






Influences of light temperature and room wall colors on tooth shade matching: a spectrophotometric analysis

Eduardo Trota Chaves¹ , Camila Raubach Dias¹ ,
Fabiola Jardim Barbon¹ , João Pedro do Couto
Caetano¹ , Noéli Boscato^{1*} 

¹ Graduate Program in Dentistry,
Federal University of Pelotas,
Pelotas, Brazil.

Corresponding author:

Noéli Boscato
Graduate Program in Dentistry,
School of Dentistry, Federal
University of Pelotas
Gonçalves Chaves 457, room 508,
Pelotas, Brazil.
Email: noeliboscato@gmail.com,
noeli.boscato@ufpel.edu.br

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Aim: This in vitro study investigates how light temperature and room wall colors influence color differences in two commonly used tooth shade guide scales for color selection in dentistry.

Methods: We examined the effects of three light temperatures (warm light at 3000K, neutral light at 4000K, cool light at 6500K), four room wall colors (white, blue, red, black), chromatic shade values (low, medium, high), and two shade-guide scales (Vita Classical and Biotone). Color differences were measured using an EasyShade spectrophotometer, with ΔE_{00} calculated via the CIEDE2000 method to assess perceptibility and acceptability thresholds. **Results:** The study revealed that high chromatic shade values on both scales showed a greenish shift in the a^* coordinate, while medium and low values inclined towards redness. All b^* values exhibited a tendency towards yellowness. For the Vita Classical scale, neutral light conditions did not significantly affect ΔE_{00} across any room wall colors ($p > 0.05$). However, for the Biotone scale, high chromatic values under specific light conditions significantly surpassed the clinical perceptibility threshold in white versus red room simulations ($p < 0.05$), indicating a notable impact on color perception.

Conclusions: Our findings suggest that both light temperature and room wall color significantly affect tooth shade perception. Adjustments in environmental conditions can corroborate for more accurate color matching between natural tooth and dental restorations. Special attention must be given to extreme light temperatures and contrasting wall colors. These results support the importance of standardized environmental settings in dental practices to ensure reliable esthetic outcomes.

Keywords: Spectrophotometry. Temperature. Color perception. Tooth. Colorimetry.

Introduction

Color perception in dentistry poses a professional challenge due to the subjective nature of human visual assessment, which involves the interaction between the dental element (object) and light incidence^{1,2}. Restorative materials such as composite resins and ceramics are widely used due to their optical properties, which closely mimic those of natural dental structures. However, accurate selection of material color is crucial for meeting patient aesthetic expectations effectively^{1,2}.

Tooth shade selection is a critical aspect of aesthetic restorative treatments, as an improper match between the restoration and adjacent natural teeth plays an important role in the treatment results². Various factors must be considered to achieve an excellent shade match between artificial and natural teeth, regardless of the technique or dental material employed. An ideal shade match is achieved through the perfect alignment of the tooth and restoration colors, influenced by luting and adhesive materials, and modified by different lighting conditions and environments³.

Various tools have been developed to aid this process, including visual shade-guide scales, spectrophotometers, colorimeters, and digital photography². The use of technological or digital devices offers greater reliability and precision, as they minimize external interference. Nonetheless, their use in clinical practice remains limited. Consequently, visual shade-guides remain the predominant method for tooth shade determination in dentistry, despite their reliance on subjective visual comparison^{4,5}. Different lighting conditions and room wall colors can promote perceptible changes in color perception, leading to unsatisfactory aesthetic outcomes due to the phenomenon known as metamerism^{4,6}.

Factors such as visual fatigue, contrast effects, and optical metamerism can also affect tooth shade selection. Previous studies have recommended that the work environment feature neutral wall colors, with natural light deemed the most suitable for tooth shade determination^{5,6}. Investigations have highlighted the complexities of the tooth shade matching process, showing a significant role of illumination in the accuracy of color selection^{4,10}. Al-Dwairi et al.¹¹ (2014) observed notable gender differences and moderate agreement between skin color and tooth shade under various lighting conditions. Computational optimization methods have proven more effective in extending color coverage for dental shade guides¹². The VITA Linearguide 3D-Master has been shown to offer superior color matching due to its enhanced distribution of tooth color shades⁵.

Additionally, controlled lighting conditions have been shown to improve the reliability and consistency of visual shade matching, emphasizing the importance of standardized illumination in achieving accurate tooth shade selection¹³. The primary objective of this study is to investigate the effects of light temperature (i.e., warm, neutral, or cool) and room wall color (i.e., white, black, blue, or red) on color differences (ΔE_{00}) using two shade-guide scales (i.e., Vita Classical or Biotone) available for tooth shade selection in dentistry. The hypotheses tested are that different light temperatures and room wall colors would significantly influence color

differences in tooth shade selection across the two shade-guide scales tested, and that high, medium, and low chromatic shade values would yield distinct ΔE_{00} values under different exposure conditions.”

Materials & Methods

Study Design

This in vitro study employed a 3×4×3×2 factorial design considering: *light temperature* (three levels: warm light at 3000K, neutral light at 4000K, and cool light at 6500K); *room wall color* (four levels: white, blue, red, and black); *chromatic shade value* (three levels: low, medium, and high); and *shade-guide scales* (two levels: Vita Classical from Vita Zahnfabrik, Bad Säckingen, Germany, and Biotone from Dentsply Sirona, Konstanz, Germany). The response variables were color differences (ΔE_{00}) and CIE Lab* color coordinates.

