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CIE L*a*b* Color Analyses of Anterior Maxillary Teeth According to Gender and Localization Variables

Maksiller Anterior Dişlerin Cinsiyet ve Lokalizasyon Değişkenlerine Göre CIE L*a*b* Renk Analizi

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Abstract

Objective: This study aimed to investigate the distribution of color values of the anterior maxillary teeth of a Turkish population in the CIE L* a* b* color space by gender and right-left localization variables.

Material-Method: The study was carried out on 434 dental students aged 18-22 years with upper intact central, lateral, and canine teeth. Measurements were achieved by a dental spectrophotometer (VITA Easyshade) from the labial one-third centers to get the CIE L* a* b* values. To evaluate the difference in color, $[(\Delta L^*)^2+ (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$ formula was used. Maxillary right-left side localization and gender variables were used to classify the data. Kolmogorov Smirnov statistical analyses were used to confirm normal distribution. The data did not exhibit a normal distribution, so Mann Whitney U, Kruskal Wallis, and Wilcoxon tests were used. IBM SPSS V23 (IBM, New York, USA) statistical program was used for statistical analyses ($p<0.05$).

Results: L* a* b* analysis according to gender variable showed that L* values in canine, lateral and central incisor groups were higher in females ($p=0.03$, $p<0.001$, $p<0.001$ respectively). The a* parameter showed higher values in males for canine, lateral and central incisors ($p=0.001$, $p<0.001$, $p<0.001$ respectively). The b* parameter also showed higher values in males for all canine, lateral, and central incisor teeth ($p=0.001$, $p<0.001$, $p<0.001$, respectively). When the resultant ΔE values examined according to the gender variable, canine teeth of male and female participants showed a statistical difference ($p=0.008$), while lateral and central incisors showed no statistical difference ($p=0.105$, $p=0.129$ respectively). Based on the right-left localization variable, L* (Right L*: 79.7 - Left L*: 80.2 $p<0.001$), and a* parameters showed statistical higher (Right a*: -0.1 / Left a*: -0.2 $p=0.020$) values in general. The ΔE values among right and left canines, lateral, and central incisors (ΔE=2.67, ΔE=2.94, ΔE=2.14 respectively) also exhibited statistical difference ($p<0.001$).

Conclusions: CIE L*a*b* color values of teeth in the anterior maxillary region in a young Turkish population are affected by gender and right-left localization variables.

Keywords: Color selection, Color distribution, Spectrophotometer.

Özet

Amaç: Bir Türk toplumunda maksiller anterior dişlerin cinsiyet ve lokalizasyon değişkenlerine göre CIE L* a* b* renk uzayında analizini gerçekleştirmek.

Materyal-Metot: Bu çalışma üst santral, lateral ve kanin dişleri bulunan 434 öğrenci üzerinde yürütüldü. Ölçümler bir dental spektrofotometre (VITA Easyshade V) cihazı ile doğal dişlerin labial orta üçte bir merkezlerinden yapıldı ve ortalama CIE L*a*b* değerleri kaydedildi. Gruplar arası karşılaştırmada renk farklılıklarının tespiti için $\Delta E=[(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2}$ formülü kullanıldı. Veriler, cinsiyet ve sağ-sol lokalizasyon değişkenlerine göre sınıflandı. Verilerin normal dağılıma uygunluğu Kolmogorow Smirnow testi ile gerçekleştirildi. Normal dağılım göstermeyen verilerin analizi için Mann Whitney U, Kruskal Wallis ve Wilcoxon testleri uygulandı. İstatiksel analiz için IBM SPSS V23 (IBM, New York, USA) programı kullanıldı ($p<0,05$).

