Original Articles

Color Analysis and Tooth Shades among Maxillary Anterior Teeth and Premolars in Thai Population

Chakree Ongthiemsak[1], Panita Chantanawilas[1], Kanwara Vilamas[2], Jiroj Maharat[2], Chutatip Losithong[2], Tanchanok Raknganchang[2], Thanyaphurt Utamavatin[2], Bussara Pongsermsuk[2]

[1]Department of Prosthetic Dentistry, Faculty of Dentistry, Prince of Songkla University, Songkhla, Thailand

[2]Dental student, Faculty of Dentistry, Prince of Songkla University, Songkhla, Thailand

Abstract

The color of anterior teeth is usually different in nature. Therefore, knowing the color differences of these teeth is useful in cosmetic dentistry. The aim of this study was to analyze the CIE L*a*b* color coordinates, the color differences, and tooth shade among the maxillary central incisor, the lateral incisor, the canine, and the premolar in a group of 181 Thai participants (75 males and 106 females) aged 18 to 30 years old who were recruited for this study. The color coordinate of L*, a*, b*, and tooth shade according to the VITA 3D-Master shade guide of the maxillary anterior teeth and the premolar were measured by a spectrophotometer. The color coordinates were analyzed by one-way ANOVA and Scheffe multiple comparisons. The lightness difference (|ΔL*|), redness-greenness difference (|Δa*|), blueness-yellowness difference (|Δb*|), and the total color difference (ΔE^*_{ab}) among the central incisor, the lateral incisor, the canine, and the premolar were calculated and analyzed by the Kruskal-Wallis test. Both male and female participants presented similar results. ΔE^*_{ab} between the maxillary canine and the central incisor was the highest. The central incisor was the lightest, followed by the lateral incisor and the premolar. The canine showed more red and yellow colors followed by the premolar and the lateral incisor. The |Δb*| was greater than the |ΔL*| and |Δa*| in all groups except for a group of the canine/premolar. It can be concluded that the color differences between all maxillary anterior teeth and the premolar were mainly due to the influence of the color yellow. The higher the lightness, the lower the red and yellow colors will be found. The most common shades are 2M2 for the central and the lateral incisor, 2M3 for the canine and the premolar in young Thai adults.

Keywords: Anterior tooth, Spectrophotometer, Tooth color, Tooth shade

Received Date: Jun 25, 2020 **Revised Date:** Aug 7, 2020 **Accepted Date:** Oct 12, 2020
doi: 10.14456/jdat.2021.11

Correspondence to:
Chakree Ongthiemsak, Department of Prosthetic Dentistry, Prince of Songkla University, Hat Yai, Songkhla, 90112, Thailand. Tel: 074-429874 E-mail: chakree.o@psu.ac.th

Funding: This study was supported by a grant from the Faculty of Dentistry, Prince of Songkla University

Introduction

Tooth color is a factor affecting esthetic dentistry. Assessing tooth color can be done by comparing with a shade guide or using a color measuring device.[1] A spectrophotometer is a color measuring device. It can specify color values with higher accuracy and more precision than shade matching.[2-3] Currently, it has been developed to be smaller, and can be used clinically. A chairside spectrophotometer is reliable and accurate enough for daily clinical work in order to assess tooth color.[2,4] This device can measure the tooth color that is reported as the color coordinate of L*, a*, b*, chroma, hue, and values. It can also report the measured color in the popular shade guide such as the VITA classical or the VITA 3D-Master.[5] The Commission Internationale de l'Eclairage (CIE) developed a system called the CIE L*a*b* that describes colors in three dimensions. L* is the lightness from the darkest (0) to brightest (100), a* is a color from green (-) to red (+) and b* is a color from blue (-) to yellow (+). The numeric value of L*a* b* can be converted to a color arranged in a sphere.[6] The two color differences can be calculated from ΔL*, Δa*, Δb* values and presented as ΔE^*_{ab}.[7] The higher the value of ΔE^*_{ab}, the greater the color difference is demonstrated.

The natural color creation of the visible teeth in a full mouth restoration is an integral part of the esthetic. The color of each tooth is not usually uniform in nature. Therefore, a natural appearance of these teeth can be created with different colors. A study in Romania found that the central incisor was the most light, followed by the canine and the molar. The molar was the most chromatic with the highest a* and b* values.[8] A study in Kosovo also reported that the L* value of the maxillary central incisor was the highest, followed by the lateral incisor, and the canine. On the other hand, the a*, b* values of the canine were found to be the greatest, followed by the lateral incisor, and the central incisor.[9]

Age is an important factor affecting tooth color. Falcone *et al.*[10] reported in the United States that the ΔE^*_{ab} of the maxillary central incisor and the canine decreased with age due to changes of the central incisor. Hassel *et al.*[11] found that the maxillary central incisor changed more during middle age than in old age. Rodrigues *et al.*[12] studied the color of the maxillary central incisor and the mandibular central incisor in India, and found that teeth became significantly darker with age. The study showed no shade difference in both genders. Eiffler *et al.*[13] evaluated the color of the maxillary anterior teeth and the premolars in Germany, and also found that gender did not affect the tooth color.