Sample Size Estimation and Power Analysis

Our sample size estimation and power analysis were informed by the study by Gomez-Polo et al.¹⁴ (2014), which used the Easyshade compact spectrophotometer to assess agreement between visual and instrumental color matching methods. Following their approach of three repeated measurements, we extended our protocol to five measurements per factor combination to enhance data reliability and precision. We conducted our power analysis aiming to detect a medium effect size ($f = 0.25$), with an alpha level (α) of 0.05 and a power ($1 - \beta$) of 0.80. These parameters were chosen to ensure that our study was adequately powered to detect clinically meaningful differences in ΔE_{00} values under various lighting and environmental conditions. All measurements were performed by the same experienced operator in a light-controlled environment to maintain consistency and minimize external variability, reinforcing the validity of our results.

Light Temperature and Room Wall Color

The average daylight temperature is 6500K^{10,15}, equivalent to the cool light temperature used in this study. From the light temperature scale, three wavelengths were selected: warm at 3000K, neutral at 4000K, and cool at 6500K. These were reproduced using LED lights from Luminatti (São Paulo, SP, Brazil) with an efficiency of 85 lm/W and a 30W bulb generating approximately 2550 lumens. Four room wall colors (red, blue, white, and black) were selected to simulate the clinical and laboratory environment within a photographic studio box.

Shade-Guide Scales

For this study, we selected the Vita Classical and Biotone shade-guide scales, which are widely recognized and utilized in dental practices globally, based on their prevalent use in clinical settings. These shade guides are not only popular but also represent different materials and color palettes, which is crucial for understanding how various environmental conditions affect the perception of different dental materials. Vita Classical is predominantly used with composite resins and ceramics, making it ideal

for studies involving these materials. In contrast, Biotone is frequently employed with acrylic-based materials, providing a comparative basis to evaluate and assess the influence of light and environmental factors across a broader range of dental restorative materials. The Vita Classical shade-guide includes 16 chromatic shades, from which three chromatic shade values were selected: high (B1), medium (A3), and low (C4). The Biotone shade-guide consists of eight chromatic shades, selecting high (66), medium (61), and low (81) chromatic shade values (Figure 1).

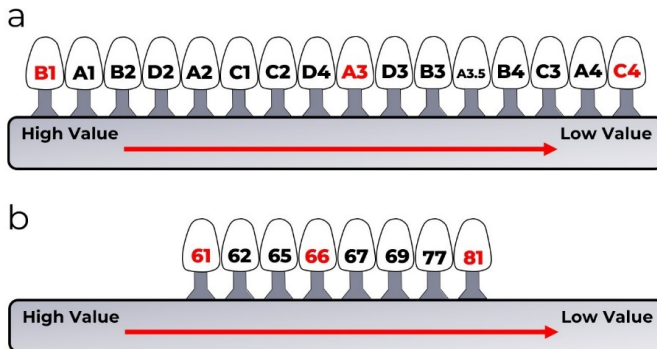


Figure 1. Vita Classical (Vita Zahnfabrik) (a) and Biotone (Dentsply) (b) scales arranged by value order, showing selected color guides in red.

Color Measurements and Calibration with Luxmeter

A Puluz photography lightbox (Shenzhen, China) measuring 20×24×22 cm was used for ΔE_{00} measurements. Lights with three different temperatures were attached to the top of the box. Light intensity was standardized and verified using a digital lux meter from Intrusul (Esteio, RS, Brazil) to 445 lumens/m² after each color measurement (Figure 2).

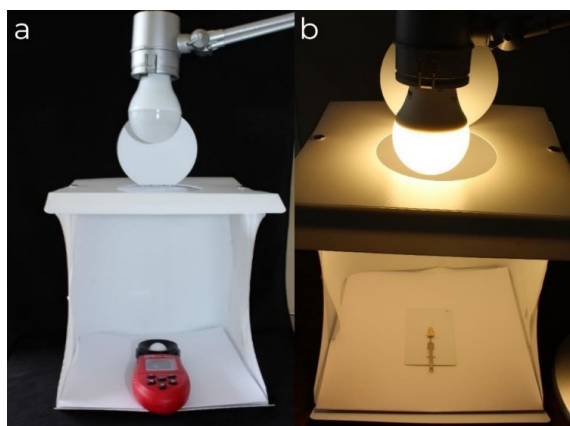


Figure 2. Location of assessments with a lux meter in the center for standardization of luminosity (a); color guide positioned in the center of the simulated environment (b).

Color Differences (ΔE_{00}) and CIELab* Coordinates

ΔE_{00} measurements were conducted with each chromatic shade centrally positioned in the study box. Five measurements were performed at each light temperature and room wall color for high, medium, and low chromatic values of each shade selection scale using an Easysshade spectrophotometer (Vita Zahnfabrik, Bad Säckingen, Germany) based on the CIEDE2000 system. The probe tip was positioned on the middle third of the coronal labial surface of each artificial tooth. Color differences were calculated using the CIEDE2000 formula:

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{k_L S_L} \right)^2 + \left(\frac{\Delta C'}{k_C S_C} \right)^2 + \left(\frac{\Delta H'}{k_H S_H} \right)^2 + R_T \left(\frac{\Delta C'}{k_C S_C} \right) \left(\frac{\Delta H'}{k_H S_H} \right) \right]^{\frac{2}{T}}$$

Where $\Delta L'$, $\Delta C'$, and $\Delta H'$ are the differences in lightness, chroma, and hue between two sets of color coordinates; R_T is the rotation function accounting for the interaction between chroma and hue differences in the blue region; and S_L , S_C , and S_H are weighting functions adjusting the total color difference for variation in perceived magnitude with location of the color coordinate differences between two color readings. The terms k_L , k_C , and k_H are correction factors for the experimental conditions. This study set the color difference perceptibility and acceptability thresholds at $\Delta E_{00} = 0.8$ and $\Delta E_{00} = 1.8$, respectively¹². CIELab* coordinates were noted and considered in separate analyses.