Bulgular: Cinsiyet değişkenine göre incelendiğinde, L* değerlerinin tüm dişler için kadınlarda daha yüksek olduğu (kanin $p=0,03$/lateral $p<0,001$/santral $p<0,001$), a* değerinin tüm diş gruplarında erkekler lehine (kanin $p=0,001$/lateral $p<0,001$/santral $p<0,001$), ve b* değerinin de tüm diş gruplarında erkekler lehine daha yüksek olduğu (kanin $p=0,001$/lateral $p<0,001$/santral $p<0,001$) gözlenmiştir. Cinsiyet değişkenine göre dişler arasındaki ΔE incelendiğinde ise kanin dişler arasında anlamlı fark bulunurken ($p=0,008$), lateral ve santral dişler arasında anlamlı fark gözlenmemiştir (sırası ile $p=0,105$, $p=0,129$). Lokalizasyon değişkeni esas alındığında ise katılımcıların sol anterior dişlerine ilişkin L* (Sağ L*: 79,7/Sol L*: 80,2 $p<0,001$) ve a* değerlerinin (Sağ a*: -0,1/Sol a*:-0,2 $p=0,020$) istatistiksel olarak daha yüksek olduğu gözlenmiştir. Sağ-sol lokalizasyon değişkenine göre ΔE değerleri (ΔE kanin: 2,67/ΔE lateral: 2,94/ΔE santral: 2,14) incelendiğinde ise tüm kanin, lateral ve santral diş renkleri arasındaki farkın anlamlı olduğu gözlenmiştir ($p<0,001$).

Sonuç: CIE L*a*b* renk parametrelerine göre cinsiyet ve sağ-sol lokalizasyon değişkenleri genç bir Türk toplumunda maksiller anterior bölge dişlerin renk değerlerini etkilemektedir.

Anahtar kelimeler: Renk seçimi, Renk dağılımı, Spektrofotometre.

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Introduction

The increasing importance of aesthetic values in human life directly affects the materials used as well as technics and treatment protocols in dentistry. Therefore, aesthetic practices in dentistry have become a progressive and evolving study site (1).

Replicating tooth color is an essential factor for dentists who want to make a successful restoration, and for patients with high aesthetic demand. The dentin layer plays the most critical role in the perception of the primary color of the tooth while the surface properties, the amount of permeability, and the thickness of the enamel layer influence the color brightness. When the amount of permeability in the enamel layer increases, its dominance over the color of the dentin layer increases. The brightness is the least at the gingival and the incisal one-third of the natural teeth, whereas highest at the middle one-third (2).

Two methods are used for color selection in dentistry, visual color selection, and instrumental color selection. The most commonly preferred color selection method is the visual technique made with the help of color scales (3). However, the visual selection of tooth color is very subjective. The type of light used in color selection, lighting conditions, the experience of the clinician, age and eye fatigue caused by constant stimulation of the eye by the same stimulant, color blindness can cause incorrect color selection. It is often difficult to match a consistent color because of these factors (4).

The most widely used system in visual color selection is Munsell's color system. Munsell defines three parameters of color as hue, luminosity (value), and color intensity (chroma) (5). However, it is not possible to define the color differences in the Munsell color system. Therefore, the CIE L*a*b* color system has been developed by CIE (Commission Internationale de l'eclairage '-CIE). The color space of the CIE L*a*b* has a regular structure. There are three different axes in this three-dimensional color space: L*, a*, and b* axes. The L* value can be explained as the brightness of the object, and the scale is perfect black at 0, and the perfect white at 100 units. The a* axis represents redness if it has a positive value, and greenery if it has a negative value. Finally, the b* axis represents yellowness if it has a positive value, and blueness if it has a negative value. The a* and b* coordinates reach 0 in neutral colors and increase in more saturated and dense colors. The most important advantage of the CIE L*a*b * system is that color differences are expressed as a quantifiable unit (6).