Tjan *et al.*[14] revealed that displaying the six maxillary anterior teeth and premolars was one of the characteristics of the typical smile. They showed that 48.6% of the teeth displaying in a smile were six anterior teeth and first premolar. Many studies had found a clear different color between the maxillary central incisors and the canines.[7,9-12] Unfortunately, there is limited information about the color differences among all the maxillary anterior teeth and the premolar. In addition, most of the data from those studies were done with Caucasian people, and there is very little information about Asians. The objective of this study was to investigate and compare the differences of L*, a*, b*, ΔL*, Δa*, Δb*, ΔE^*_{ab}, and tooth shade among the maxillary central incisor, the lateral incisor, the canine, and the premolar in young Thai people.

Materials and methods

This study has been approved by the ethics committee of Faculty of Dentistry, Prince of Songkla University (No. EC6101-08-J-LR). Informed consent was obtained before starting, and 181 participants (75 males and 106 females) were recruited for this study. They included students, faculties and employees of Prince of Songkla University between the ages of 18-30 years old. A questionnaire consisting of gender, age and dental history was used for the first step screening according to inclusion and exclusion criteria. Oral examination was then taken, and the teeth were cleaned with a No. 3 pumice by only one examiner for further screening. All the participants, without a history of orthodontic treatment, must have their maxillary central incisor, their lateral incisor, their canine, and their first or

second premolar in their mouth without any pathology at the buccal surface of the teeth. The exclusion criteria were used for participants who presented the appearance of the teeth as follows: caries; unpolished stains; discoloration that could be clearly detected by the eyes; history of root canal treatment; bleaching; restoration including filling, veneer, crown; primary abutment for removable partial denture; tooth wear; tooth abnormalities such as fluorosis, amelogenesis imperfecta, dentinogenesis imperfecta or tetracycline teeth.

The tooth surface was dried with gauze before measuring. Five consecutive measurements of each tooth were made using a spectrophotometer (Vita Easyshade Advance 4.0, VITA Zahnfabrik H Rauter GmbH and Co. KG, Bad Sackingen, Germany). The measuring device was calibrated with the calibration block provided by the manufacturer before carrying out any measurement. While taking measurements, the tip of the measuring device was in contact with the middle third of the buccal surface of each tooth at right angles. The tip was covered with disposable plastic for cross infection control, and all measurements were taken by the same examiner.

L*, a*, b*, and tooth shade (according to VITA 3D-Master) of the maxillary central incisor, the lateral incisor, the canine, and the first premolar (or the second premolar in case of losing the first premolar) were obtained from the spectrophotometer. The values of L*, a*, b* were taken from the mean of three middle data from five. Tooth shade was taken from the most frequency of the five measurements. For comparison, the teeth in each participant were matched and the shade differences were recorded as $\Delta L^*=L^*_1-L^*_2$, $\Delta a^*=a^*_1-a^*_2$, and $\Delta b^*=b^*_1-b^*_2$. All ΔL^*, Δa^*, Δb^* were adjusted to absolute data ($|\Delta L^*|$, $|\Delta a^*|$, and $|\Delta b^*|$). Color differences (ΔE^*_{ab}) between teeth were calculated using the equation: $\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$. Normal distribution was evaluated by the Kolmogorov–Smirnov test, and the homogeneity of variance was assessed by Levene's test. L*, a*, b* in each tooth type and gender were compared and analyzed with One-way ANOVA and Scheffe multiple comparison. ΔE^*_{ab} between teeth in the same participant and between gender were analyzed with the Kruskal-Wallis test and the Mann-Whitney U test. The $|\Delta L^*|$, $|\Delta a^*|$, and $|\Delta b^*|$ were compared and analyzed like ΔE^*_{ab}. The level of significance was set at $P < 0.05$. The frequency of tooth shade according to the VITA 3D-Master was counted and compared as a percentage.

Results

The average ages and standard deviations were 20.85 ± 1.82 years old and 20.72 ± 1.66 years old for male and female, respectively. The mean and standard deviation values of L*, a*, and b* color coordinates of each tooth are presented in Table 1.

