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Natural Tooth Color Evaluation in the Korean Elderly Population

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Purpose: This study is to investigate the distribution of natural tooth shades in the Korean elderly population to quantify the correlation and changes of tooth color with age and gender. In addition, the possible effects of habits on tooth color were assessed.
Materials and Methods: The tooth color of one of the maxillary central incisors of 200 Korean individuals aged 50 to 89 years, males and female, was measured using the portable intraoral spectrophotometer (VITA Easyshade V). CIELab and CIELCh color coordinates were recorded. We conducted the survey about the tobacco smoking, chronic disease, medication, eating habits, oral health behaviors and satisfaction with tooth color. Experimental data were statistically analyzed by using the t-test ($P<0.05$), two-way analysis of variance and Pearson's correlation test.
Result: The most frequent color in the Korean elderly population was 3M3 & A3.5 shade. L* and h* values decreased, whereas C*, a* and b* values increased progressively with age. There was a significant interaction between age and color coordinates for b* values ($r=0.245$, $P<0.05$). Males generally have significantly higher C*, a*, b* values and lower L*, h* value compared to females. Individuals who consumed alcohol had a higher L* value ($P<0.05$).
Conclusion: Within the limitation of this study, the central incisors were getting darker, more reddish, and yellowish with age. Information on the chromatic range of natural teeth by age and gender could help to select colors for esthetic dental restorations.

Key Words: Aged; Color; Population; Sex; Tooth

Introduction

Tooth color plays a crucial role in evaluating dental restorations. It is vital to choose a tooth color that aligns with the tooth's function, the morphology of the restoration, and the color of the surrounding teeth[1,2]. Color perception is subjective and varies among individuals, necessitating the creation of standardized color systems. The Munsell color system is one such well-known system[3]. Munsell defined

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color as having three attributes: hue, value (lightness), and chroma. Hue is the attribute that distinguishes one color from another, value differentiates bright colors from dark ones, and chroma separates strong colors from weak ones[4]. Another widely used color system is the CIE color system. The CIE (Commission Internationale de l' Eclaairage) established this system in 1931 as a method for measuring and displaying colors using a spectrophotometer. It was later refined and evolved into the CIELAB color space in 1976. In this color space, 'L' denotes brightness, while 'a' and 'b' represent the green(-)-red(+) and blue(-)-yellow(+) color axes, respectively[5].

Tooth color is typically not characterized by a single shade. O'Brien et al.[6], after conducting a CIE L*a*b* system analysis on the color of extracted incisors, found that according to the tooth location, incisal, middle, and cervical sites each exhibited distinct colors. Clark[7] also observed that the cervical region of vital teeth tends to be more yellow than gray, while the middle third of the tooth displays an equal balance of yellow and gray. They noted that the incisal site is predominantly gray[7]. Also, in a study involving Korean participants, Park and Chung[8] found a pattern where the yellow hue intensifies around the cervical site and the gray hue becomes more pronounced around the incisal site. They also reported that the cervical site has a higher yellow chroma (b) than the incisal and middle sites Furthermore, O'Brien et al.[6] investigated the color distribution in human incisors according to the position (cervical, middle, and incisal) and observed significant differences among those three locations. They concluded that the middle third of a tooth was the most suitable for representing tooth color, and that the labial third showed the most consistent color measurement outcomes[4].

Previous studies exploring the relationship between age, sex, race, and tooth color have identified age as the most influential factor in determining the color of central incisors[4]. Some studies have found the L* value to be most strongly correlated with age[9,10], while others have suggested the b* value has the strongest correlation[11]. As individuals age, tooth color tends to darken due to the thinning of enamel, decreased transparency, and the formation of secondary dentin beneath the enamel. This process results in increased pigmentation and ion deposition[12,13]. Some research has suggested that female central incisors are brighter and less chromatic than their male counterparts, while other studies have found no discernible differences in the color of maxillary central incisors between male and female[4]. An examination of tooth color across different races has revealed variations between racial group[14].

In the age of super-aging, the demand for dental treatment by the elderly is increasing, and aesthetic demands are also increasing. In addition, there are different points to consider in aesthetic treatment of the elderly due to wear and fracture of teeth over the years. In order to perform aesthetic restoration for the elderly group, it will be essential to acquire information on the color analysis of teeth according to age. Therefore, the purpose of this study is to investigate the color of each location of the tooth according to age in patients aged 50 or older. It also evaluates the effect of habits on tooth color. The null hypothesis is as follows. First, there is no difference in the color of each part of the tooth according to age and gender. Second, there is no effect of habits on the color of teeth.