Statistical Analysis

ΔE_{00} means and standard deviations were presented through descriptive analysis. The ΔE_{00} between-group differences related to high, medium, and low chromatic values, considering the Biotone and Vita Classical shade-guides, were analyzed using two-way ANOVA, considering light temperature vs. room wall color, followed by post-hoc Tukey test comparisons ($\alpha = 0.05$). Data normality was analyzed using the Shapiro-Wilk test, and non-parametric data were transformed into ranks. CIELab* coordinates were also analyzed using two-way ANOVA, considering chromatic shade values vs. light temperature, followed by post-hoc Duncan's test comparisons ($\alpha = 0.05$).

Results

Table 1 presents the mean values of ΔE_{00} across high, medium, and low chromatic shade values for both Vita Classical and Biotone scales, considering variations in light temperature. All ΔE_{00} values fell below the clinical acceptability threshold ($\Delta E_{00} = 1.8$). For the Vita Classical scale, the medium chromatic shade value (shade A3) in the Warm vs. Cool light temperature condition exhibited a statistically significant difference ($p = 0.001$) compared to the Neutral-Warm and Neutral-Cool conditions. Chromatic shade values, specifically shade B1 and medium (shade A3), registered values exceeding the clinical perceptibility threshold ($\Delta E_{00} > 0.8$). There were statistically significant differences ($p \leq 0.002$) observed for the high chromatic

B1 shade when compared to A3 and C4 shades under the Warm vs. Cool light temperature condition.

Table 1. ΔE_{00} mean and standard deviations values for high, medium, and low chromatic shade values considering Vita Classical and Biotone scales at different light temperatures and tooth shades.

Scales	Tooth-shades	Neutral × Warm	Neutral × Cool	Warm × Cool
Vita	B1	0.54 (0.39) Aab	0.66 (0.51) Aa	0.98 (0.53) Aa
	A3	0.75 (0.20) Aa	0.81 (0.20) Aa	0.27 (0.13) Bb
	C4	0.26 (0.03) Ab	0.28 (0.03) Aa	0.26 (0.08) Ab
Biotone	61	0.81 (0.32) Aa	0.70 (0.19) Aa	0.44 (0.10) Aab
	66	0.26 (0.11) Bb	0.50 (0.35) ABb	0.65 (0.35) Aa
	81	0.51 (0.43) Ab	0.43 (0.12) Ab	0.40 (0.35) Ab

Different uppercase in the same rows indicate significant between-group differences considering the light temperature (i.e., Neutral × Warm; Neutral × Cool; Warm × Cool) ($p < 0.05$);

Different lowercase in the same columns indicates within-group differences considering the chromatic shade values for each shade selection scale (i.e., Vita Classical and Biotone) ($p < 0.05$).

For the Biotone shade-guide scale, only the medium chromatic 66 shade value displayed statistically significant differences ($p = 0.004$) according to light temperature variability. The Neutral vs. Cool light temperature condition was found to be similar to the other conditions (Neutral vs. Warm and Warm vs. Cool; $p \geq 0.098$), which showed significant differences from each other ($p = 0.004$). The Neutral vs. Warm light temperature condition did not significantly alter the high-chromatic 61 shade value, which was the only value to exceed the ΔE_{00} perceptibility threshold (>0.8).

Table 2 details ΔE_{00} mean values for the Vita Classical scale across cool, neutral, and warm light temperatures under different simulated room wall colors (White vs. Black, White vs. Red, and White vs. Blue). All ΔE_{00} values remained below the clinical perceptibility limit ($\Delta E_{00} \leq 0.8$). However, the simulated room wall colors did not produce a statistically significant difference for the high chromatic B1 shade value ($p = 0.944$). In contrast, ΔE_{00} means for medium (A3 shade) and low (C4 shade) chromatic values were significantly different, particularly under cool light temperature in the simulated White vs. Black room wall color condition compared to White vs. Red and White vs. Blue ($p \leq 0.001$). The White vs. Black condition yielded the lowest ΔE_{00} mean values, whereas White vs. Blue comparisons revealed a significant difference only for the low-chromatic C4 shade value under warm light temperature ($p \leq 0.03$).

Table 2. ΔE_{00} mean and standard deviation values for high, medium, and low chromatic shade values considering the Vita Classical scale at different room wall color comparisons, light temperature, and tooth shades.

Light Temperature	White x Black	White X Red	White X Blue
High Value (B1)			
Cool light	0.71 (0.54) Aa	0.58 (0.48) Aa	0.63 (0.44) Aa
Neutral light	0.35 (0.11) Aa	0.25 (0.05) Aa	0.31 (0.35) Aa
Warm light	0.68 (0.30) Aa	0.60 (0.54) Aa	0.47 (0.32) Aa
Medium Value (A3)			
Cool light	0.15 (0.10) Bb	0.49 (0.20) Aa	0.57 (0.15) Aa
Neutral light	0.59 (0.16) Aa	0.68 (0.25) Aa	0.56 (0.15) Aa
Warm light	0.38 (0.24) Aab	0.16 (0.02) Ab	0.31 (0.19) Aa
Low Value (C4)			
Cool light	0.11 (0.02) Bb	0.44 (0.18) Aa	0.58 (0.32) Aa
Neutral light	0.33 (0.23) Aa	0.27 (0.10) Aa	0.27 (0.05) Aa
Warm light	0.28 (0.09) Aa	0.25 (0.14) ABa	0.14 (0.06) Bb

Different uppercase in the same rows indicate significant between-group differences considering the light temperature (i.e., Neutral vs. Warm; Neutral vs. Cool; Warm vs. Cool) ($p < 0.05$);

Different lowercase in the same columns indicates within-group differences considering the chromatic shade values for Vita Classical scale ($p < 0.05$).