To make more objective, fast, repeatable measurements, and to evaluate the results statistically, researchers developed shade selection devices (7). Colorimeters, spectrophotometers, and spectroradiometers are being used to determine tooth color. Among these, spectrophotometers are the most reliable ones that can be used for shade selection in dentistry (8, 9). Spectrophotometers define the color of the teeth with pre-determined color codes (8, 10). The accuracy and reliability of these devices are proven in most studies (11, 12). The significant advantage of the Vita Easy Shade V spectrophotometer used in this present study is that it can define natural tooth color via CIE L*a*b* values and can also interpret the results into Vita Classic and Vita 3D Master scale values (13).

Various studies have reported diversity for tooth color among different races and populations (14-17). When the literature is examined, few studies discuss the color evaluation of young individuals' anterior maxillary teeth in a Turkish population (18, 19). These studies have well documented the CIE L*a*b* value differences among maxillary canines, lateral, and central incisors (14-19).

This study aims to identify the anterior maxillary teeth color according to the CIE L*a*b* system and to analyze these values according to gender, and right-left side localization. The null hypothesis is: the CIE L*a*b* color values of the teeth located in the anterior maxillary region are not affected by gender and localization variables, and the differences are purely a coincidence.

Material and Methods

This present study included a total of 434 volunteered Suleyman Demirel University Faculty of Dentistry students (232 females / 202 males). The study was approved by Suleyman Demirel University Faculty of Medicine Ethics Committee (18.01.2017 / No:15). The volunteers signed a written consent form following the Helsinki Declaration of the World Medical Association (20). The inclusion criteria were as follows: to be born between the years 1995-1999, to have intact maxillary canine, lateral and central incisor teeth, not to have tooth whitening procedure, not to have periodontal disease or orthodontic treatment background.

Before the shade assessment procedure, the participants brushed their teeth with a standardized toothbrush (Oral-B Complete, Procter & Gamble, İstanbul, Türkiye), and toothpaste (Colgate Total, Colgate-Palmolive, İstanbul, Türkiye) for one minute. Vita Easyshade V dental spectrophotometer (VITA Easyshade, VITA Zahnfabrik, Bad Säckingen, Germany) was used for the procedure. During the entire protocol, the user guide of the manufacturing company was strictly respected. Assessments were carried out between 11:00-13:00 hours of the day under indirect sunlight to avoid bias. Infection protection barriers specially produced for the equipment by the manufacturing company were used for each participant. The device was calibrated before each assessment using a calibration component on it.

The targeted shade assessment areas were the labial middle third centers of right and left maxillary canines, lateral, and central incisors. To avoid bias, the same researcher executed the assessments. "Single measurement" option of the application was selected, and the probe of the equipment was placed with a 90° angle on the targeted area. Three consecutive measurements were executed for each tooth, and the CIE L* a* b* scores were recorded. The ΔE formula ($\Delta E = [(\Delta L^*)^2+(\Delta a^*)^2+(\Delta b^*)^2]^{1/2}$) is used to determine the color differences within the participants themselves and among each other. ΔE scores were assessed as follows (21);

• ΔE=0 Defines no color change assessed

• ΔE≤1 Defines that only 50% of the observers can detect the color difference, and this difference cannot be detected clinically,

• 1≤ΔE≤2 Clinically detectable color difference

• 2≤ΔE≤3.7 Clinically detectable by 100% of the observers, and clinically acceptable

• ΔE>3.7 Clinically unacceptable color difference and poor adaptation.

The data were analyzed with the IBM SPSS V23. The Kolmogorov Smirnov test was used to examine the normal distribution of data. The Mann Whitney U test, Kruskal Wallis and Wilcoxon tests were used to compare data that did not comply with the normal distribution. As the data does not conform to the normal distribution, the results are presented in the median (minimum-maximum) form. The statistical significance level is p<0.05.

Results

A total of 2604 teeth of 434 participants were examined for the study. The L*a*b* values and the resultant ΔE scores were assessed.

