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Spectrophotometric Evaluation of Natural Tooth Color Distribution Across Three Dental Shade Guide Systems: A Cross-Sectional Study

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Abstract

Accurate determination of tooth color is essential for achieving optimal esthetic outcomes in restorative dentistry. Spectrophotometry has emerged as a reliable method for objective color assessment, overcoming the limitations of visual shade selection. This study aimed to evaluate the distribution of natural tooth color using spectrophotometric measurements, to compare its representation across three dental shade guide systems, and to assess its variation according to gender and age. A total of 235 participants aged 18–69 years were included in this cross-sectional study. Tooth color of maxillary central incisors was measured using a non-contact spectrophotometer (ShadePilot). The obtained values were matched to VITA Classical, Ivoclar Chromascop, and VITA 3D-Master shade guides. Statistical analysis was performed using the Pearson Chi-square test ($p < 0.05$). Shades from Group A (VITA Classical), Group 100 (Chromascop), and Group 2 (VITA 3D-Master) were the most prevalent. Significant differences in shade distribution were observed across all three systems.

Both gender and age showed statistically significant influence on tooth color ($p < 0.05$), with a clear trend toward darker shades in older age groups. Natural tooth color distribution varies depending on the shade guide system used and is significantly influenced by demographic factors. Spectrophotometric analysis provides a reliable approach for improving shade selection and enhancing esthetic outcomes in clinical practice.

Keywords: Tooth color; Spectrophotometry; Shade guides; Esthetic dentistry

Introduction

Accurate tooth color determination is essential for achieving optimal esthetic outcomes in restorative dentistry. The optical properties of natural teeth are highly individual, resulting from complex interactions between enamel translucency, dentin characteristics, and light reflection, which produce a wide spectrum of shades under clinical conditions. However, conventional shade guides are limited to a finite number of prefabricated samples and often fail to fully represent the variability of natural dentition, leading to inconsistencies in shade matching. Visual shade selection, although widely used, is influenced by subjective factors such as lighting conditions, operator experience, and visual perception, as emphasized by Chu and Paravina (2010) and Paravina and Powers (2004). To overcome these limitations, spectrophotometry has been introduced as an objective method for tooth color measurement (Lee et al., 2024; Hardan et al., 2022). Spectrophotometers provide quantitative assessment of tooth color based on the CIELAB color space, enabling precise evaluation of L*, a*, and b* parameters, as well as calculation of color differences (ΔE^*ab). Recent studies have demonstrated that spectrophotometric methods offer improved accuracy and reproducibility compared to visual assessment and digital approaches (Lee et al., 2024; Hardan et al., 2022; Crespo et al., 2022; Alvarado-Lorenzo et al., 2025). Despite these advantages, discrepancies between devices and differences in translating instrumental measurements into various shade guide systems remain a challenge (Crespo et al., 2022; Kupke et al., 2025). In addition, the distribution of natural tooth color is not uniform and varies across populations and methodologies, emphasizing the need for further investigation (Gasparik et al., 2025).

The aim of this study was to evaluate the distribution of natural tooth color using spectrophotometric measurements, to compare its representation across three dental shade guide systems, and to assess its variation according to gender and age.

Methods

Study design

This cross-sectional clinical study included 235 patients aged 18–69 years, consecutively recruited from individuals seeking dental care. The study population consisted of 127 females and 108 males. The study was conducted at the Dental Laboratory for Scientific Research, Faculty of Medical Sciences, Goce Delcev University, Stip, North Macedonia.

Tooth color readings were performed using a non-contact surface spectrophotometer, ShadePilot™ (DeguDent, Germany), with an optical geometry of 45/0°. The device allows objective and reproducible color measurement by minimizing the influence of external lighting conditions.

Criteria

Inclusion criteria:

1. Maxillary permanent central incisor (right or left)
2. Teeth with minimal to moderate inclination
3. Minimal incisal wear; small cracks were acceptable
4. Minor extrinsic discolorations allowed
5. Age ≥18 years.

Exclusion criteria:

1. Presence of dental caries
2. Teeth with restorations, crowns, or veneers
3. Endodontically treated teeth
4. Severe erosion or abrasion
5. Severely rotated or inclined teeth
6. Intrinsic discoloration (fluorosis, tetracycline staining, trauma)
7. Structural abnormalities (e.g., enamel hypoplasia, dentinogenesis imperfecta)
8. History of tooth bleaching.