Materials and Methods

1. Participants

This study involved 200 patients who sought treatment at the Department of Conservative Dentistry at the Veterans Health Service Medical Center between August 1, 2022, and February 24, 2023. The Institutional Review Board of the Veterans Health Service Medical Center granted approval for this study (2022-06-007). Once the study's purpose was clearly explained to the patients, those who agreed to participate completed an informed consent form, had their tooth colors measured, and filled out a questionnaire. The color measurement was taken from one of the maxillary incisors. The participants were patients with natural teeth and no dental prostheses. The exclusion criteria were as follows: teeth discolored by tetracycline or fluorine, teeth with spots, teeth where dental caries or crown fractures affected two-thirds of the tooth, teeth with color changes due to whitening, and pairs of left and right teeth with noticeably different colors were all excluded from the study.

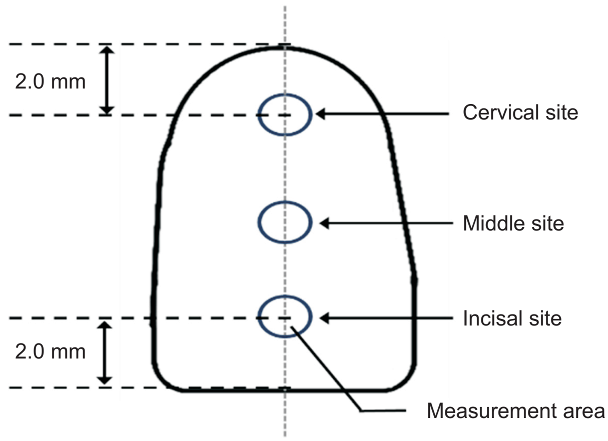

Fig. 1. Sites of spectrophotometer measurement on natural tooth.

2. Measurement Instrument and Method

1) Tooth Color Measurement

The VITA Easyshade V (Vita-Zahnfabrik, Bad Säckingen, Germany) were utilized in this study to assess the color of the participants' teeth. Before the color measurements were conducted, teeth were polished with pumice and rubber cups for a duration of 10 seconds to eliminate any residual discoloration, food particles, and plaque. The tooth surface was gently wiped with gauze. To prevent cross-contamination, we placed an infection-control shield over the tip of the measuring instrument. We performed white balancing on the calibration block. The tip was placed perpendicular to the tooth surface and the shade was measured. We took measurements in three distinct areas: after identifying the center of the tooth, we measured 2 mm from the incisal line (incisal site), 2 mm from the gingiva line (cervical site), and at the midpoint between these two areas (middle site) (Fig. 1). We recorded the results obtained using VITA System 3D-Master and the VITA Classical A1-D4 Shade on the VITA Easyshade V (Vita-Zahnfabrik), and also recorded the L*, C*, h*, a*, and b* values for each shade (L*: lightness, C*: chroma, h*: hue, a*: red chroma, b*: yellow chroma).

2) Questionnaire

A survey was carried out, focusing on nine factors believed to influence the color of the incisor: age, sex, smoking habits, alcohol consumption, chronic disease, medication, oral hygiene habits, dietary habits, and satisfaction with tooth color (Table 1).

3) Data Analysis

The statistical analysis was conducted using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Two-way analysis of variance was used to evaluate the effects of age and sex on each variable (CIE L*, a*, b*). Pearson correlation testing was conducted to evaluate the linear relationship between age and the color coordinate. Validation was performed at a 95% confidence level.

Result

1. General Characteristics of Participants

The study included a total of 200 participants, of which 161 were male (80.5%) and 39 were female (19.5%), indicating a higher number of male participants. The age group of 70 to 79 had the highest representation (138 participants, 69.0%), followed by the 60 to 69 age group (40 participants, 20.0%). Among the participants, 23 were smokers (11.5%), 177 were non-smokers (88.5%), among the non-smokers, 94 had a history of smoking (53.1%). Alcohol consumption was reported by 77 participants (38.5%), while