The participants' (232 females, 202 males) anterior maxillary teeth assessed for the gender variable (Table1). Results show that the canine teeth' median L*a*b* values showed a significant difference (respective p values: 0.030, 0.001, and p<0.001). The L* values were found to be higher in females, while a* and b* values were higher in male participants. The lateral incisor teeth' median L*, a*, and b* values showed significant difference (respective p values: <0.001, <0.001, and 0.001). The L* values were found to be higher in females, while a* and b* values were higher in males, c) the central incisor teeth' median L*, a*, and b* values also showed a significant difference (all p values: <0.001). The L* values were found to be higher in females, while a* and b* values were higher in males.

The L*a*b* values of the assessed teeth were also analyzed according to each gender (female and male) variable separately (Table 2). As for the female participants a) the median L* values differ significantly according to teeth variable (p<0.001), the highest L* values were recorded in central incisors, and the lowest was in canine teeth, b) the median a* values differ significantly according to teeth variable (p<0.001). The lowest a* values were recorded for the central incisors, and the highest was in canine, c) the median b* values differ significantly according to teeth variable (p<0.001). The highest b* values were recorded for the canine teeth, and the lowest was recorded for the central incisors. As for the male participants, a) the median L* values also differ significantly according to teeth variable (p<0.001). The highest L* values were recorded in central incisors, and the lowest was in canine teeth, b) the median a* values differ significantly according to teeth variable (p<0.001). The lowest a* values were recorded in central incisors, and the highest was recorded in canine teeth., c) the median b* values differ significantly according to teeth variable (p<0.001). The highest b* values recorded in canine teeth and the lowest were recorded in central incisors (Table 2).

Table 1. Comparison of L*, a*, and b* values of the maxillary anterior teeth according to gender

Teeth	Gender	L*	a*	b*
Canine	Female	77.80 (65.10–86.30)	1.00 (-1.60–5.20)	27.80(13.10–37.20)
	Male	77.20 (63.50–89.00)	1.10 (-1.00–4.90)	28.70 (19.00–40.30)
	p	**0.030**	**0.001**	**<0.001**
Lateral Incisor	Female	81.10 (62.80–90.50)	-0.50 (-2.60–7.40)	22.30 (12.00–37.10)
	Male	80.00 (66.70–88.30)	-0.10 (-2.10–5.10)	23.40 (3.60–39.60)
	p	**<0.001**	**<0.001**	**0.001**
Central Incisor	Female	83.00 (66.90–92.60)	-1.40 (-2.70–3.00)	19.00 (11.50–34.50)
	Male	81.55 (66.60–89.90)	-1.00 (-2.80–4.70)	20.10 (11.40–39.30)
	p	**<0.001**	**<0.001**	**<0.001**

Median (min-max)

Table 2. Comparison of L*a*b* values of the maxillary anterior teeth within each gender

Gender	Teeth	L*	a*	b*
Female	Canine	77.80 (65.10–86.30) a	1.00 (-1.60–5.20) a	27.80 (13.10–37.20) a
	Lateral incisor	81.10 (62.80–90.50) b	-0.50 (-2.60–7.40) b	22.30 (12.00–37.10) b
	Central incisor	83.00 (66.90–92.60) c	-1.40 (-2.70–3.00) c	19.00 (11.50–34.50) c
	p	**<0.001**	**<0.001**	**<0.001**
Male	Canine	77.20 (63.50–89.00) a	1.10 (-1.00–4.90) a	28.70 (19.00–40.30) a
	Lateral incisor	80.00 (66.70–88.30) b	-0.10 (-2.10–5.10) b	23.40 (3.60–39.60) b
	Central incisor	81.55 (66.60–89.90) c	-1.00 (-2.80–4.70) c	20.10 (11.40–39.30) c
	p	**<0.001**	**<0.001**	**<0.001**

Median (min-max) a, b, c: No statistical difference among the groups represented with the same letter.

In the comparison of anterior maxillary teeth' median ΔE values, canine teeth showed statistical significance according to gender (p=0.008). Lateral and central incisor teeth' median ΔE values showed no statistical difference among gender (p= 0.105, and p=0.129, respectively) (Table 3).