Table 1 *Mean (standard deviation) of L*, a*, b**

		MEAN (SD)	
		MALE	FEMALE
L*	Central Incisor	83.03 (2.65)^{A}	83.33 (2.48)^{A}
	Lateral Incisor	81.58 (2.75)^{B}	82.06 (2.68)^{B}
	Canine	78.72 (2.42)^{D}	78.98 (2.47)^{D}
	Premolar	80.03 (2.92)^{C}	80.23 (2.77)^{C}
a*	Central Incisor	-1.23 (0.70)^{C}	-1.29 (0.62)^{D}
	Lateral Incisor	-0.48 (0.80)^{B}	-0.66 (0.75)^{C}
	Canine	0.66 (0.76)^{A}	0.68 (0.74)^{A}
	Premolar	0.42 (0.87)^{A}	0.37 (0.97)^{B}
b*	Central Incisor	17.49 (3.90)^{C}	16.72 (3.61)^{C}
	Lateral Incisor	21.80 (3.69)^{B}	20.81 (3.38)^{B}
	Canine	26.75 (3.15)^{A}	25.93 (3.13)^{A}
	Premolar	25.18 (3.51)^{A}	24.89 (3.86)^{A}

SD = Standard deviation
Data in the same group columns with distinct superscript letters indicate statistically significant differences (P<0.05)
Data in the same row show no statistically significant differences (P>0.05)

Both males and females showed similar results without statistically significant differences. The most lightness value was found for the central incisor followed by the lateral incisor and the premolar while the least lightness value was the canine. The highest a* and b* values were found in the canine followed by the premolar and the lateral incisor while the lowest a* and b* values were the central incisor. However, the b* coordinate of the canine and the premolar in both genders and the a* coordinate of the canine and the premolar in males were not significantly different ($P > 0.05$). Figure 1 presents all data of L*, a*, b* color coordinates. In general, most of the central incisors were the farthest from the canines and the premolars.

The median and interquartile range values of |ΔL*|, |Δa*|, |Δb*| are presented in Table 2.

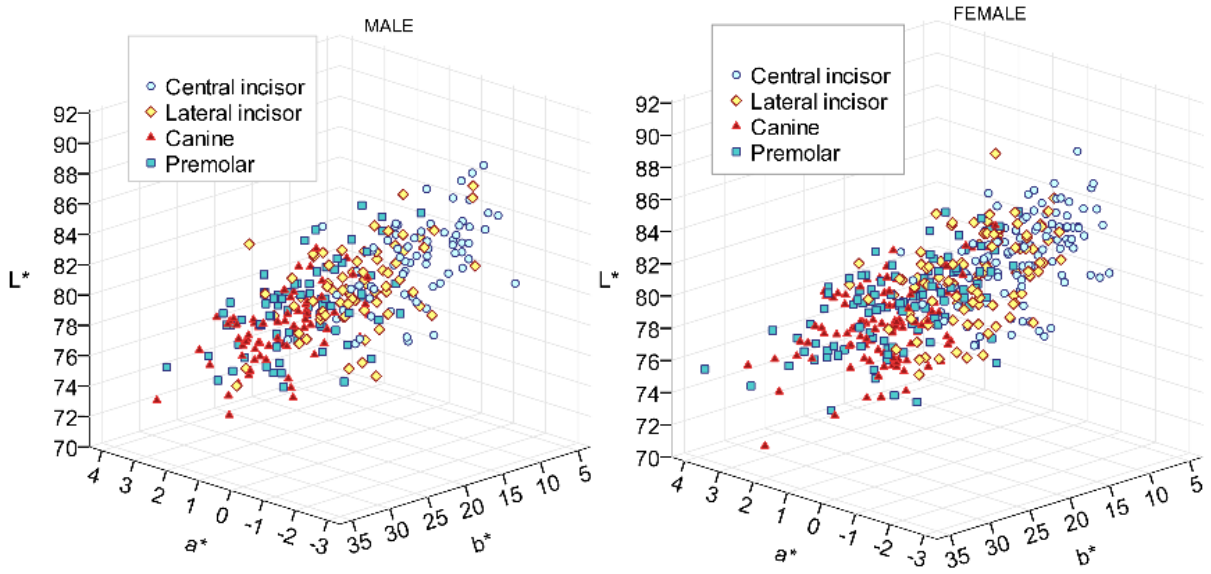

Figure 1 *3D scatter of L*, a*, b* color coordinates of maxillary central incisor, lateral incisor, canine, and premolar separated by male and female*

Table 2 *Median (interquartile range) of absolute ΔL*, Δa*, Δb* between each individual tooth comparison*