Table 1. Items of questionnaire

1. Sex What is your sex? ( )
1) Male 2) Female
2. Age How old are you? ( ) years old
3. Smoking
(1) Are you currently a smoker?
1) Yes (smoker) → go to 3-(2) 2) No (non-smoker) → go to 3-(3)
(2)-① How long have you smoked? ( ) years
1) 0~5 years 2) 5~10 years 3) 10~20 years 4) 20~30 years 5) 30 years or more
(2)-② How many cigarettes do you smoke a day? ( ) cigarettes
(2)-③ What do you smoke?
1) Tobacco 2) Liquid vaporizer 3) Cigarette-type vaporizer
(3) Have you smoked in the past?
1) Yes (have smoked) → go to (4) 2) No
(4) How long did you smoke in the past? ( ) years
1) 0~5 years 2) 5~10 years 3) 10 years or more
4. Drinking
(1) Do you drink alcohol?
1) Yes 2) No
(2) How many times do you drink alcohol in a week?
5. Chronic diseases
(1) Do you have any chronic diseases?
1) Yes 2) No
(2) Indicate your chronic disease.
1) Hypertension 2) Diabetes 3) Thyroid disease 4) Anemia 5) Others ( )
6. Drugs
(1) Are you currently on any drugs?
1) Yes 2) No
(2) What drugs are you using currently?
1) Hypertension 2) Diabetes 3) Thyroid disease 4) Anemia 5) Others ( )
7. Oral hygiene activities
(1) How often do you brush your teeth a day? ( ) times
1) Less than 3 times 2) 3 times or more
(2) How long do you brush your teeth? ( ) minutes
1) Less than 3 minutes 2) 3 minutes or more
(3) Do you use toothpaste?
1) Yes 2) No
(4) Do you scale your teeth (plaque removal) on a regular basis?
1) Yes 2) No
8. Dietary habits
-1) Once or more a day: often
-2) Less than once a day: rarely
(1) Carbonated drinks (2) Coffee (3) Red tea (4) Green tea (5) Chocolate (6) Gochujang (red pepper paste) (7) Soy sauce
(8) Kimchi (9) Wine
9. Satisfaction about tooth colors
(1) Are you satisfied with your tooth color?
1) Yes (satisfied) 2) No (not satisfied) → go to 9-(2)
(2) Why are you not satisfied with your tooth color?
(ex., I wish they were whiter. I wish they were brighter.)

123 participants (61.5%) abstained from alcohol. Chronic diseases were reported by 142 participants (71.0%), with hypertension (142 participants, 71.0%) and diabetes (57 participants, 28.5%) being the most common. A total of 159 participants (79.5%) were on medication, primarily for hypertension (93 participants, 46.5%) and diabetes (55 participants, 27.5%) (Table 2).

2. *Color Distribution in Different Parts of Teeth*

Table 3 presents the most common tooth colors in each section, as measured by the 3D-Master and Classic systems. For the male participants, the most common color was 3M3, A4 shade at the cervical site, 3M3, A3.5 shade at the middle site, and 3M3, A3.5 shade at the incisal site. In contrast, the female participants most frequently exhibited a 3M3, A3 shade at the cervical site, a 3M2, A3 shade at the middle site, and a 3M2, A3 shade at the incisal site. Overall, the most common color across all sites was the 3M3, A3.5 shade, appearing most frequently at the cervical, middle, and incisal sites.

Table 4 summarizes the L*, C*, h*, a*, and b* values in various sections of the tooth. The L* value was found to be highest at the middle of the tooth, followed by the cervical area, and then the incisal region. The a* value was most elevated in the incisal region, next was the cervical area, and lastly the middle of the tooth. The b* value was highest in the cervical area, followed by the middle of the tooth, and finally the incisal region.

3. *Comparison of Colors according to Sex*

A comparison of tooth color in different areas, based on sex, reveals that male participants exhibited a lower value for lightness (L*), hue (h*), and a higher value for chroma (C*), red chroma (a*), and yellow chroma (b*). The differences in L*, C*, h*, a*, and b* were all statistically significant at the middle site (Table 5).

Table 2. General characteristics of participants

Characteristics		N	%
Sex	Male	161	80.5
	Female	39	19.5
Age	50~59	14	7.0
	60~69	40	20.0
	70~79	138	69.0
	80~89	8	4.0
Smoking	Smoker	23	11.5
	Non-smoker	177	88.5
	Past smoker	94	47.0
	Non-past smoker	83	41.5
Drinking	Yes	77	38.5
	No	123	61.5
Chronic disease	Yes	142	71.0
	No	56	28.0
Medication	Yes	159	79.5
	No	41	20.5
Total		200	100

Table 3. Most frequent colors in classic & 3D-Master system (percentage)