Spectrophotometric procedure

Before the measurement procedure, each participant was instructed to brush their teeth using their usual oral hygiene technique in order to remove plaque and surface debris that could affect color readings. The measuring tip of the spectrophotometer was replaced after each patient to maintain infection control and sterility.

The spectrophotometer was calibrated before each series of measurements using white and green ceramic calibration plates provided by the manufacturer. Calibration was performed according to the manufacturer's instructions to ensure accuracy and consistency of the recorded values.

All spectrophotometric assessments were performed by a single trained operator with prior experience in using the device to minimize inter-operator variability and reduce errors.

Color recordings were obtained from the middle third of the labial surface of the maxillary central incisor. This region was selected because it is considered the most representative of the intrinsic tooth color, as it is less influenced by gingival reflection compared to the cervical third and less affected by translucency compared to the incisal third.

In addition, the device automatically matched the measured tooth color to the closest corresponding shades in three different dental shade guide systems. For the purpose of this study, the closest shade value displayed by the device was selected for analysis.

In order to assess the influence of age on tooth color, participants were divided into three age groups: Group I: 18–30 years, Group II: 31–49 years, Group III: 50–69 years

All participants were informed about the purpose of the study and provided written informed consent prior to participation.

Statistical analysis

Statistical analysis was performed using appropriate statistical methods. Categorical variables, including gender, age groups, and shade distribution, were expressed as percentages. Differences between groups were analyzed using the Pearson Chi-square test. Statistical significance was set at $p < 0.05$.

Results

Descriptive Statistics of the Study Population

A total of 235 participants were included in the analysis, of whom 127 (54.04%) were female and 108 (45.96%) were male (Table 1).

Table 1: Gender distribution of participants

Gender	**N**		**%**
Female	127		54.04
Male	108		45.96
Total	**235**		**100**

To evaluate the influence of age on tooth color distribution, participants were divided into three age groups (Table 2).

Table 2: Distribution of participants according to age groups

Group	**Age range**	**N**	**%**
I	18–30	77	32.78
II	31–49	99	42.13
III	50–69	59	25.11

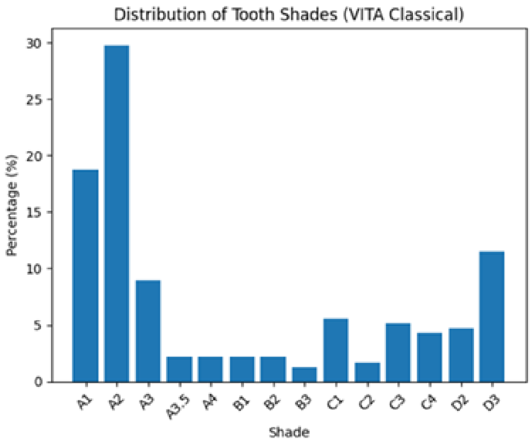
VITA Classical Shade Distribution

Shades from Group A (reddish-orange shades) were the most prevalent, observed in 145 incisors (61.7%) out of the total number of examined teeth (n = 235). Among them, A2 was the most frequent shade, recorded in 70 teeth (29.79%). Group B (yellow shades) showed the lowest representation, accounting for 13 teeth (5.53%).

Within this group, shades B1 and B2 were equally represented, each observed in 5 incisors (2.13%)(Table 3).

Table 3: Distribution of tooth color according to the VITA Classical shade guide

VITA Classical	N	%
A1	44	18.72
A2	70	29.79
A3	21	8.94
A3.5	5	2.13
A4	5	2.13
B1	5	2.13
B2	5	2.13
B3	3	1.28
C1	13	5.53
C2	4	1.70
C3	12	5.11
C4	10	4.26
D2	11	4.68
D3	27	11.49
Total	**235**	**100**