	MALE			FEMALE		
	|ΔL*|	|Δa*|	|Δb*|	|ΔL*|	|Δa*|	|Δb*|
Central incisor : Lateral incisor	1.83 (1.96)^{D,b}	0.80 (0.63)^{CD,c}	4.13 (3.26)^{B,a}	1.43 (2.08)^{E,b}	0.67 (0.60)^{D,c}	4.33 (2.89)^{B,a}
Central incisor: Canine	4.60 (3.27)^{A,b}	1.93 (0.94)^{A,c}	9.10 (5.03)^{A,a}	4.35 (3.00)^{A,b}	1.93 (1.03)^{A,c}	9.35 (4.78)^{A,a}
Central incisor: Premolar	3.47 (3.03)^{AB,b}	1.60 (1.16)^{A,c}	7.93 (3.93)^{A,a}	3.30 (2.91)^{AB,b}	1.52 (1.22)^{AB,c}	8.12 (5.70)^{A,a}
Lateral incisor: Canine	2.63 (3.07)^{BC,b}	1.00 (0.90)^{B,c}	4.60 (3.63)^{B,a}	2.83 (2.34)^{BC,b}	1.23 (1.07)^{BC,c}	4.98 (4.31)^{B,a}
Lateral incisor: Premolar	1.77 (3.04)^{CD,b}	0.80 (0.95)^{BC,c}	3.53 (4.37)^{B,a}	2.13 (2.60)^{CD,b}	1.02 (1.21)^{C,c}	4.44 (5.45)^{B,a}
Canine: Premolar	1.80 (2.13)^{D,a}	0.40 (0.66)^{D,b}	1.83 (2.27)^{C,a}	1.57 (2.09)^{DE,a}	0.55 (0.65)^{D,b}	1.92 (2.44)^{C,a}

Data followed by distinct superscript letters (uppercase in the columns and lowercase in the rows) indicate statistically significant differences (P<0.05)

All matched teeth showed similar results in both genders. The most different color coordinates were |Δb*| followed by |ΔL*| and |Δa*| in all groups. However, |Δb*| and |ΔL*| in a group of canines and premolars showed no statistically significant differences. Boxplots of |ΔL*|, |Δa*|, |Δb*| are presented in figure 2. |ΔL*|, |Δa*|, |Δb*| in the group of central incisors and canines were the highest.