Table 3 presents ΔE_{00} mean values for the Biotone scale across cool, neutral, and warm light temperatures under varying simulated room wall color conditions (White vs. Black, White vs. Red, and White vs. Blue). All values were within the clinical acceptability limit ($\Delta E_{00} \leq 1.8$). The high chromatic 61 shade value exceeded the clinical perceptibility threshold ($\Delta E_{00} \leq 0.8$) under neutral light temperature when comparing the White vs. Red room wall color condition. A statistically significant difference was noted in the warm light temperature for the high chromatic 61 shade value in White vs. Black ($p = 0.038$) and White vs. Red ($p = 0.005$) room wall color condition comparisons. No significant differences were observed in White vs. Blue comparisons across any tested light temperatures ($p > 0.185$). Medium chromatic 66 shade value and low chromatic 81 shade value exhibited no statistical differences in any room wall color comparison considering light temperatures ($p > 0.231$).

Table 3. ΔE_{00} mean and standard deviation values for high, medium, and low chromatic shade values considering the Biotone scale at different room wall color comparisons, light temperature, and tooth shades.

	White x Black	White X Red	White X Blue
High Value (61)			
Cool light	0.21 (0.07) Ab	0.32 (0.10) Ab	0.50 (0.27) Aa
Neutral light	0.57 (0.27) Aa	0.84 (0.03) Aa	0.61 (0.22) Aa
Warm light	0.45 (0.31) ABab	0.38 (0.19) Bb	0.77 (0.21) Aa
Medium Value (66)			
Cool light	0.70 (0.30) Aa	0.54 (0.45) Aa	0.47 (0.39) Aa
Neutral light	0.20 (0.12) Aa	0.43 (0.12) Aa	0.32 (0.11) Aa
Warm light	0.30 (0.16) Aa	0.67 (0.36) Aa	0.61 (0.10) Aa
Low Value (81)			
Cool light	0.62 (0.40) Aa	0.68 (0.46) Aa	0.32 (0.29) Aa
Neutral light	0.29 (0.16) Aa	0.40 (0.30) Aa	0.29 (0.14) Aa
Warm light	0.44 (0.34) Aa	0.66 (0.39) Aa	0.58 (0.43) Aa

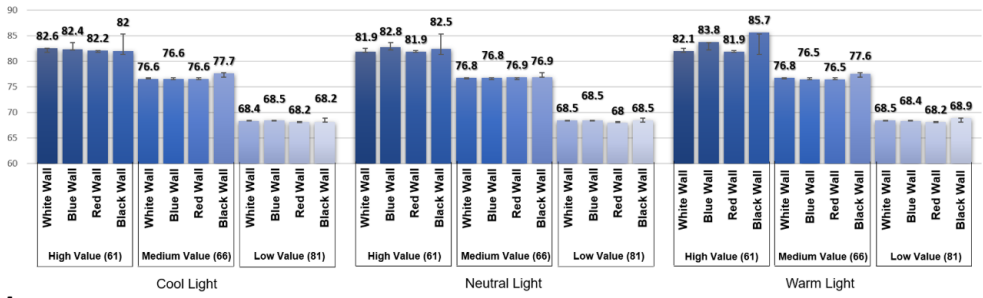
Different uppercase in the same rows indicate significant between-group differences considering the light temperature (i.e., Neutral vs. Warm; Neutral vs. Cool; Warm vs. Cool) ($p < 0.05$);

Different lowercase in the same columns indicates within-group differences considering the chromatic shade values for the Biotone scale ($p < 0.05$).

Figures 3 and 4 illustrate the CIELab* coordinates' means for the Vita Classical and Biotone shade-guide scales, respectively. Both scales showed a tendency toward greener hues for high chromatic shade values (B1 and 61 shades), while medium chromatic (A3 and 66 shades) and low chromatic (C4 and 81 shades) values leaned towards reddening. Both shade guides displayed a yellowing tendency for the b^* coordinate. The L^* coordinate in high-chromatic values (B1 and 61 shades) approached white, whereas it distanced from white in low-chromatic values (C4 and 81 shades). Medium-chromatic values (A3 and 66 shades) exhibited an intermediate L^* value compared to high and low-chromatic values.