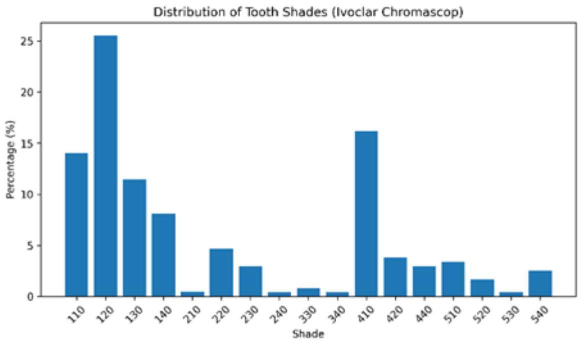
Ivoclar Chromascop Shade Distribution

Among the total number of examined teeth (n = 235), the most frequently represented group was Group 100 (white shades), observed in 139 teeth (59.15%). Within this group, shade 120 was the most common, recorded in 60 teeth (25.53%).

The least represented group was Group 300 (orange shades), observed in only 3 teeth (1.28%), with shade 330 recorded in 2 teeth (0.85%)(Table 4).

Table 4: Distribution of tooth color according to the Ivoclar Chromascop shade guide

Ivoclar Chromascop	N	%
110	33	14.04
120	60	25.53
130	27	11.49
140	19	8.09
210	1	0.46
220	11	4.68
230	7	2.98
240	1	0.43
330	2	0.85
340	1	0.43
410	38	16.17
420	9	3.83
440	7	2.98
510	8	3.40
520	4	1.70
530	1	0.43
540	6	2.55
Total	**235**	**100**



VITA 3D-Master Shade Distribution

A. Distribution according to value (lightness groups) (Table 5)

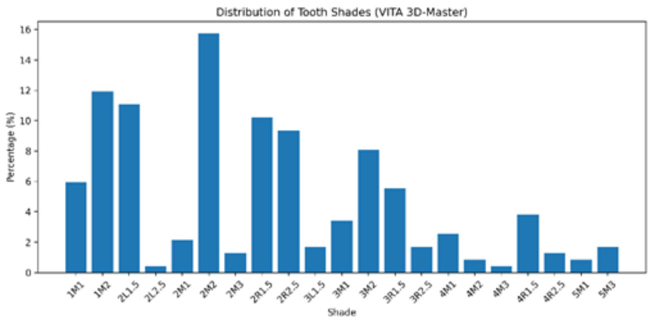
- Group 2 was the most prevalent, observed in 118 incisors (50.21%), with 2M2 as the dominant shade (37 teeth; 15.74%).
- Group 5 was the least represented, observed in only 6 incisors (2.56%), with 5M3 being the most common (4 teeth; 1.70%).

B. Distribution according to hue (L, M, R groups)

- The highest representation was observed in the M group (medium shades) with 129 incisors (54.90%).

Table 5: Distribution of tooth color according to the VITA 3D-Master shade guide

VITA 3D-Master	N	%
1M1	14	5.96
1M2	28	11.91
2L1.5	26	11.06
2L2.5	1	0.43
2M1	5	2.13
2M2	37	15.74
2M3	3	1.28
2R1.5	24	10.21
2R2.5	22	9.36
3L1.5	4	1.70
3M1	8	3.40
3M2	19	8.09
3R1.5	13	5.53
3R2.5	4	1.70
4M1	6	2.55
4M2	2	0.85
4M3	1	0.43
4R1.5	9	3.83
4R2.5	3	1.28
5M1	2	0.85
5M3	4	1.70
Total	**235**	**100**



Gender-Based Differences in Tooth Color Distribution

The distribution of shades according to gender using the **VITA Classical shade guide** showed a statistically significant difference ($p < 0.01$; $p = 0.005$).

The most frequent shade in both genders was A2, equally represented in 35 incisors (14.89%). Among female participants (n = 127; 54.04%), the least represented shade was B2, observed in only 1 incisor (0.43%), while shades B3 and C2 were not recorded. In male participants (n = 108; 45.96%), the least frequent shade was B1, observed in only 1 incisor (0.43%) (Table 6).