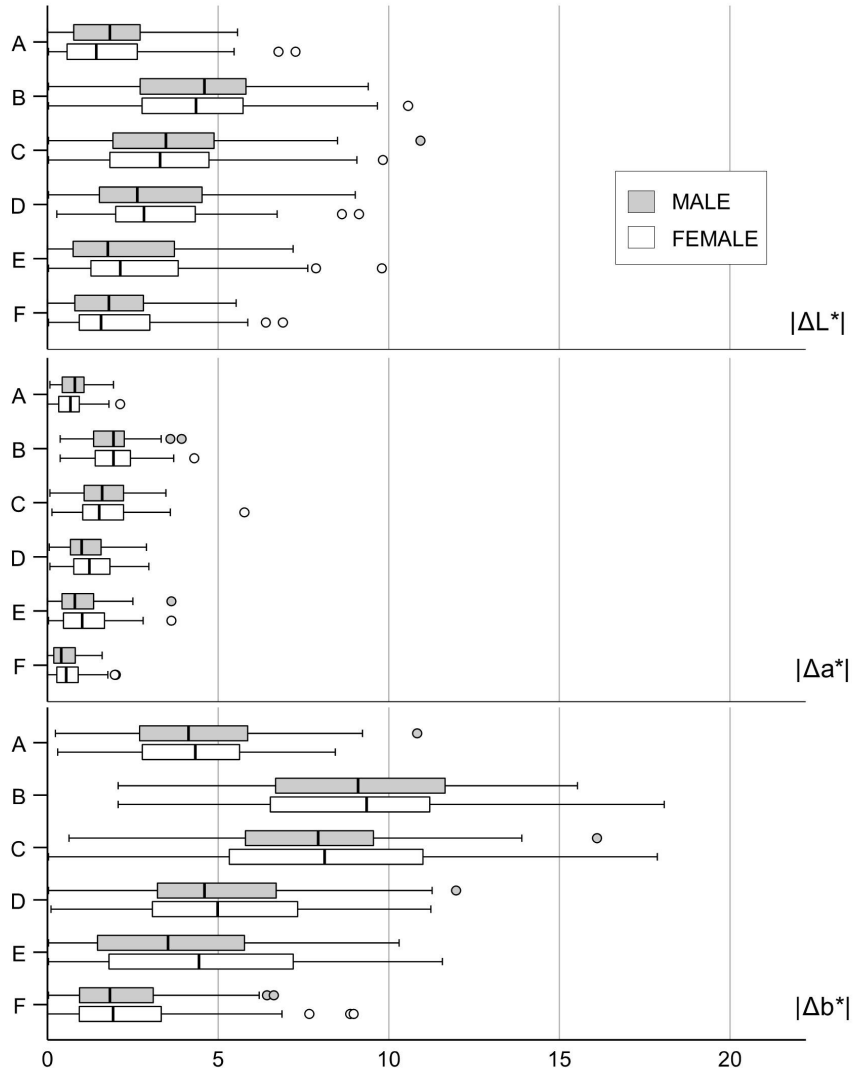

Figure 2 *Boxplots of |ΔL*|, |Δa*|, |Δb*| between central incisor and lateral incisor (A), central incisor and canine (B), central incisor and premolar (C), lateral incisor and canine (D), lateral incisor and premolar (E), canine and premolar (F) separated by male and female*

Table 3 *Mean (SD) and median (IQR) of ΔE^*_{ab} between each individual tooth comparison*

	MALE		FEMALE	
	MEAN (SD)	MEDIAN (IQR)	MEAN (SD)	MEDIAN (IQR)
Central Incisor: Lateral Incisor	5.05 (2.17)	4.74 (3.32)^{B}	4.89 (1.97)	4.77 (2.53)^{B}
Central Incisor: Canine	10.61 (3.32)	10.95 (5.11)^{A}	10.67 (3.32)	10.49 (5.30)^{A}
Central Incisor: Premolar	8.96 (3.23)	8.89 (4.32)^{A}	9.44 (3.80)	9.28 (5.21)^{A}
Lateral Incisor: Canine	6.29 (2.56)	5.73 (3.45)^{B}	6.54 (2.69)	6.31 (3.75)^{B}
Lateral Incisor: Premolar	5.03 (2.43)	4.86 (3.48)^{B}	5.78 (2.84)	5.50 (4.68)^{B}
Canine: Premolar	3.28 (1.62)	2.90 (2.38)^{C}	3.51 (2.05)	3.23 (2.71)^{C}

SD = Standard deviation, IQR = Interquartile range

Data in the columns with distinct superscript letters indicate statistically significant differences (P<0.05)

Data in the same row show no statistically significant differences (P>0.05)

Table 3 presents the mean, standard deviation, median, and interquartile range of ΔE^*_{ab}. Both the male and female participants showed similar results. A group of central incisors and canines showed the most color difference followed by central incisors and premolars, lateral incisors and canines, lateral incisors and premolars, central incisors and lateral incisors. A group of canines and premolars showed the smallest color differences. Boxplots of ΔE^*_{ab} are presented in figure 3.

The top three frequency shades according to the VITA 3D-Master shade guide are shown in figure 4. The most frequency shades were 2M2, 1M1, 2L1.5 for the central incisor; 2M2, 2M3, 2L1.5 for the lateral incisor; 2M3, 3M3, 2M2 for the canine in males and 2M3, 2R2.5, 2M2 for the canine in females; 2M3, 2M2, 2R2.5 for the premolar in males and 2M3, 2M2, 3M3 for the premolar in females.

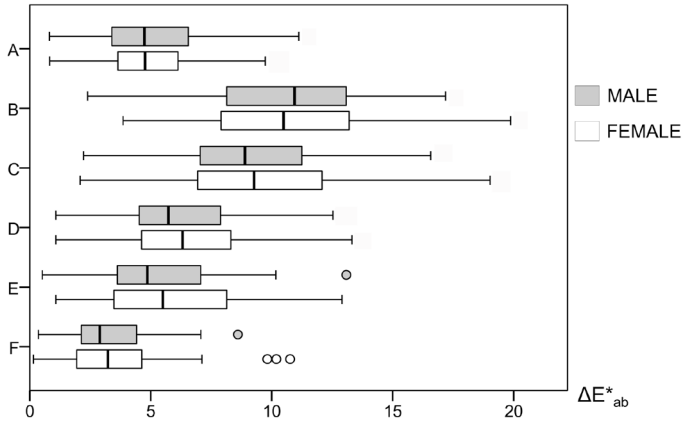

Figure 3 *Boxplots of ΔE^*_{ab} between central incisor and lateral incisor (A), central incisor and canine (B), central incisor and premolar (C), lateral incisor and canine (D), lateral incisor and premolar (E), canine and premolar (F) separated by male and female*