		3D-Master			Classic		
Male	Cervical	3M3 (31.0)	4M3 (12.5)	2M2 (9.5)	A4 (35.3)	A3.5 (23.5)	B4 (17.6)
	Middle	3M3 (20.0)	4M3 (11.8)	4L1.5 (9.4)	A3.5 (25.9)	A4 (22.4)	A3 (17.6)
	Incisal	3M2 (12.9)	4M2 (10.6)	4M3 (9.4)	A4 (22.4)	A3.5 (13.1)	A3.5 (12.9)
Female	Cervical	3M3 (25.0)	3R2.5 (18.8)	3M2 (12.5)	A3 (31.3)	A4 (18.8)	B4 (18.8)
	Middle	3M2 (37.5)	2M2 (18.8)	4M2 (12.5)	A3 (18.8)	A2 (18.8)	B3 (18.8)
	Incisal	3M2 (37.5)	3R2.5 (12.5)	3R1.5 (12.5)	A3 (18.8)	D3 (18.8)	A3.5 (12.5)
Total	Cervical	3M3 (31.0)	4M3 (12.5)	2M3 (9.5)	A3.5 (31.5)	A4 (27.5)	B4 (14.0)
	Middle	3M3 (20.0)	4M3 (12.0)	2M2 (11.5)	A3.5 (26.0)	A4 (19.5)	A3 (17.5)
	Incisal	3M3 (15.5)	3M2 (12.0)	2M2 (9.5)	A3.5 (18.5)	A4 (18.5)	A3 (17.5)

Table 4. Mean L*, C*, h*, a*, b* of maxillary incisor teeth in various sections

Location	L*	C*	h*	a*	b*
Cervical	69.67±15.25	29.58±9.56	83.84±14.07	5.94±18.34	28.55±6.14
Middle	70.81±14.95	27.71±10.70	84.76±14.10	5.67±18.86	26.30±6.20
Incisal	68.49±16.49	25.87±10.56	83.72±15.59	3.23±19.56	24.55±6.47

L*: lightness, C*: chroma, h*: hue, a*: red chroma, b*: yellow chroma.
Values are presented as mean±standard deviation.

Table 5. Teeth color according to sex

Color values	Sex		
	Male (n=161)	Female (n=39)	P-value
L* Cervical	71.90	76.20	0.000*
Middle	73.70	75.70	0.040*
Incisal	72.20	73.20	0.423
C* Cervical	29.40	27.20	0.010*
Middle	28.20	21.60	0.000*
Incisal	25.40	20.00	0.000*
h* Cervical	86.80	87.60	0.238
Middle	87.10	88.10	0.035*
Incisal	86.30	87.10	0.090
a* Cervical	1.60	1.20	0.389
Middle	1.50	0.80	0.006*
Incisal	1.70	1.10	0.069
b* Cervical	29.00	27.30	0.071
Middle	27.11	22.96	0.000*
Incisal	25.23	21.76	0.002*

L*: lightness, C*: chroma, h*: hue, a*: red chroma, b*: yellow chroma.
*P-value<0.05, significant correlation.

4. Comparison of Colors according to Age

Table 6 presents the color coordinates in various sections of the tooth, categorized by age. Fig. 2 graphically represents these coordinates in relation to age. As age advanced, both the lightness value (L*) and hue (h*) showed a decrease, while chroma (C*), red chroma (a*), and yellow chroma (b*) exhibited an increase. Notably, yellow chroma (b*) demonstrated a statistically significant correlation with age (r=0.245, P<0.05).

5. Comparison of Tooth Color according to Behavioral Habits

Among the participants, 11.50% were smokers and 88.50% were non-smokers, totaling 177 individuals. Of those who smoked, 9.52% had been smoking for 0.5 years, 19.05% for 20~30 years, and 71.43% for 30 years or more. The majority of smokers, 90%, used tobacco. Among the non-smokers, 53.1% (94 individuals) had previously smoked. Regarding the duration of their past smoking habits, 13.19% had smoked for 0.5 years, 9.89% for 5~10 years, and 76.92% for 10 years or more. While a comparison of the maxillary incisors' colors based on smoking status revealed that non-smokers exhibited a higher lightness value (L*), red chroma (a*), and yellow chroma (b*), these differences were not statistically significant.

Of the study participants, 77 individuals (38.50%) consumed alcohol, while 123 individuals (61.50%) abstained completely. Among the alcohol consumers, 33 individuals (42.86%) drank less than once a week, 40 individuals (51.95%) drank between 1 and 3 times a week, and 4 individuals (5.19%) drank 4~7 times a week. A comparison of the coloration of the maxillary incisors based on drinking habits revealed that individuals who consumed alcohol had a higher lightness value (L*), red chroma (a*), and yellow chroma (b*). Furthermore, a significant correlation was found between the lightness value (L*) and alcohol consumption (P<0.05).