Table 6: Distribution of VITA Classical shades according to gender

VITA Classical	Female (N=127)	%	Male (N=108)	%
A1	33	14.04	11	4.68
A2	35	14.89	35	14.89
A3	6	2.55	15	6.38
A3.5	3	1.28	2	0.85
A4	2	0.85	3	1.28
B1	4	1.70	1	0.43
B2	1	0.43	4	1.70
B3	0	0.00	3	1.28
C1	9	3.83	4	1.70
C2	0	0.00	4	1.70
C3	6	2.55	6	2.55
C4	4	1.70	6	2.55
D2	6	2.55	5	2.13
D3	18	7.66	9	3.83
Total	**127**	**54.04**	**108**	**45.96**

Pearson Chi-square = 29.93; p = 0.005

The distribution of tooth shades according to gender using the **Ivoclar Chromascop** shade guide also showed a **statistically significant difference** ($p < 0.001$). The most frequently observed shade in both genders was **120**, recorded in 32 incisors (13.62%) in females and 28 incisors (11.91%) in males (Table 7).

Table 7: Distribution of Ivoclar Chromascop shades according to gender

Shade	Female (N=127)	%	Male (N=108)	%
110	29	12.34	4	1.70
120	32	13.62	28	11.91
130	16	6.81	11	4.68
140	5	2.13	14	5.96
210	0	0.00	1	0.43
220	3	1.28	8	3.40
230	3	1.28	4	1.70
240	1	0.43	0	0.00
330	0	0.00	2	0.85
340	1	0.43	0	0.00
410	24	10.21	14	5.96
420	1	0.43	8	3.40
440	7	2.98	0	0.00
510	2	0.85	6	2.55
520	1	0.43	3	1.28
530	0	0.00	1	0.43
540	2	0.85	4	1.70
Total	**127**	**54.04**	**108**	**45.96**

Pearson Chi-square = 50.35; p < 0.001

The distribution of tooth shades according to gender using the VITA 3D-Master also showed a statistically significant difference ($p < 0.001$).

Among females, the most frequent shade was 1M2, recorded in 22 teeth (9.36%), whereas among males the most frequent shade was 2L1.5, recorded in 18 teeth (7.66%)(Table 8).

Table 8: Distribution of VITA 3D-Master shades according to gender

Shade	Female (N=127)	%	Male (N=108)	%
1M1	12	5.11	2	0.85
1M2	22	9.36	6	2.55
2M1	5	2.13	0	0.00
2M2	20	8.51	17	7.23
2M3	0	0.00	3	1.28
3M1	5	2.13	3	1.28
3M2	5	2.13	14	5.96
4M1	5	2.13	1	0.43
4M2	1	0.43	1	0.43
4M3	0	0.00	1	0.43
5M1	1	0.43	1	0.43
5M3	1	0.43	3	1.28
2L1.5	9	3.83	18	7.66
3L1.5	3	1.28	1	0.43
2R1.5	14	5.96	10	4.26
3R1.5	11	4.68	3	1.28
3R2.5	2	0.85	2	0.85
2R2.5	7	2.98	14	5.96
4R2.5	1	0.43	2	0.85
4R1.5	3	1.28	6	2.55
Total	**127**	**54.04**	**108**	**45.96**

Pearson Chi-square = 45.63; $p < 0.001$

Age-Related Differences in Tooth Color Distribution

The distribution of tooth shades according to age groups using the VITA Classical shade guide showed a **statistically significant difference** ($p < 0.001$)(Table 9). In the youngest age group (18–30 years; n = 77; 32.77%), the most frequently observed shade was **A1**, recorded in 33 incisors (14.04%).In the middle age group (31–49 years; n = 99; 42.13%), the most prevalent shade was **A2**, recorded in 39 incisors (16.60%). In the oldest age group (50–69 years; n = 59; 25.11%), the most frequently observed shade was **C3**, recorded in 12 incisors (5.11%).

Table 9: Distribution of VITA Classical shades according to age groups

Shade	18–30 (N=77)	%	31–49 (N=99)	%	50–69 (N=59)	%
A1	33	14.04	7	2.98	4	1.70
A2	28	11.91	39	16.60	3	1.28
A3	4	1.70	13	5.53	4	1.70
A3.5	0	0.00	2	0.85	3	1.28
A4	0	0.00	0	0.00	5	2.13
B1	2	0.85	3	1.28	0	0.00
B2	3	1.28	2	0.85	0	0.00
B3	0	0.00	0	0.00	3	1.28
C1	3	1.28	8	3.40	2	0.85
C2	0	0.00	4	1.70	0	0.00
C3	0	0.00	0	0.00	12	5.11
C4	0	0.00	0	0.00	10	4.26
D2	0	0.00	6	2.55	5	2.13
D3	4	1.70	15	6.38	8	3.40
Total	**77**	**32.77**	**99**	**42.13**	**59**	**25.11**

