values extend only in the positive directions [Figure 5] and V3D values also extend in the positive directions with few tabs in negative direction toward blue [Figure 6]. It is seen that although the V3D values are more regularly arranged and more enlarged in both chroma and lightness as compared to SVH and VL, they do not seem to cover the chromaticity ranges of the Indian population tooth color. The chroma ranges of V3D extend much farther than the population whereas it seems to be deficient in the lightness scale as compared to the population.

The linear regression analysis ($P < 0.001$) revealed a significant negative relationship between the L*a*b* values of population vs. V3D and a* b* values of Population vs SVH, but the L* values of Population vs SVH are moderately significant. Similarly, with VL vs. population, the relationship is moderately significant with respect to L* value ($P < 0.005$). The chroma coverage of SVH and V3D is better and more extended as compared to VL. The a* and b* values of all the shade guides seem to be deficient in their coverage in the negative direction (−a* and −b*), with the V3D being better than the VL and SVH.
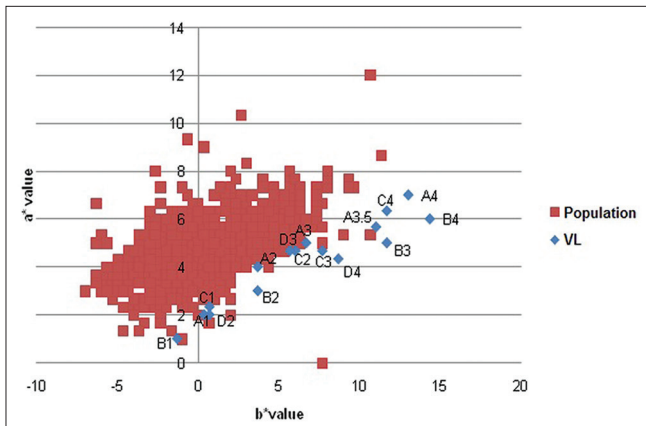
The maximum ΔE* values were seen in V3D shade guide, indicating a mismatch in shade selection [Figure 7].

Discussion

Selection of teeth is frustrating and subject to error when done visually with the shades that are available. According to the research of Kawargi *et al.*, over 80% patients are not satisfied with the color of metal–ceramic crowns in esthetic region compared to natural tooth.[24]

Yamamoto with Minolta and Shofu offered the natural color concept from a worldwide clinical study of tooth shades of 3500 patients, which were recorded and analyzed spectrophotometrically.[25-27] VL was introduced by Vita over 50 years ago and in 1998 V3D shade guide was developed. Studies have shown that in V3D shade guide, chromaticity ranges extend to cover the colors of natural tooth and all three color parameters – the value, chroma, and hue – are more regularly arranged and enlarged compared to the traditional shade guides.[28,29] The recent shade guides have resulted in less coverage error and more ordered color distributions than previous shade guides, but in various studies, most of the dental shade guides cover a limited color space of natural tooth.[21,30,31]
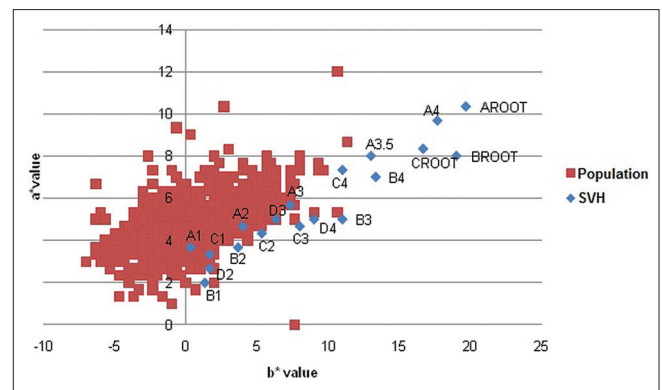

Figure 4: a* and b* plot of population and VITA Lumin vaccum shade guide

Figure 5: a* and b* plot of population and Shofu's Vintage Halo NCC shade guide
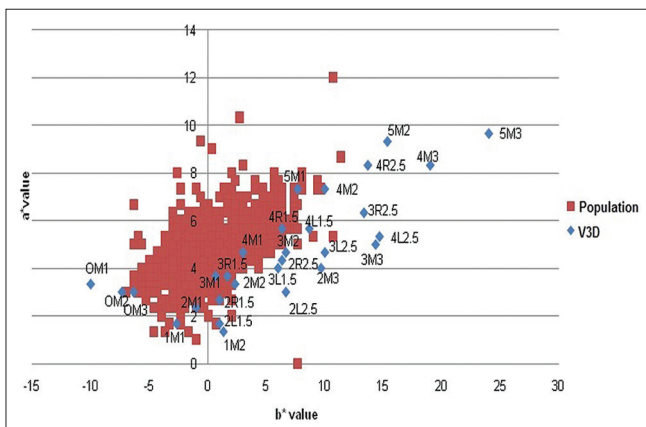