Although a comparison of the coloration of the maxillary incisors in relation to chronic diseases indicated that those with chronic diseases exhibited a lower lightness value (L*), red chroma (a*), and yellow chroma (b*) than those without chronic diseases, the differences were not statistically significant.

Individuals who brushed their teeth three times a

Table 6. Teeth color according to age group

Color values	Age				
	50~59 (n=14)	60~69 (n=40)	70~79 (n=138)	80~89 (n=8)	P-value
L* Cervical	60.78±32.30	70.44±15.38	70.16±12.71	72.83±4.26	0.148
Middle	60.26±31.16	71.95±14.01	71.23±12.70	76.34±6.15	0.037*
Incisal	59.26±30.08	68.12±14.76	69.30±15.27	72.65±8.06	0.155
C* Cervical	37.11±21.10	26.69±6.25	29.70±8.31	28.84±6.32	0.005*
Middle	33.78±23.37	24.13±6.32	28.06±9.64	29.01±6.54	0.025*
Incisal	32.81±23.41	23.14±10.22	26.05±8.45	24.20±5.70	0.028*
h* Cervical	72.94±26.54	84.84±14.50	84.49±12.13	86.81±2.51	0.025*
Middle	74.01±27.65	85.94±14.30	85.37±12.03	87.10±2.49	0.029*
Incisal	74.13±27.96	83.47±19.21	84.60±12.73	86.61±4.35	0.110
a* Cervical	1.64±1.08	5.77±18.85	6.68±19.59	1.59±1.42	0.697
Middle	1.15±0.78	5.42±19.45	6.44±20.13	1.59±1.68	0.705
Incisal	0.89±1.60	5.43±18.80	7.25±21.19	1.96±2.25	0.604
b* Cervical	26.01±3.36	26.50±6.40	29.38±6.12	28.76±6.31	0.023*
Middle	22.38±3.98	23.97±6.23	27.43±6.09	25.18±5.58	0.001*
Incisal	21.57±4.22	22.16±5.90	25.58±6.64	24.06±5.57	0.007*

L*: lightness, C*: chroma, h*: hue, a*: red chroma, b*: yellow chroma.
Values are presented as mean±standard deviation.
*P-value<0.05, significant correlation.