Pearson Chi-square = 170.40; p < 0.001

A statistically significant difference was also observed in shade distribution among age groups using the Ivoclar Chromascop system (p < 0.001). In the youngest group (18–30 years), the most frequent shade was **120**, recorded in 38 incisors (16.17%). In the middle age group (31–49 years), the most common shade was **410**, recorded in 24 incisors (10.21%). In the oldest group (50–69 years), the most frequent shade was also **410**, recorded in 10 incisors (4.26%)(Table 10).

Table 10: Distribution of Ivoclar Chromascop shades according to age group

Shade	18–30	%	31–49	%	50–69	%
110	22	9.36	7	2.98	4	1.70
120	38	16.17	20	8.51	2	0.85
130	6	2.55	18	7.66	3	1.28
140	4	1.70	14	5.96	1	0.43
210	0	0.00	0	0.00	1	0.43
220	2	0.85	7	2.98	2	0.85
230	0	0.00	3	1.28	4	1.70
240	0	0.00	0	0.00	1	0.43
330	0	0.00	0	0.00	2	0.85
340	0	0.00	0	0.00	1	0.43
410	4	1.70	24	10.21	10	4.26
420	1	0.43	6	2.55	2	0.85
440	0	0.00	0	0.00	7	2.98
510	0	0.00	0	0.00	8	3.40
520	0	0.00	0	0.00	4	1.70
530	0	0.00	0	0.00	1	0.43
540	0	0.00	0	0.00	6	2.55
Total	**77**	**32.77**	**99**	**42.13**	**59**	**25.11**

Pearson Chi-square = 174.02; p < 0.001

Table 11: Distribution of VITA 3D-Master shades according to age groups

Shade	18–30	%	31–49	%	50–69	%
1M1	9	3.83	3	1.28	2	0.85
1M2	23	9.79	1	0.43	4	1.70
2M1	1	0.43	4	1.70	0	0.00
2M2	12	5.11	24	10.21	1	0.43
2M3	0	0.00	1	0.43	2	0.85
2L1.5	11	4.68	15	6.38	1	0.43
2R1.5	11	4.68	11	4.68	2	0.85
2R2.5	4	1.70	14	5.96	3	1.28
3M1	0	0.00	4	1.70	4	1.70
3M2	3	1.28	13	5.53	3	1.28
3L1.5	1	0.43	3	1.28	0	0.00
3R1.5	2	0.85	5	2.13	7	2.98
3R2.5	0	0.00	1	0.43	3	1.28
4M1	0	0.00	0	0.00	6	2.55
4M2	0	0.00	0	0.00	2	0.85
4M3	0	0.00	0	0.00	1	0.43
4R1.5	0	0.00	0	0.00	9	3.83
4R2.5	0	0.00	0	0.00	3	1.28
5M1	0	0.00	0	0.00	2	0.85
5M3	0	0.00	0	0.00	4	1.70
Total	**77**	**32.77**	**99**	**42.13**	**59**	**25.11**

Pearson Chi-square = 175.81; p < 0.001

The distribution of shades according to age groups using the VITA 3D-Master system also demonstrated a **statistically significant difference** (p < 0.001). In the youngest age group, the most frequent shade was **1M2**, recorded in 23 incisors (9.79%). In the middle age group, the most common shade was **2M2**, recorded in 24 incisors (10.21%). In the oldest age group, the most prevalent shade was **4R1.5**, recorded in 9 incisors (3.83%)(Table 11).

Discussion

Accurate determination of tooth color is a critical component of esthetic dentistry, where achieving a natural appearance is directly linked to patient satisfaction. In clinical practice, maxillary central incisors are commonly used as reference teeth due to their prominent position in the smile and their accessibility for both visual and instrumental assessment. The precision of shade matching depends not only on the clinician's experience but also on the method used for color determination. Numerous studies have demonstrated that instrumental methods, especially spectrophotometry, provide superior objectivity, reproducibility, and accuracy compared to conventional visual techniques (Chu et al., 2010; Paravina & Powers, 2004; Lee et al., 2024; Hardan et al., 2022).