L* Coordinate

a



b

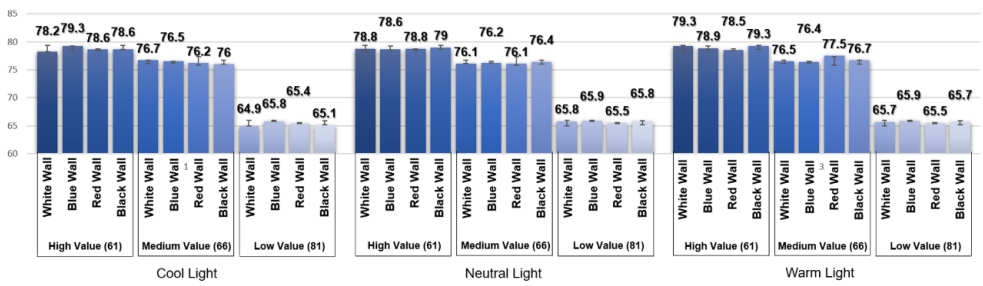
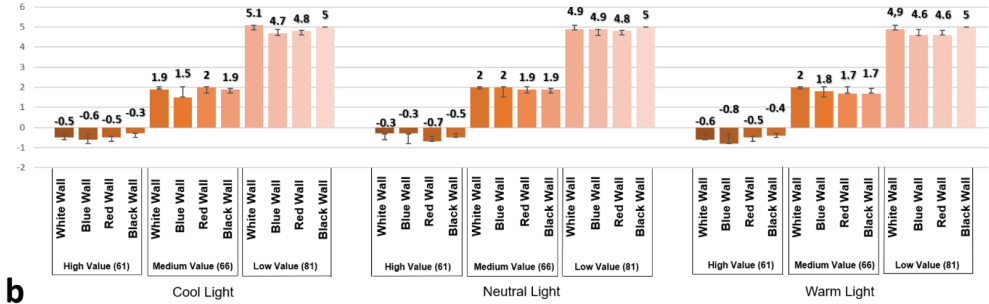


Figure 3. Mean \pm standard deviation ΔE_{00} , CIE L* coordinate values considering (a) Biotone shade-guide scale and (b) Vita Classical shade-guide scale, for the different light temperatures (i.e. cool, neutral, warm), chromatic shade values (i.e. high, medium and low), and room wall colors (i.e. white, blue, red and black).

a* Coordinate

a



b

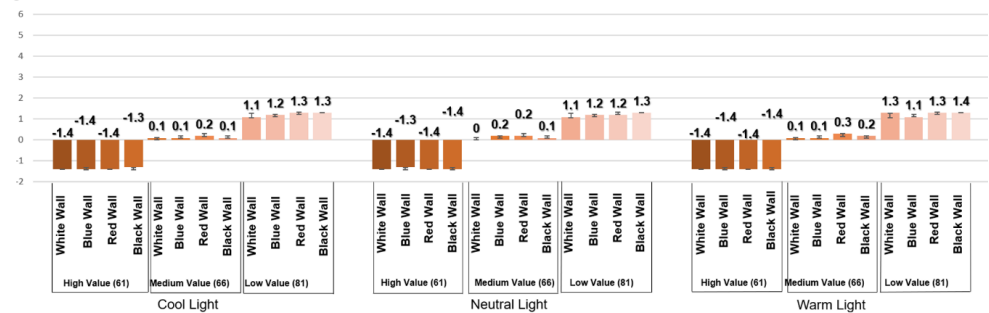


Figure 4. Mean \pm standard deviation ΔE_{00} , CIE a* coordinate values considering (a) Biotone shade-guide scale and (b) Vita Classical shade-guide scale, for the different light temperatures (i.e. cool, neutral, warm), chromatic shade values (i.e. high, medium and low), and room wall colors (i.e. white, blue, red and black).

b* Coordinate

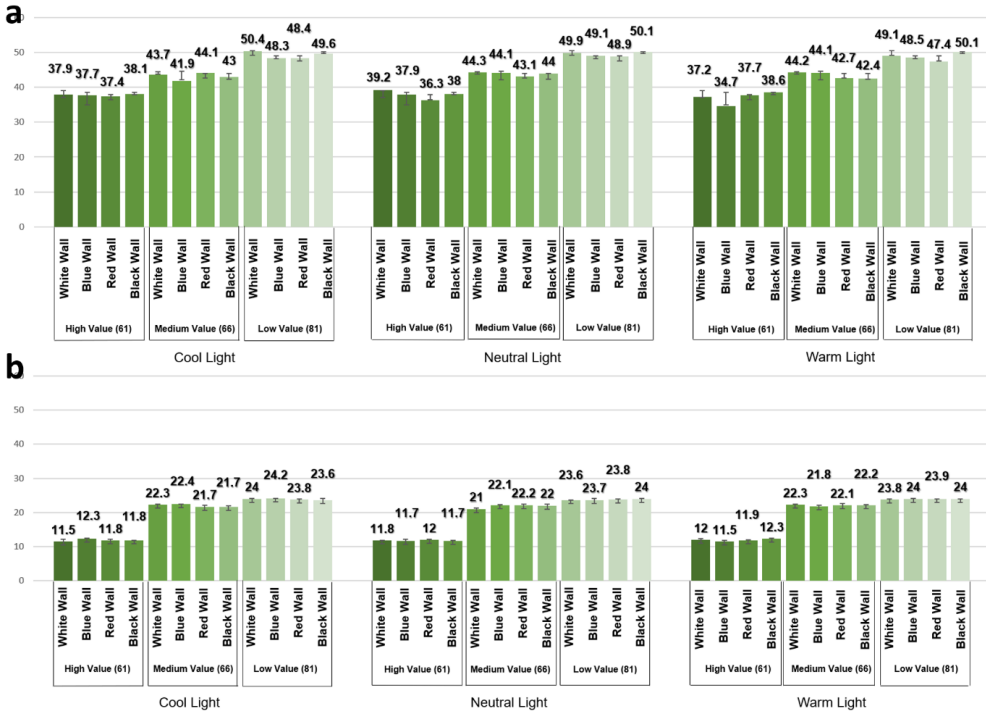


Figure 5. Mean \pm standard deviation ΔE_{00} , CIE b^* coordinate values considering (a) Biotone shade-guide scale and (b) Vita Classical shade-guide scale, for the different light temperatures (i.e. cool, neutral, warm), chromatic shade values (i.e. high, medium and low), and room wall colors (i.e. white, blue, red and black).