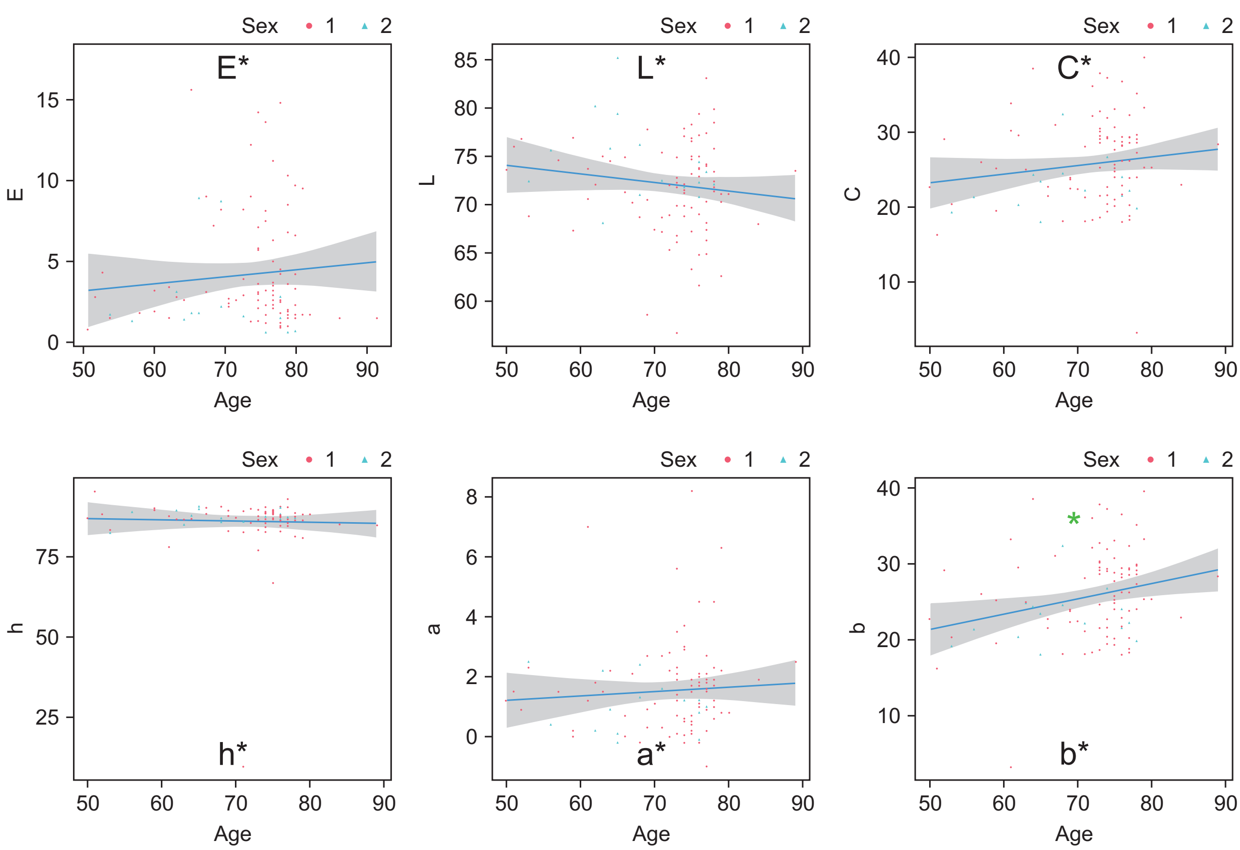

Fig. 2. Linear regression between the color coordinates (E*, L*, C*, h*, a*, b*) according to age. E*: overall shade deviation, L*: lightness, C*: chroma, h*: hue, a*: red chroma, b*: yellow chroma.

day exhibited lower values of L* and red chroma (a*), and higher values of yellow chroma (b*) compared to those who brushed less frequently. However, these differences were not statistically significant. Similarly, those who brushed their teeth for three minutes or longer had higher values of L* and yellow chroma (b*), and lower values of red chroma (a*) compared to those who brushed for less than three minutes, but these differences were also not significant. Individuals who used toothpaste showed lower values of L*, red chroma (a*), and yellow chroma (b*) compared to those who did not use toothpaste. Notably, the difference in L* value was statistically significant ($P<0.05$). Lastly, although those who regularly had their teeth scaled demonstrated higher values of L* and lower values of red chroma (a*) and yellow chroma (b*) compared to those who did not, these differences were not statistically significant (Table 7).

The coloration of the maxillary incisors was analyzed in relation to dietary habits. Individuals who frequently consumed black tea exhibited a higher hue (h*) compared to those who consumed it less frequently. Regular green tea drinkers showed a higher lightness value (L*) and hue (h*) than occasional drinkers. Those who often consumed chocolate had a higher hue (h*) than those who consumed it less frequently. Frequent consumption of chili pepper (Gochujang) was associated with a higher red chroma (a*) compared to occasional consumption. Similarly, regular soy sauce consumers exhibited a higher red chroma (a*) than those who consumed it

Table 7. Teeth color according to habits

Habits		L*	a*	b*
Smoking	Smoker	69.57±18.34	4.97±17.59	25.59±7.00
	Non-smoker	70.97±14.51	5.76±19.06	26.39±6.10
	Ex-smoker	72.24±5.25	1.52±1.32	27.83±5.06
	P-value	0.673	0.851	0.562
Drinking	Yes	73.61±9.32	5.90±19.45	27.20±6.73
	No	69.06±17.40	5.52±18.56	25.73±5.80
	P-value	0.017*	0.893	0.103
Chronic disease	Yes	70.30±15.55	5.61±18.69	26.24±6.23
	No	72.06±13.67	5.98±19.76	26.34±5.90
	P-value	0.461	0.902	0.924
Brushing frequency	<3	71.61±12.08	5.87±19.01	26.20±6.40
	≥3	69.64±18.40	5.36±18.75	26.45±5.92
	P-value	0.398	0.851	0.780
Brushing time	<3 min	69.27±16.80	5.69±19.02	25.71±6.11
	≥3 min	72.33±12.80	5.64±18.80	26.87±6.26
	P-value	0.149	0.986	0.186
Toothpaste	Yes	70.71±15.09	5.32±18.13	26.24±6.21
	No	75.60±2.09	22.65±42.78	29.15±5.68
	P-value	0.007*	0.477	0.354
Scaling	Yes	72.77±11.81	5.48±18.65	26.24±5.75
	No	68.77±17.48	5.86±19.17	26.36±6.66
	P-value	0.06	0.887	0.884

L*: lightness, a*: red chroma, b*: yellow chroma.
Values are presented as mean±standard deviation.
*P-value<0.05, significant correlation.

less frequently. In contrast, frequent kimchi consumers had a lower hue (h*) but a higher red chroma (a*) than occasional consumers. Lastly, those who regularly consumed wine had a higher lightness value (L*) and hue (h*), but a lower chroma (C*) and red chroma (a*) than those who consumed it less frequently (Table 8).