In the present study, tooth color was measured using a non-contact spectrophotometer, focusing on the middle third of the labial surface of the maxillary central incisors. This region was selected because it is considered the most representative of the intrinsic tooth color, as it is less influenced by gingival reflection compared to the cervical region and less affected by translucency compared to the incisal edge. These methodological considerations are supported by Dozić et al. (2004), who reported no statistically significant differences in CIELAB values between the middle third and other regions of the tooth.

The results of this study showed that, according to the VITA Classical shade guide, the most prevalent shades belonged to Group A (reddish-orange hues), accounting for 61.7% of all examined teeth. Among these, shade A2 was the most frequently observed. This finding is consistent with several studies that have reported a predominance of A-group shades in natural dentition, regardless of the measurement method used (Gasparik et al., 2025; Lee et al., 2024; Alvarado-Lorenzo et al., 2025).

Paravina et al. (2004) reported a lower prevalence of Group A shades (43.9%), followed by Group C (24%), Group B (20.4%), and Group D (11.7%). These differences may be explained by variations in study design, including the inclusion of multiple tooth types (incisors, canines, premolars, and molars), as well as differences in sample size and population characteristics.

Within Group A, shade A2 was the most dominant, which agrees with findings reported by Herekar et al. (2018), even though their study relied on visual shade selection.

Regarding the Ivoclar Chromascop system, the present study demonstrated that Group 100 (white shades) was the most prevalent, accounting for 59.15% of the examined teeth, with shade 120 being the most frequently observed. These findings are in line with earlier research by Ansari et al. (2010), who also reported a predominance of lighter shades using visual assessment methods.

In the VITA 3D-Master system, the majority of shades were distributed within the M group (intermediate hues), accounting for 54.9% of the sample, with shade 2M2 being the most dominant. This observation supports the concept that natural tooth color tends to cluster around intermediate hue values rather than extreme yellow or red variations. Recent studies using digital and spectrophotometric methods have also confirmed that the 3D-Master system provides a more uniform and systematic distribution of tooth color compared to traditional shade guides (Lee et al., 2024; Crespo et al., 2022).

An important finding of this study is that the three shade guide systems used (VITA Classical, Ivoclar Chromascop, and VITA 3D-Master) do not show direct correspondence in their most frequently observed shades. This lack of compatibility between shade guides has important clinical implications. In everyday practice, shade guides serve as a communication tool between the clinician and the dental technician. If different systems are used, discrepancies in shade interpretation may occur, leading to mismatched restorations. This is particularly critical in the anterior region, where even minor color differences can significantly affect esthetic outcomes.

From a perceptual standpoint, the importance of color parameters must also be considered. It is well established that value (lightness) is the most critical parameter in visual color perception, followed by translucency, while hue and chroma play secondary roles. Yamamoto (1992) emphasized that differences between high-value shades (e.g., A1 and B1) are difficult to perceive visually, whereas differences become more noticeable as value decreases and chroma increases.

The null hypothesis of this study, which assumed that tooth color distribution is independent of demographic variables, was rejected. Both sex and age were found to significantly influence tooth color distribution across all three shade guide systems.

Sex-related differences indicated that males tend to exhibit darker and more saturated shades, whereas females more frequently present lighter shades. These findings are consistent with studies by Hasegawa et al. (2000), Hammad (2003), and Hassel et al. (2008), although conflicting results have also been reported. As reported by Odioso et al. (2000), women across different age groups tend to be more dissatisfied with the appearance and whiteness of their smile compared to men.

Age-related differences showed a clear trend toward darker, more saturated, and less translucent tooth shades with increasing age. In the youngest group (18–30 years), lighter shades such as A1, 120, and 1M2 were predominant. In the middle age group (31–49 years), shades such as A2, 410, and 2M2 were more common, while in the oldest group (50–69 years), darker shades such as C3, 410, and 4R1.5 were dominant. These findings are consistent with previous studies indicating that aging leads to increased dentin thickness, enamel wear, and accumulation of pigments, resulting in reduced lightness and increased chroma (Rodrigues et al., 2012).