Discussion

This study evaluated the influence of light temperature and room wall color on ΔE_{00} values of two different shade-guide scales using low, medium, and high chromatic shade values. The tested hypotheses were accepted since the extreme light temperatures (warm and cool) and darker room wall color conditions (black and red) yielded ΔE_{00} values with statistically significant differences in both evaluated shade-guide scales.

Environmental illumination and external conditions are critical for tooth shade selection in dentistry, significantly influencing the final color of restorations¹⁵⁻¹⁷. Previous reports have assessed ΔE_{00} and hue values considering different shade guides^{17,18}, light temperatures^{8,19}, and measurement methods²⁰⁻²³. However, to the best of our knowledge, no published studies have examined how light temperature and environmental characteristics (e.g., room wall color) influence final tooth shade selection.

Natural daylight (averaging 6500K) is considered the best option for visual scale-aided color selection in dentistry, as it is the most efficient white light source^{6,10,18,24}. However, daylight is not always constant due to factors like time, weather, humidity, and pollution⁹. Thus, neutral light sources are good options for dental offices²⁵. Our study showed that neutral light had less ΔE_{00} variability, as seen in Tables 1 and 2, where

neutral vs. warm and neutral vs. cool conditions did not show statistical differences. Our results showed significant variations in ΔE_{00} between different light temperatures for the Vita Classical scale, especially for the medium chromatic value (A3) between warm and cool light conditions. High chromaticity (B1) and medium chromaticity (A3) shades exceeded the clinical perceptibility threshold ($\Delta E_{00} > 0.8$), indicating that these color differences are visible to more than 50% of the population.

The results from Table 2 showed that for the Vita Classical scale, the simulated room wall colors did not produce statistically significant differences for the high chromatic B1 shade value. However, for medium (A3) and low (C4) chromatic values, the differences were significant, particularly under cool light temperature in the white vs. black wall color condition. This suggests that wall color can influence color perception under cool light. For the Biotone scale, all ΔE_{00} values remained within the clinical acceptability limit ($\Delta E_{00} \leq 1.8$). The high chromatic 61 shade exceeded the clinical perceptibility threshold under neutral light temperature when comparing white vs. red wall color. Statistically significant differences were noted for the high chromatic 61 shade under warm light in white vs. black and white vs. red wall color comparisons.

We observed significant variation in the high chromatic B1 shade compared to the A3 and C4 shades under warm vs. cool light temperature conditions using the Vita scale. This can be explained by the specific optical characteristics of the B1 shade. Known for its high luminosity, B1 reflects more light, making it particularly sensitive to changes in light temperature. Under warm light, B1 may appear brighter and less chromatic. Under cool light, B1 may appear darker and more saturated.

Both shade guides showed a tendency toward greener hues for high chromatic values (B1 and 61), while medium chromatic (A3 and 66) and low chromatic (C4 and 81) values leaned towards reddening. The b^* coordinate indicated a yellowing trend for all high, medium, and low chromatic values in both scales. The L^* coordinate showed that high chromatic values (B1 and 61) approached white, while low chromatic values (C4 and 81) distanced from white. Medium chromatic values (A3 and 66) exhibited intermediate L^* values compared to high and low chromatic values.

The ΔE_{00} perceptibility and acceptability thresholds are 0.8 and 1.8, respectively^{15,26}. In our experiment, all ΔE_{00} values were below the clinical acceptability limit, though some were above the clinical perceptibility limit, meaning these differences can be observed by more than 50% of the population. The highest ΔE_{00} value (0.98) was found in warm vs. cool light temperature conditions for the Vita shade-guide scale with the B1 shade.

In dental offices, it is recommended to use a minimum illuminance of 500 lux²¹. In our study, the simulated environment achieved 445 lux, close to the standard recommendation, allowing comparison with a dental office. Regarding room wall color, the room's atmosphere can influence human visual perception. High contrasts between the workspace and wall color require more visual effort for eye adaptation²⁷. Therefore, the workspace wall color should have a harmonious composition to avoid these contrasts. Recent studies on wall color and ambient light show minimal influence on intraoral scanner performance^{25,28}.

Based on our findings, we recommend using neutral light temperatures (around 4000K to 5000K) and light-colored walls (soft whites or grays) for tooth shade matching to minimize ΔE_{00} variability. These recommendations aim to optimize environmental conditions for tooth shade selection, improving accuracy and consistency in dental aesthetics. While our results provide valuable insights, caution is needed when applying these findings to real-world settings. Future studies should explore how these environmental variables interact in more dynamically lit and decorated spaces common in dental clinics.

Ongoing research should also focus on developing new technologies in lighting and color measurement tools that better simulate natural daylight and provide more accurate color matching capabilities. Further studies are necessary to validate our findings and explore their effects in practical clinical scenarios, considering variables like different types of artificial and natural lighting throughout the day.

Our study had some limitations, such as the high level of environmental control that cannot be fully replicated in typical dental offices. This ideal experimental setup for isolating variables does not fully represent the variability and challenges in everyday clinical environments, which may limit the direct applicability of our findings. However, some strengths include the frequent use of shade-guide scales for tooth shade selection in daily clinical practice. The color of the workspace is crucial due to its strong influence on the final restorative process. More studies are needed to determine the interaction between wall color and ambient light in tooth shade selection. The clinical effect of actual environment size should now be investigated, considering light temperature, wall color, stress, and visual fatigue as possible variables.