6. Satisfaction with Tooth Color

There were 125 participants who answered "yes" to the question asking whether they were satisfied with their tooth color (62.50%) and 75 who answered "no" (37.5%).

Discussion

This study involved 200 older Asian adults from Korea, ranging in age from 50 to just under 90. There are two primary methods for evaluating the colors of teeth and dental materials: visual and mechanical. According to Choi et al.[15], digital analysis of tooth colors provides more accurate and reproducible results than visual assessment. The CIEDE2000 color system, which is based on the CIELAB system, includes parameters such as lightness (L), chroma (C), hue (H), and the interaction between chroma and hue of blue. Additionally, a* represents grayscale. The CIEDE2000 color system is the most closely aligned with the range of colors that the human eye can perceive[16]. The VITA Easyshade V (Vita-Zahnfabrik), a clinical spectrophotometer used in this study, is a tool for determining tooth colors. For the purposes of this study, we chose the mechanical method using the Easyshade V spectrophotometer to provide an objective indicator for color selection. Measurements were taken and recorded based on both the CIEDE2000 and CIELAB color systems.

In the restorations for damaged or missing teeth, it is crucial to not only restore the shape and function of the teeth, but also to accurately replicate their natural color. Clark[7] emphasized the importance of

Table 8. Teeth color according to dietary habits

Color values	Carbohydrate drink	Coffee	Black tea	Green tea	Chocolate	Chili pepper	Soy sauce	Kimchi	Wine
L* Frequently	62.73±24.43	71.49±14.60	73.82±4.18	75.16±4.10*	72.61±8.77	70.62±15.38	70.59±15.40	70.74±15.18	75.62±4.35*
Rarely	71.61±13.52	69.03±15.86	70.72±15.16	70.56±15.32*	70.46±15.89	71.32±13.53	71.56±13.49	71.56±12.81	70.51±15.34*
C* Frequently	27.83±14.43	27.46±10.31	29.25±4.45	26.05±5.11	25.61±5.95	27.68±9.81	27.90±9.75	27.83±10.05	23.82±5.90*
Rarely	27.70±10.31	28.38±11.73	27.67±10.83	27.81±10.93	29.13±11.37	27.84±13.44	27.11±13.49	26.51±16.20	27.96±10.89*
h* Frequently	78.71±24.23	84.96±14.89	87.02±1.22*	88.15±2.25*	88.29±2.53*	84.32±15.24	84.73±14.00	84.47±14.71*	89.48±2.14*
Rarely	85.36±12.63	84.22±11.86	84.69±14.31*	84.56±14.47*	84.06±15.30*	86.28±9.15	84.84±14.58	87.71±3.57*	84.46±14.48*
a* Frequently	6.82±20.94	6.56±20.93	16.42±35.76	17.06±35.53	13.96±31.33	6.93±21.26*	6.99±21.32*	6.09±19.72*	0.58±0.67*
Rarely	5.55±18.70	3.32±11.60	5.33±18.16	5.00±17.36	4.09±14.86	1.32±1.19*	1.23±1.24*	1.34±1.35*	5.99±19.41*
b* Frequently	24.84±6.22	26.25±6.31	29.22±4.40	26.03±5.09	25.57±5.93	26.32±6.29	26.53±6.22	26.41±6.27	23.81±5.89
Rarely	26.44±6.19	26.41±5.94	26.21±6.23	26.31±6.27	26.44±6.26	26.21±5.95	25.52±6.14	25.18±5.43	26.46±6.20

L*: lightness, C*: chroma, h*: hue, a*: red chroma, b*: yellow chroma.
Values are presented as mean±standard deviation.
*P-value<0.05, significant correlation.

scientific color recognition in dentistry, meticulously analyzing the colors of various parts of natural teeth with the aim of applying this knowledge in dental practice. In this study, we examined the labial surface of teeth in three distinct areas: the cervical site, the middle site, and the incisal site. We then compared these areas in relation to the sex, age, and tooth colors of the participants. A prior study suggested that the incisal site, being generally transparent, can be influenced by the tooth's background. Additionally, the color of the cervical site can appear different based on the intensity of light scattering from the gum[17]. Therefore, it was concluded that the middle third of the tooth is the most accurate location for determining tooth color[14].