The ΔE scores of anterior maxillary teeth were evaluated for each gender separately. ΔE scores of female participants showed a statistical difference (p<0.001) (Table 4). ΔE values of canine and central incisor teeth showed no statistical difference, while median ΔE values of lateral incisors were statistically higher compared to canine and central incisor teeth. As for the male participants, ΔE values exhibit a statistical difference (p<0.001). ΔE values of canine and lateral incisor teeth do not differ statistically, while median ΔE values of central incisors were statistically lower than both canine and lateral incisor teeth (Table 4).

Anterior maxillary teeth' median L*a*b* values were also evaluated for the localization (right-left side) variable (Table 5). The L* values were significantly higher for the left side anterior teeth (p<0.001), while the a* and b* values exhibited no statistical difference (respective p values 0.02, and 0.674). The median ΔE values of right vs. left teeth were 2.67 for canines, 2.94 for lateral incisors, and 2.14 for central incisors (p<0.001) (Table 6).

Table 3. Comparison of ΔE values of the maxillary anterior teeth according to gender

Tooth	Gender	ΔE
Canine	Female	2.38 (0.00–17.36)
	Male	2.83 (0.00–11.88)
	p	**0.008**
Lateral incisor	Female	2.81 (0.00–9.35)
	Male	2.97 (0.00–23.22)
	p	**0.105**
Central incisor	Female	2.08 (0.35–13.32)
	Male	2.26 (0.22–11.51)
		0.129

Median (min-max)

Table 4. Comparison of the gender variable for the ΔE values of the maxillary anterior teeth

Gender	Tooth	ΔE
Female	Canine	2.38 (0–17.36) a
	Lateral incisor	2.81 (0–9.35) b
	Central incisor	2.08 (0.35–13.32) a
	p	**<0.001**
Male	Canine	2.83 (0–11.88) a
	Lateral incisor	2.97 (0–23.22) a
	Central incisor	2.26 (0.22–11.51) b
	p	**<0.001**

Median (min-max) a, b, c: No statistical difference among the groups represented with the same letter.

Table 5. Comparison of L*, a*, b* values among right-left side teeth

Parameter	Right	Left	p
L*	79.70 (63.50–91.70)	80.20 (62.80–92.60)	**<0.001**
a*	-0.10 (-2.80–5.50)	-0.20 (-2.80–7.40)	**0.020**
b*	23.80 (3.60–40.30)	23.65 (11.40–39.10)	**0.674**

Median (min-max)

Table 6. Comparison of ΔE values according to right-left side teeth

Tooth	ΔE Differences among right-left side teeth
Canine	2.67 (0–17.36) **a**
Lateral incisor	2.94 (0–23.22) **b**
Central incisor	2.14 (0.22–13.32) **c**
p	**<0.001**

Median (min-max) a, b, c: No statistical difference among the groups represented with the same letter.

Discussion

The aim of aesthetic dentistry today is to restore the missing aesthetic appearance of the patient. If a single color is selected for the restoration of all the anterior teeth, the resulting restoration will exhibit an image far from naturality. It is essential to define the color of the anterior teeth relative to each other to solve this problem (14). Natural teeth have many features that are complicating color selection. The tooth's morphological properties, surface structure, and translucency affect the color perception of the tooth. Besides, dryness of the tooth can cause incorrect results. Since the diversity of tooth color increases from gingival to incisal, the middle third of the tooth should be referenced in the color selection procedure (22, 23).

Visual and instrumental color selection methods have been used in determining tooth color in the studies. Researches usually prefer the instrumental shade selection method, as it can rapidly evaluate tooth color in a repeatable and objective manner. Among these instruments, dental spectrophotometers are the most reliable ones (9). In most of the studies, the accuracy and reliability of these devices are proven (12, 13).