From a clinical perspective, these findings are particularly relevant when selecting tooth color for prosthetic restorations, especially in edentulous patients. The chosen shade should not only replicate the natural dentition but also correspond to the patient’s age, facial features, skin tone, and overall esthetic profile.

Although ΔE values were recorded, the present analysis focused on categorical shade distribution; future studies should incorporate full CIELAB analysis for enhanced precision.

Finally, the results of this study reinforce the importance of using objective, instrument-based methods for shade selection in modern dentistry. While visual methods remain widely used due to their simplicity, they are subject to significant variability. The integration of spectrophotometric devices into routine clinical practice can significantly improve the accuracy and predictability of esthetic treatments and improve communication between clinicians and dental technicians and enhance the predictability of restorations.

Conclusions

Spectrophotometric assessment demonstrated high reliability and objectivity in evaluating natural tooth color distribution. The findings confirm substantial variability across shade guide systems, underscoring the lack of standardization in clinical shade selection. Significant associations with sex and age were identified, with a consistent shift toward darker and more saturated shades over time. These results reinforce the need for individualized, data-driven shade selection protocols. The integration of spectrophotometric methods into routine practice may substantially improve accuracy, consistency, and clinical outcomes in esthetic dentistry.

Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All data are included in the content of the paper.

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Declaration for Human Participants: This study has been approved by the Faculty of Medical Science, Goce Delcev University, Stip, North Macedonia and the principles of the Declaration of Helsinki were followed. Written informed consent was obtained from all participants.

References:

1. Alvarado-Lorenzo, M., et al. (2025). Impact of vision defects on tooth shade selection. *Journal of Clinical Medicine, 14*(1), 293.
2. Ansari, L., et al. (2010). Evaluation of tooth color distribution. *Journal of Dental Research, Dental Clinics, Dental Prospects*.
3. Chu, S. J., Trushkowsky, R. D., & Paravina, R. D. (2010). *Dental color matching: Instruments and systems*. Quintessence Publishing.
4. Crespo, P. C., et al. (2022). Variability in tooth color selection by different spectrophotometers: A systematic review. *The Open Dentistry Journal, 16*, e187421062211180.

5. Dozić, A., Kleverlaan, C. J., Aartman, I. H. A., & Feilzer, A. J. (2004). Relation in color of three regions of vital human incisors. *Dental Materials, 20*(9), 832–838.
6. Gasparik, C., Culic, B., Badea, M. E., & Dudea, D. (2025). The color of natural teeth: A scoping review. *Dental Materials*.
7. Hardan, L., Bourgi, R., Cuevas-Suárez, C. E., et al. (2022). Novel trends in dental color match using different shade selection methods. *Journal of Clinical Medicine, 11*(1), 123.
8. Hasegawa, A., Motonomi, A., Ikeda, I., & Kawaguchi, S. (2000). Color of natural tooth crown. *Color Research and Application, 25*(1), 43–48.
9. Hammad, I. A. (2003). Intrarater repeatability of shade selections. *Journal of Prosthetic Dentistry, 89*(1), 50–53.
10. Hassel, A. J., et al. (2008). Influence of age and gender on tooth color. *Journal of Prosthetic Dentistry, 100*(6), 439–445.
11. Herekar, M. G., Sethi, M., et al. (2018). Tooth shade selection: A clinical study. *Journal of Prosthodontics*.
12. Kupke, L., et al. (2025). In vivo reproducibility of tooth shade determination on intraoral scans compared to spectrophotometric methods. *Clinical Oral Investigations*.
13. Lee, J. H., Kim, M. J., Kim, S. H., et al. (2024). A comparative study of shade-matching performance using an intraoral scanner, spectrophotometer, and visual assessment. *Scientific Reports, 14*, 74354.
14. Odioso, L. L., Gibb, R. D., & Gerlach, R. W. (2000). Impact of demographic variables on tooth color perception. *Journal of Dentistry*.
15. Paravina, R. D., & Powers, J. M. (2004). *Esthetic color training in dentistry*. Elsevier Mosby.
16. Rodrigues, S., et al. (2012). Tooth color distribution and its relationship with age. *Journal of Esthetic and Restorative Dentistry*.
17. Yamamoto, M. (1992). *Metal-ceramics: Principles and methods*. Quintessence Publishing.