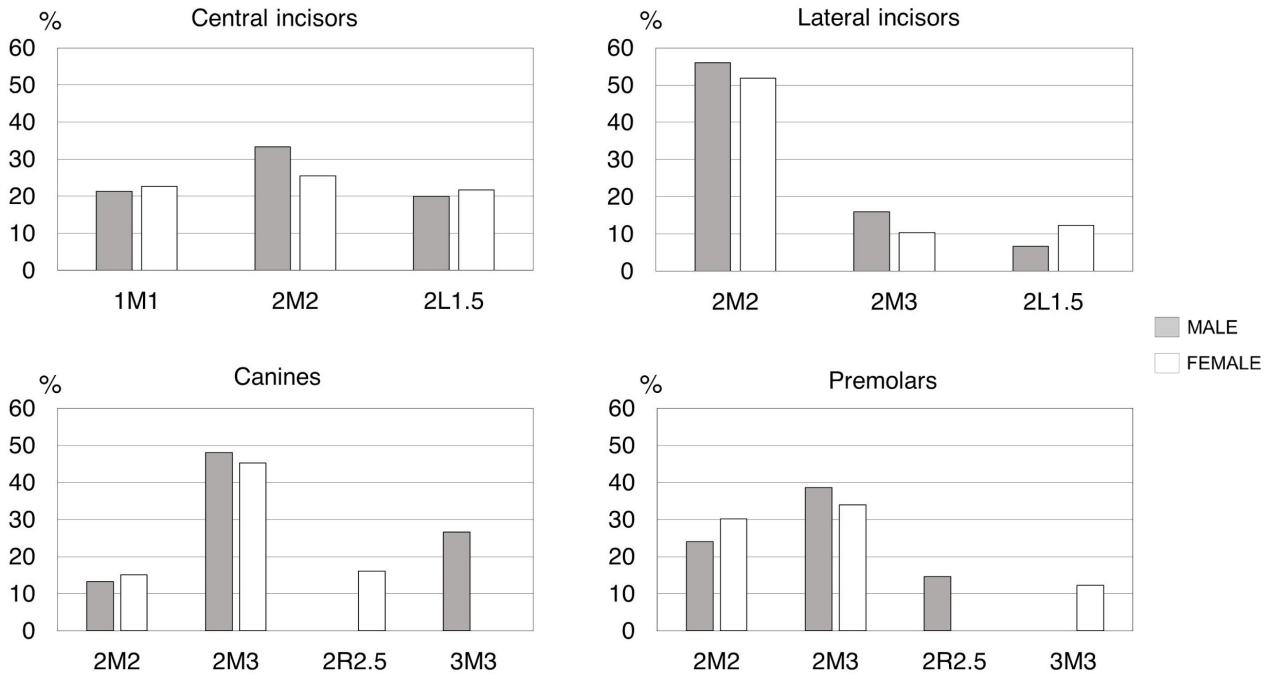

Figure 4 *Bar charts present the top three frequencies of Vita 3D-Master shade found in maxillary central incisors, lateral incisors, canines and premolars*

Discussion

Although the center of the tooth surface is the suitable site for color measurement because the translucency of enamel at the incisal site is affected by the background, and the cervical site is affected by the pink gingival tissue,[15] placing the tip of measuring device on the same position of the tooth surface is practically impossible. In our pilot study, some outliers were found from repeated measurements. Therefore, multiple measurements were designed and the maximum and minimum values of L*, a*, b* were discarded. Instead of using an average of five measurements, only the three middle data were averaged to reduce the outlier effect.

In this current study, it was found that both males and females provided consistent tooth color information. Although the number of males was less than females, the data were sufficient for the normal distribution and the homogeneity of variance for the all color coordinates. Nevertheless, this sample size may not be sufficient for the values of $|\Delta L^*|$, $|\Delta a^*|$, $|\Delta b^*|$, and ΔE^*_{ab} to be analyzed with parametric statistics. These values were obtained by calculating the difference of L*, a*, b* values of the two teeth in the same person. Therefore, the variance of the data was higher from those calculations, and some groups failed to achieve normal distribution.

The values of ΔL^*, Δa^*, Δb^* affect the color differences from the equation of ΔE^*_{ab}. All values are squared in the equation which shows that only the range of differences are considered regardless of the direction of differences. This study analyzed the absolute values of ΔL^*, Δa^*, Δb^* in order to compare the range of differences. Figures 2 and 3 show that the ΔE^*ab value corresponded to the value of $|\Delta b^*|$ more than others. Therefore, it can be said that the color difference between these teeth was mainly due to the influence of yellow, following by ΔL^*. The mean color difference between the maxillary central incisor and the canine of both males and females in the current study was higher than that of the previous study in Romania (ΔE^*_{ab} = 9.13),[8] and in the Turkish study (ΔE^*_{ab} = 8.1).[16]

The central incisor was the lightest, followed by the lateral incisor, and the premolar. The canine showed the most darkness. However, the teeth with a high a* value also had a high b* value, but there was less lightness. The sequence of teeth according to a* and b* values appeared to be opposite to the lightness. In general, the canine and the premolar had more red and yellow tones (more a* and b* values) followed by the lateral incisor, but the central incisor showed the least colors (table 1). However, no significant differences were found between canines and premolars in all color coordinates except for the a * value in females, indicating that the canine was redder than premolars in females.