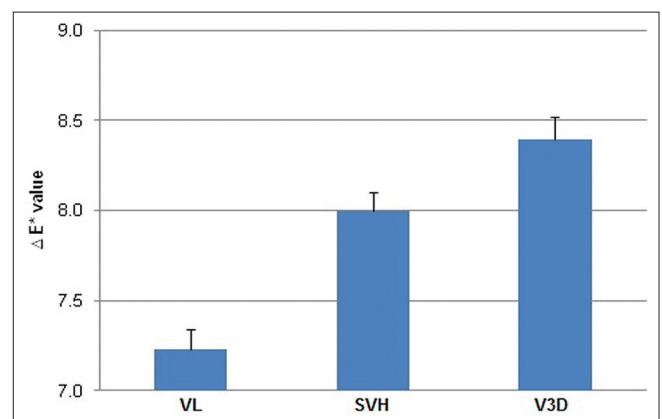**Figure 6:** a* and b* plot of population and Vitapan 3-D master shade guide

Figure 7: Mean Δ E* of three shade guides

Culpepper[32] pointed out the inconsistencies among individual dentists in matching natural tooth shades and the inability of some dentists to duplicate their own shade selections reliably from one time to another. Some of the errors in color matching must be attributed to human variables and other errors to the inadequacy of the available guides.

The mean ΔE^* values between the Indian population and VL, SVH, and V3D in this study were 7.22, 7.99, and 8.39 respectively. This suggests that all the shade guides used in this study do not cover the entire natural tooth color space of the Indian population and thus had a coverage error.

The L* value of population ranged from 50.33 to 91.66 whereas the L* values for all the shade guides ranged from 63.33 to 84. The a* values of population ranged from 1 to 12, and for the shade guides, it was between 1 and 10.33. The range of b* values for the population was 7–11.33, and for the shade guides, it was between 10 and 24. In the Indian population, there is a negative shift of the b* toward blue. O'Brien et al.[30] reported that shade tabs from VL has negative a* values while in the present study negative b* values were noted. Hasegawa et al.[18] and Schwabacher et al.[23] have reported that the VL does not match natural teeth well in red–green chromaticity; the present study supports this view. Another finding in the present study was that the VL extends toward yellow (+b), but does not cover the blue region. However, the V3D seemed to cover the population well in the blue yellow region.

Hayashi[33] described the color space for the Japanese population. Schwabacher et al.[23] described it as a flounder-like configuration within the Munsell system. Vita described the natural tooth color space as a banana shaped situated in a vertical position, its length representing the lightness axis of the three-dimensional plot.[34] The plotted CIE L*a*b* values of the Indian population for color space using software ColorThink Pro 2.1.1 (Chromix, USA)

formed an elongated, cone with irregular base [Figure 8]. It was also used to plot all the shade guides together and was noted that the color space of the three shade guides together improved the coverage [Figure 9]. Hence, it may be advisable to use more than one shade guide to obtain better matches.

In this study, shade selection was limited to readings of only middle portion of individual's image. A more appropriate method would be to divide the image of tooth and choose the shade for different sections. There could be conversion and a nonlinear transpose of the color data in Adobe Photoshop software. Similar studies can be conducted using spectrophotometers and considering validation of color measurement for translucent objects. As spatial differences exist and the shade guides have a larger coverage error for the Indian population, it may be advisable to develop a shade guide, especially for Indian's tooth color space, so that predictable definitive color matches can be achieved.

Conclusions

Within the limitations of this study, the following conclusions can be stated: the L*a*b* and L*C*H* values of the three shade guides were not in the range of the Indian population values. All the three shade guides were deficient in their coverage in the blue and green region. V3D has a systematic and logical arrangement in color space, but it does not cover the Indian teeth color space. The most frequently occurring shades were 4M1 and 2M2 for V3D and B2, followed by A2 for VL and SVH. The mean color differences between the Indian population and the shade guides were not acceptable. The digital photography was found to be a helpful for color matching.
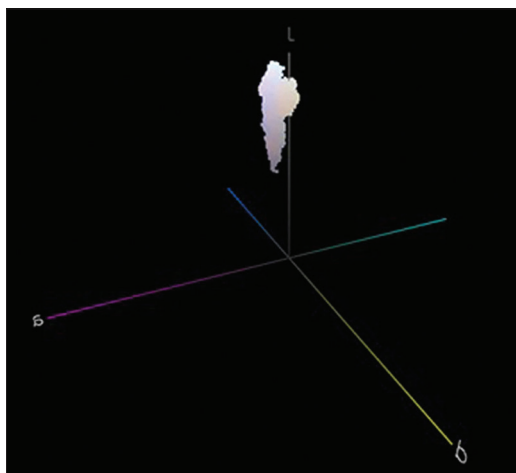
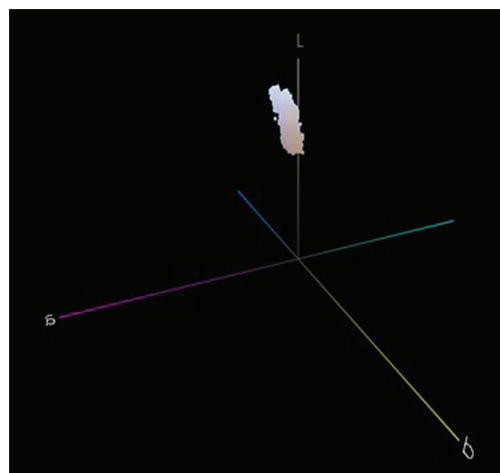Figure 8: Color space distribution of the Indian population

Figure 9: Color space distribution of VITA Lumin vaccum, Vitapan 3-D master, and Shofu's Vintage Halo NCC shade guides

Conflicts of interest

There are no conflicts of interest.

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