In some studies that aimed at tooth color assessment, results showed no significant correlation between gender and tooth color (16, 24). Al-Saleh et al. (16) evaluated central incisor teeth of one hundred Saudi individuals by Vita Easyshade dental spectrophotometer. They compared the L*a*b* values according to gender. They found no statistical difference in terms of L* and concluded that the female participants' teeth exhibit a lower color density because of a* and b* values. The a*, and b* value results of this present study also shows lower values for the female participants, and the resultant lower color density of female's central incisors, while the L* values of the studies do not coincide. The difference between the sample sizes of the studies (n=100 vs. n=434) may be a reason for the difference. Tunçdemir et al. (24) also investigated the relationship between anterior teeth' color values with gender (n=125, age: 16-63). They found no correlation between gender and tooth color. The number of participants (n=125) and the age groups of this study (participants' age: 16-63) may be a reason for this divergence. The participants recruited in

this present study were among 19-23 years of age.

Karaman et al. (20) also studied the color values of anterior maxillary teeth in a Turkish population (n=345). However, the researchers did not assess the teeth color by CIE L*a*b* values. They evaluated the shade tab values of the teeth via Vita Easyshade dental spectrophotometer. They compared the percentage scores of obtained shade tabs in their studies, instead of comparing the ΔE (CIE L*a*b*) values. The results of that study showed no statistical difference for the color difference of anterior maxillary teeth ($p<0.05$). The color assessment method difference among this study and this present study does not enable to compare the results.

Öngül et al. (19) also studied color evaluation for the anterior maxillary teeth of a Turkish population by Vita Easyshade (n=164). In their study, the smallest ΔE difference was found for the central-lateral incisor comparison of female participants (ΔE=0.64). The results of this present study (n=434) support this difference by a difference value of ΔE=0.3 in female participants. In both studies, the most significant ΔE difference was for the central incisors and canine teeth.

In this present study, when the L*a*b* values of anterior maxillary teeth were compared according to their localization (right or left) on the maxilla, the L* values of left side teeth were statistically higher, and the a* values were statistically lower ($L^*<0.001$, $a^*=0.020$). The b* values exhibited no statistical difference ($p=0.674$). It has been reported that 85-90% of the population uses the right hand as dominant, while a part of the population can use both hands (66% right dominant, 30% both hands), and only 4% is left hand dominant (25). The statistical difference of L* values among right and left side teeth can be a result of right-hand use during tooth-brushing.

The ΔE scores of for right vs. left canine of the participants' teeth exhibit a value of 2.67, and it represents a color difference that can be perceived by all observers but clinically acceptable ($\Delta E<3.7$). Similarly, statistical significant ΔE differences were exhibited for right and left lateral incisors and central incisors (2.94 and 2.14, respectively). When the studies on the color evaluation of anterior maxillary teeth were examined, no study could be found comparing the CIE L*a*b* values of the anterior maxillary region teeth according to the right-left side localization.

Conclusion

The statistical results of this study rejected the null hypothesis stating that the CIE L*a*b* color values of the anterior maxillary teeth are not affected by gender and localization group variables, and the differences are entirely random.

When the participants grouped as female and male, the L* values were found to be higher in females. This finding suggests that females have brighter anterior maxillary teeth compared to males.

In this present study, maxillary left anterior teeth' L* values were found to be statistically higher when compared to maxillary right anterior teeth. This result may be associated with the high ratio of right-handed individuals in the population, as they brush their teeth with the right hand. However, there was no study comparing the CIE L*a*b* values of maxillary right vs. left anterior teeth. This information may be a router for future studies.

Comparative ΔE values among the left-right side anterior maxillary teeth exhibit color differences that can be perceived by all observers but clinically acceptable. Median ΔE values among central - lateral incisors, lateral incisors - canines, and central incisors – canines are all bigger than the clinical acceptable ΔE value ($\Delta E>3.7$).

These findings may route future studies, especially in aesthetic and digital dentistry.

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