The maximum values of ΔL^*, Δa^*, Δb^* were found between central incisors and canines, and resulted in the greatest difference in color. A study in Kosovo showed that the lightness, a*, and b* values of maxillary central incisors, lateral incisors and canines were similar to the results of this current study.[9] Lee[17] studied the six maxillary and mandibular anterior teeth of Koreans, and reported that tooth color coordinates were related to each other. The L* value was negatively related to the a* and b* values. The color coordinate of a* had a positive correlation with b*. Lighter teeth were less chromatic both in the a* and b* coordinates. However, a study in Turkey used a colorimeter to evaluate the color, and it was found that all the maxillary anterior teeth had a lower L * and a higher a * values compared to this study.[16] A study of central incisors and canines in Romania found that the a * and b * values were close to this study, but the L * values were higher.[8] Eiffler *et al.*[13] found that the maxillary canine were brighter than the premolar in the older group (73-75 years of age). Gómez-Polo *et al.*[18] reported that maxillary central incisors become darker, yellower and more reddish with increasing age. The L* coordinate is more strongly related to tooth color in aging than a* and b*.

The VITA Classical and VITA 3D-Master are the most popular shade guides. However, it has been shown that the VITA 3D-Master is better suited to natural teeth than the VITA Classical.[19-21] It contains shade tabs that are uniformly arranged in the color space of natural tooth

and significantly improves repeatability of measuring tooth shade compared to a traditional shade guide for general practitioners.[22,23] Therefore, the color of the VITA 3D-Master was chosen and presented in this study. In this study, the most common shades found in males and females were similar and could be divided into two groups; 2M2 for central incisors and lateral incisors, 2M3 for canines and premolars. However, the three most common shades of the central incisor and the premolar were more dispersed than the canine and the lateral incisor. A former study from Romanian (aged 21-29 years) reported the most common shades of incisors and canines were 1M1 and 2M3, respectively.[8] Their incisor was brighter than the incisor in this study. According to the VITA Classical shade guide, a study in Turkey (aged 15-70 years) showed the most common shades as A2 for the central and lateral incisor and B3 for the canine .[24]

The buccal surface of the premolar was more curved than the anterior teeth. It was impossible to place the tip of the measuring tool completely close to the tooth surface. Edge loss effect might occur on the premolar causing the L * value to be lower than it should be.[25] The other limitation of this study was that most of the volunteers (87.8%) were in southern Thailand. Although all of them were Thai, people in other parts of Thailand may show different results. Therefore, further studies in other regions of Thailand should be investigated in the future.

Studying tooth color in different ages may produce different results. Many studies showed that teeth become darker and yellower as people get older.[25,26] Therefore, comparing the tooth color obtained from various studies should consider this point. The study in young adults gives information before tooth color changes with age. Tooth color at this age is useful as the reference because the tooth color is the brightest and whitest. The results of this study are helpful for dentists and dental technicians to select different colors of the anterior teeth and create natural-looking restorations. Restoring the entire anterior teeth and premolar to the same color is completely unnatural and should not be done, especially in full-mouth rehabilitation. When a full mouth restoration is required and the shades of the entire teeth have to be completely redefined, it is appropriate to employ the shade according to the tooth position.

Conclusions

Within the limitation of this study, it can be concluded that the maxillary central incisor and the canine were the most different in color while the canine and the premolar were the least different. The color difference between the maxillary anterior teeth and the premolar were mainly due to the influence of yellow, followed by lightness. The higher the lightness, the lower the red and yellow color will be found among the maxillary anterior teeth and the premolar. The most common shades are 2M2 for the central and lateral incisor and 2M3 for the canine and premolar in young Thais.

References

1. Joiner A. Tooth colour: a review of the literature. ***J Dent*** 2004; 32Suppl1:3-12.

2. Posavec I, Prpić V, Zlatarić DK. Influence of light conditions and light sources on clinical measurement of natural teeth color using VITA easyshade advance 4.0 spectrophotometer. pilot study. ***Acta stomatol Croat*** 2016;50(4):337-47.

3. Horn DJ, Bulan-Brady J, Hicks ML. Sphere spectrophotometer versus human evaluation of tooth shade. ***J Endod*** 1998;24(12):786-90.