In this study, the tooth color distribution revealed that the 3M3/A3.5 shade was the most common at the cervical, middle, and incisal sites. A similar study conducted with Korean participants found that the most frequent color among those aged 60~89 was 3M2, 4M2.5[4]. When compared to the results of this study, the value and hue were identical, but there were differences in chroma. This discrepancy is likely due to the higher proportion of female participants in the previous study compared to this one.

Campos and Tincoines[18] described normal enamel as having a bluish-gray hue, while normal dentin is typically brownish-yellow. They noted that the color of the dentin can be observed through the enamel. The enamel is thickest at the incisal edge and cusp, measuring 2 mm or more, and gradually thins as it approaches the cervical area. This means that a yellow hue becomes more pronounced near the cervical area, while a gray hue intensifies around the incisal edge[19]. They reported that the L, a, and b values, which represent the color dimensions of teeth, all decrease from the cervical area towards the incisal edge. They also found that teeth appear darker and more yellow as a person ages, and that a red hue becomes more prominent if the incisal edge of the incisors is worn down[3]. These findings align with the results of this study, which observed a high red chroma at the incisal edge and a high yellow chroma at the cervical area.

Sex is recognized as a factor influencing tooth color, and male participants in this study demonstrated lower values of (L*), hue (h*), and higher chroma (C*), red chroma (a*), and yellow chroma (b*) than their female counterparts across all parts. This aligns with the findings of numerous prior studies[9,20]. Terry et al.[21] proposed that the perceived brightness of teeth in females compared to those in males is due to the smaller size of teeth in females, which consequently results in a relatively lower amount of dentin.

As the age increased, the lightness value (L*) and hue (h*) decreased, and chroma (C*), red chroma (a*), and yellow chroma (b*) increased. A statistically significant correlation was observed between age and yellow chroma (b*). This aligns with a previous study, which found that the teeth of individuals aged 60~89 became noticeably more yellow with age, and a significant correlation was observed between age and yellow chroma (b*). This is likely due to the decalcification of the enamel layer as age increases[13], the formation of secondary dentin[12], and an increase in discoloration. As a result, the first null hypothesis was rejected.

Tooth discoloration can be attributed to both external factors, such as tea, coffee, red wine, cigarettes, coke, metal salts, and poor oral hygiene, and internal factors, such as changes in the composition or thickness of tooth hard tissues. While a previous study suggested that smoking may lead to tooth discoloration[22], our comparison of tooth colors between smokers and non-smokers found no significant differences. However, we did find that those who consumed alcohol had significantly higher discoloration values than those who did not. Certain conditions, including metabolic diseases, liver diseases, and calcium deficiency, are known to potentially cause tooth discoloration by affecting tooth enamel. Despite this, our analysis of tooth color differences in relation to the presence of chronic diseases did not yield statistically significant results. When comparing tooth colors in relation to oral hygiene habits, we found no significant differences based on the frequency of brushing, brushing duration, or regular scaling. This finding does not align with previous literature, which suggests a close relationship between oral hygiene and tooth color.

Previous research on the relationships between diet and tooth color suggested that certain foods and beverages can alter the hue of both deciduous and permanent teeth by affecting the enamel color[23]. Studies have specifically examined the impact of red wine, coke, soy sauce, gochujang, coffee, and tea, reporting that these substances can lead to the discoloration of natural teeth[24]. However, the findings from these studies differ from the results of the current investigation. In our study, there was a difference in color coordinate according to the frequency of food intake, but it was not statistically significant. The difference in these results is thought to be due to the difference in the age of the study subjects. This is because in previous studies, major age group is 21 to 30 years old, while this study is an elderly group over 50 years old. In the elderly group, it seems that the effect of eating habits on tooth coloration appeared less due to changes in the histological structure of teeth according to age. As such, we can only partially reject the second null hypothesis.

This study has the following limitations. More uniform sample sizes in terms of sex and age could have yielded more statistically significant results. However, despite this limitation, the study remains meaningful. As we enter an era where the aesthetic demands of middle-aged and older adults are on the rise, this research offers valuable insights by examining the color distribution in individuals aged 50 and above. In addition, the study measured the colors of different parts of the tooth, gathered the data, and analyzed the impact of long-term habits on tooth color. With the color data collected, we can select restoration materials of matching colors, enabling more aesthetically pleasing restoration treatments.

Conclusion

For Korean individuals aged 50 and above, the most common tooth color is the 3M3/A3.5 shade. This shade is most frequently observed at the cervical site, the middle site, and the incisal site. Male participants exhibited a lower (L*) value and hue, but a higher chroma. As age increases, both (L*) value and hue tend to decrease, while chroma exhibits an increase. Specifically, a significant correlation was observed between yellow chroma and age.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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