In conclusion, within the limitations of this study, it was concluded that neutral light temperature produces lower ΔE_{00} values across all simulated room wall colors using the Vita Classical shade-guide scale. However, for the Biotone shade-guide scale, high-chromatic shade values (i.e., B1 and 66 shades) measured under neutral light exceeded the perceptibility threshold in the White vs. Red room wall color condition. Both shade-guide scales showed a reddish tendency (a^* coordinate) in low- and medium-chromatic shade values (i.e., A3, 61, C4, and 81 shades), while high-chromatic values (i.e., B1 and 66 shades) exhibited a greenish hue. Additionally, a yellowing trend (b^* coordinate) was observed across all chromatic shade values for both shade-guide scales.

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Conflicts of interest

None.

Disclosure Statement

The authors do not have any financial interest in the companies whose materials are included in this article.

Author Contribution

Eduardo Trota Chaves: software, formal analysis, investigation, writing – original draft, writing – review and editing, supervision, project administration, funding acquisition. **Camila Raubach Dias:** conceptualization, methodology, software, formal analysis, investigation, resources, data curation, writing – original draft, writing – review and editing, supervision, project administration, funding acquisition. **Fabiola Jardim Barbon:** conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing – original draft, writing – review and editing, supervision, project administration, funding acquisition. **João Pedro do Couto Caetano:** investigation, writing – original draft, writing – review and editing, supervision, project administration, funding acquisition. **Noéli Boscato:** conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing – original draft, writing – review and editing, supervision, project administration, funding acquisition. All authors actively revised and approved the final version of the manuscript.

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Supplementary Material

Sup Table 1. Mean and (standard deviation) values of the CIE L*, a* and b* coordinates from high, medium and low values refer to the Vita Classical shade-guide scale for the light temperature in simulated room wall colors environments.

	White Wall	Black Wall	Red Wall	Blue Wall
High Value (B1)				
CIE L*				
Cool light	78,2 (0,8) Bb	79,3 (0,2) Aa	78,6 (0,3) Bab	78,6 (0,1) Bb
Neutral light	78,8 (0,1) Aa	78,6 (0,2) Ab	78,8 (0,2) Aa	79,0 (0,6) Ab
Warm light	79,3 (0,8) Aa	78,9 (0,2) Ab	78,5 (0,1) Bb	79,3 (0,0) Aa
CIE a*				
Cool light	-1,4 (0,0) BCa	-1,4 (0,0) Bb	-1,4 (0,1) Ca	-1,3 (0,0) Aa
Neutral light	-1,4 (0,1) Ba	-1,3 (0,1) Aa	-1,4 (0,1) Ba	-1,4 (0,0) Bb
Warm light	-1,4 (0,0) Aa	-1,4 (0,0) Ab	-1,4 (0,0) Aa	-1,4 (0,0) Ab
CIE b*				
Cool light	11,5 (0,7) Aa	12,3 (0,1) Aa	11,8 (0,3) Aa	11,8 (0,1) Ab
Neutral light	11,8 (0,1) Ba	11,7 (0,4) Bb	12,0 (0,2) Aa	11,7 (0,2) Bb
Warm light	12,0 (0,3) ABa	11,5 (0,4) Cb	11,9 (0,1) BCa	12,3 (0,1) Aa
Medium Value (A3)				
CIE L*				
Cool light	76,7 (0,2) Aa	76,5 (0,2) Aa	76,2 (0,2) Bb	76,0 (0,1) Bc
Neutral light	76,1 (0,1) Bb	76,2 (0,1) ABb	76,1 (0,3) Bb	76,4 (0,2) Ab
Warm light	76,5 (0,3) Ba	76,4 (0,3) Bab	77,5 (1,4) Aa	76,7 (0,2) ABa
CIE a*				
Cool light	0,1 (0,1) Aa	0,1 (0,0) Ab	0,2 (0,1) Aa	0,1 (0,1) Aa
Neutral light	0,0 (0,0) Bb	0,2 (0,0) Aa	0,2 (0,1) Aa	0,1 (0,1) Aa
Warm light	0,1 (0,1) Ba	0,1 (0,1) Bb	0,3 (0,2) Aa	0,2 (0,0) Aa
CIE b*				
Cool light	22,3 (0,1) Aa	22,4 (0,1) Aa	21,7 (0,4) Bb	21,7 (0,3) Ba
Neutral light	21,0 (0,3) Bb	22,1 (0,2) Ab	22,2 (0,3) Aa	22,0 (0,4) Aa
Warm light	22,3 (0,2) Aa	21,8 (0,4) Bb	22,1 (0,6) Aa	22,2 (0,1) Aa
Low Value (C4)				
CIE L*				
Cool light	64,9 (2,1) Ca	65,8 (0,1) Aa	65,4 (0,2) Ba	65,1 (1,7) Ba
Neutral light	65,8 (0,0) Aa	65,9 (0,4) Aa	65,5 (0,1) Ba	65,8 (0,1) Aa
Warm light	65,7 (0,2) Ba	65,9 (0,1) Aa	65,5 (0,1) Ca	65,7 (0,1) Ba
CIE a*				
Cool light	1,1 (0,1) Cb	1,2 (0,1) Ba	1,3 (0,0) Aa	1,3 (0,1) Aa
Neutral light	1,1 (0,0) Bb	1,2 (0,1) Aa	1,2 (0,1) Bb	1,3 (0,0) Aa
Warm light	1,3 (0,0) Aa	1,1 (0,1) Bb	1,3 (0,0) Aa	1,3 (0,0) Aa

CIE b*				
Cool light	24,0 (0,2) Aa	24,2 (0,0) Aa	23,8 (0,1) Ba	23,6 (0,6) Bb
Neutral light	23,6 (0,0) Bb	23,7 (0,5) Bc	23,8 (0,2) Ba	24,0 (0,1) Aa
Warm light	23,8 (0,1) Bb	24,0 (0,2) Ab	23,9 (0,0) ABa	24,0 (0,0) Aab

Different uppercase in the same rows indicate significant between simulated room wall colors differences considering the light temperature (i.e., Neutral vs. Warm; Neutral vs. Cool; Warm vs. Cool) ($p < 0.05$); Different lowercase in the same columns indicates within-group light temperatures chromatic shade values for the Vita Classical shade-guide scale ($p < 0.05$).