4. Knezović D, Zlatarić D, Illeš IŽ, Alajbeg M, Žagar. Repeatability and accuracy of VITA easyshade® advance 4.0 dental shade-matching device. ***Acta Stomatol Croat*** 2015;49(2):112-8.

5. Chu SJ, Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. Review of clinical and research aspects. ***J Dent*** 2010;38Suppl2:2-16.

6. Chang JY, Chen WC, Huang TK, Wang JC, Fu PS, Chen JH, *et al.* Evaluating the accuracy of tooth color measurement by combining the Munsell color system and dental colorimeter. ***Kaohsiung J Med Sci*** 2012;28(9):490-4.

7. Johnston WM. Color measurement in dentistry. ***J Dent*** 2009; 37Suppl1:e2-6.

8. Pop-Ciutrila IS, Colosi HA, Dudea D, Badea ME. Spectrophotometric color evaluation of permanent incisors, canines and molars. A cross-sectional clinical study. ***Clujul medical*** 2015;88(4):537-44.

9. Pustina-Krasniqi T, Shala K, Staka G, Bicaj T, Ahmedi E, Dula L. Lightness, chroma, and hue distributions in natural teeth measured by a spectrophotometer. ***Eur J Dent*** 2017;11(1):36-40.

10. Falcone ME, Kelly JR, Rungruanganut P. *In vivo* color relationships between the maxillary central incisors and canines as a function of age. ***Int J Prosthodont*** 2016;29(5):496-502.
11. Hassel AJ, Johanning M, Grill S, Schroder J, Wahl HW, Corcodel N, *et al*. Changes of tooth color in middle and old age: A longitudinal study over a decade. ***J Esthet Restor Dent*** 2017;29(6):459-63.
12. Rodrigues S, Shetty SR, Prithviraj DR. An evaluation of shade differences between natural anterior teeth in different age groups and gender using commercially available shade guides. ***J Indian Prosthodont Soc*** 2012;12(4):222-30.
13. Eiffler C, Cevirgen E, Helling S, Zornek J, Pritsch M, Hassel AJ. Differences in lightness, chroma, and hue in the anterior teeth of quinquagenarians and septuagenarians. ***Clin Oral Investig*** 2010; 14:587-91.
14. Tjan AH, Miller GD, The JG. Some esthetic factors in a smile. ***J Prosthet Dent*** 1984;51:24-8.
15. Goodkind RJ, Keenan K, Schwabacher WB. Use of a fiber-optic colorimeter for *in vivo* color measurements of 2830 anterior teeth. ***J Prosthet Dent*** 1987;58(5):535-42.
16. Turgut S, Kilinc H, Eyupoglu GB, Bagis B. Color relationships of natural anterior teeth: an *in vivo* study. ***Niger J Clin Pract*** 2018; 21(7):925-31.
17. Lee YK. Correlation between three color coordinates of human teeth. ***J Biomed Opt*** 2014;19(11):115006.
18. Gómez-Polo C, Montero J, Gómez-Polo M, de Parga JA, Celemin-Viñuela A. Natural tooth color estimation based on age and gender. ***J Prosthodont*** 2017;26(2):107-14.
19. Öngül D, Şermet B, Balkaya MC. Visual and instrumental evaluation of color match ability of 2 shade guides on a ceramic system. ***J Prosthet Dent*** 2012;108(1):9-14.
20. Paravina RD. Performance assessment of dental shade guides. ***J Dent*** 2009;37Suppl1:e15-20.
21. Li Q, Yu H, Wang YN. *In vivo* spectroradiometric evaluation of color matching errors among five shade guides. ***J Oral Rehabil*** 2008;36(1):65-70.
22. Hammad IA. Intrarater repeatability of shade selections with two shade guides. ***J Prosthet Dent*** 2003;89(1):50-3.
23. Paravina RD, Powers JM, Fay RM. Color comparison of two shade guides. ***Int J Prosthodont*** 2002;15(1):73-8.
24. Karaman T, Altintas E, Eser B, Talo Yildirim T, Oztekin F, Bozoglan A. Spectrophotometric evaluation of anterior maxillary tooth color distribution according to age and gender. ***J Prosthodont*** 2019; 28(1):e96-102.
25. Bolt RA, Tenbosch JJ, Coops JC. Influence of window size in small-window colour measurement, particularly in teeth. ***Phys Med Biol*** 1994;39(7):1133-42.
26. Hasegawa A, Motonomi A, Ikeda I, Kawaguchi S. Color of natural tooth crown in Japanese people. ***Color Res Appl*** 2000;25(1):43-8.
27. Zhao Y, Zhu J: *In vivo* color measurement of 410 maxillary anterior teeth. ***Chin J Dent Res*** 1998;1(3):49-51.