Sup Table 2. Mean and (standard deviation) values of the CIE L*, a* and b* coordinates from high, medium and low values refer to the Biotone shade-guide scale for the light temperature in simulated room wall colors environments.

	White Wall	Black Wall	Red Wall	Blue Wall
High Value (61)				
CIE L*				
Cool light	82,6 (0,2) Aa	82,4 (0,2) Aba	82,2 (0,2) BCa	82,0 (0,4) Cc
Neutral light	81,9 (0,4) Bb	82,8 (0,7) Aa	81,9 (0,2) Bb	82,5 (0,2) Ab
Warm light	82,1 (0,1) BDb	83,8 (3,3) Ca	81,9 (0,4) Dab	85,7 (3,9) Aa
CIE a*				
Cool light	-0,5 (0,0) Bb	-0,6 (0,1) Bb	-0,5 (0,1) Ba	-0,3 (0,1) Aa
Neutral light	-0,3 (0,0) Aa	-0,3 (0,1) Aa	-0,7 (0,2) Cb	-0,5 (0,1) Bb
Warm light	-0,6 (0,1) Bb	-0,8 (0,3) Cc	-0,5 (0,1) Aa	-0,4 (0,1) Aab
CIE b*				
Cool light	37,9 (0,3) Ab	37,7 (0,6) Aa	37,4 (0,6) Aab	38,1 (0,7) Aa
Neutral light	39,2 (0,1) Aa	37,9 (1,5) Ba	36,3 (1,2) Cb	38,0 (0,6) Ba
Warm light	37,2 (0,7) Bb	34,7 (4,3) Bb	37,7 (0,3) Ba	38,6 (0,4) Aa
Medium Value (66)				
CIE L*				
Cool light	76,6 (0,5) Aa	76,6 (0,2) Aa	76,6 (0,4) Aa	77,7 (0,8) Aa
Neutral light	76,8 (0,0) Aa	76,8 (0,3) Aa	76,9 (1,5) Aa	76,9 (0,5) Aa
Warm light	76,8 (0,4) ABa	76,5 (0,1) Ba	76,5 (0,3) Ba	77,6 (0,9) Aa
CIE a*				
Cool light	1,9 (0,2) Aa	1,5 (0,3) Bb	2,0 (0,1) Aa	1,9 (0,3) Aa
Neutral light	2,0 (0,0) Aa	2,0 (0,1) Aa	1,9 (0,2) Aa	1,9 (0,1) Aa
Warm light	2,0 (0,1) Aa	1,8 (0,1) Ba	1,7 (0,2) Bb	1,7 (0,2) Bb
CIE b*				
Cool light	43,7 (1,4) Aa	41,9 (1,8) Bb	44,1 (0,3) Aa	43,0 (2,2) Aa
Neutral light	44,3 (0,0) Aa	44,1 (0,4) Aa	43,1 (2,6) Aa	44,0 (0,3) Aa
Warm light	44,2 (0,1) Aa	44,1 (0,4) Aa	42,7 (1,2) Bb	42,4 (1,4) Ba
Low Value (81)				
CIE L*				
Cool light	68,4 (0,2) Aa	68,5 (0,2) Aa	68,2 (0,0) Ba	68,2 (0,1) Bc
Neutral light	68,5 (0,2) Aa	68,5 (0,1) Aa	68,0 (0,2) Ba	68,5 (0,1) Ab
Warm light	68,5 (0,2) Ba	68,4 (0,1) Ba	68,2 (0,1) Ca	68,9 (0,2) Aa
CIE a*				
Cool light	5,1 (0,2) Aa	4,7 (0,3) Bab	4,8 (0,2) Ba	5,0 (0,1) Aa
Neutral light	4,9 (0,1) Aba	4,9 (0,1) Aba	4,8 (0,2) Ba	5,0 (0,1) Aa
Warm light	4,9 (0,2) Aa	4,6 (0,2) Bb	4,6 (0,3) Ba	5,0 (0,1) Aa

CIE b*				
Cool light	50,4 (0,6) Aa	48,3 (2,0) Ba	48,4 (1,7) Ba	49,6 (0,4) Aba
Neutral light	49,9 (0,5) Aab	49,1 (0,1) Ba	48,9 (1,3) Ba	50,1 (0,7) Aa
Warm light	49,1 (0,2) Ab	48,5 (1,5) Aba	47,4 (2,0) Ba	50,1 (0,5) Aa

Different uppercase in the same rows indicate significant between simulated room wall colors differences considering the light temperature (i.e., Neutral vs. Warm; Neutral vs. Cool; Warm vs. Cool) ($p < 0.05$); Different lowercase in the same columns indicates within-group light temperatures chromatic shade values for the Biotone shade-guide scale ($p < 0.05$).