

COMPARATIVE EVALUATION OF THE RELATIONSHIP OF TEETH COLOR AND SOFT TISSUE COLOR OF THE FACE IN INDIVIDUALS WITH NATURAL DENTITION

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ABSTRACT

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Introduction The aim of this study is to make it easier for dentists to choose artificial tooth color in fully and partially edentulous patients by evaluating the relationship between the color of the soft tissues of the face and the color of the teeth.

Methodology The CIEL*a*b* color values of the maxillary central teeth of the volunteers participating in the study were measured by spectrophotometer, and skin, lip and eye color were measured from facial images containing ceramic blocks to standardize the light and color values using Adobe Photoshop software. The Kolmogorov-Smirnow test and Spearman Rank Correlation test were used to evaluate the data.

Results It was observed that there was a higher correlation between the L* values of the teeth and the L* and b* values of the skin. When the analysis between the color measurements taken from the lip photographs and the teeth was examined, it was seen that there was a statistically significant positive correlation between the L* values of the upper central teeth and the a* values of the lip.

Conclusion The results showed that the CIEL*a*b* parameters of skin color and lip color can be used in the selection of tooth color in case of loss of natural teeth or discoloration of existing teeth.

KEYWORDS

Color Measurement; Digital Camera; Spectrophotometer; Skin Color; Tooth Color.

1. INTRODUCTION

There is abundant and strong scientific evidence that the appearance of a person's face and teeth has a profound effect on perception and questioning by others [1–3]. It is also thought that the appearance of the face and teeth have a great impact on the development of the personality of the individual, getting a job, performing, believing in himself and being a victor. The social status of a personality and the attractiveness of a smile are related to each other [4]. While in the past, functional demands were taken into account in oral treatments, today the focus has shifted to aesthetic dentistry with the decrease in caries prevalence [5,6]. Establishing an appropriate balance between illusion and reality is the basis of aesthetic dentistry [7]. The ultimate purpose of aesthetic dentistry is to create beautiful smiles that are compatible with the teeth, gums, lips and face of the patient that complement each other in natural proportions [8]. One of the most important issues in aesthetic dentistry is color selection. Therefore, every dentist should know the color matching procedures for aesthetics [9].

For nearly a century, dentists have used tooth color shade guides for accurate color matching. This traditional way of picking colors is oversimplified and too subjective to constitute a standart [10]. While visual color selection with tooth color shade guides is the most common color matching system, it is considered inconsistent and subjective as it is affected by lighting, age, gender, eye fatigue [11]. In addition to the subject of color selection, which is a very challenging process in dentistry, dentists and technicians need to communicate about tooth colors during prosthesis production procedure. However, verbal communication of color differences is limited. A good color match is directly related to the quality of the prosthesis. The more precisely the tooth colors can be defined, the more accurate porcelain colors can be obtained [12–15]. To obtain the natural and harmonic restoration color, it is necessary to have an objective, precise and systematic method, from the color matching procedure in dentistry to its reproduction in the laboratory [16]. Color measuring instruments and systems such as spectrophotometers, colorimeters, spectroradiome-

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ters and digital image analysis techniques have become increasingly popular, especially in dental research. Spectrophotometers are considered among the most accurate, useful and flexible tools for color matching in dentistry [11,17]. It was found to offer a 33% increase and a more objective match in 93.3% of the cases [18].

Recent advances in photography and technology have been updated with the widespread use of the digital camera for color imaging. Digital cameras have the ability to record numerical data in an object, which data can then be used to produce an image when viewed on a computer and transmitted over the internet. Images produced by a digital camera can be analyzed using suitable imaging software that allows color values to be collected from all or part of such images. This is a much cheaper process than using traditional color measuring instruments such as spectrophotometers or colorimeters [19–21]. Digital imaging systems, on the other hand, are comparable to spectrophotometers, as they provide additional information for color measurements and can measure appearance properties beyond true color when applied correctly [22–24].

Tooth color selection can become more difficult for clinicians when there is no tooth to be used as a reference. In these cases, the choice of tooth color may be more subjective [6,25,26]. Patients not only have a healthy mouth, but they also demand a beautiful smile that is one with the shape of the face, eyes, hair and teeth. It is accepted that the harmony between tooth color and soft tissues, as well as the shape and arrangement of the teeth, significantly affects the aesthetics of the smile [27,28].

There is not enough scientific data support about the relationship between tooth color and soft tissue color of the face. The existence of a possible relationship between the soft tissue color of the face and the tooth color will facilitate the dentist's selection of artificial tooth color in fully and partially edentulous individuals. Since skin color and tooth color measurements are made with traditional and visual methods, more subjective data have been obtained in the previous studies. For this reason, in our study, tooth color was measured with a spectrophotometer and the soft tissue color of the face was measured with the help of a camera by creating a standard environment. The aim of our study is to question the existence of a possible correlation between tooth color and soft tissue color of the face in order to eliminate lack of scientific data support in the literature. The hypothesis of this study is the presence of a correlation between tooth color and the soft tissue color of the face.

2. METHODOLOGY

2.1. Sample Description

150 people aged 20-25, studying at Faculty of Dentistry, Ege University, Izmir participated in this

study. Permission was requested from all individuals participating in the study to take photographs, the reason for the study and all necessary information were explained in detail, and an informed consent form was signed by all patients. Our study was approved by the Ege University Faculty of Medicine Research Ethics Committee No. 20-11T/51.

The exclusion criteria of the patients are listed in the following items:

1. If over 25 years old,
2. If the maxillary central incisors are not fully erupted,
3. If there is any developmental defect in the maxillary central incisors,
4. If there is caries in the maxillary central incisors,
5. If any restoration, root canal treatment or teeth whitening procedures have been applied to the maxillary central incisors,
6. If extrinsic coloration is high in maxillary central incisors,
7. If there is any post-surgical scarring or malformation on the face,
8. If there is any skin disease and the presence of intense tan,
9. If the orthodontic treatment of the individual is continuing, the individuals were not included in the study.

2.2. Measurement of Tooth Color with Spectrophotometer

Tooth color was measured from the middle third of the labial portion of both maxillary central teeth. Before the color selection, dental prophylaxis was applied to the target teeth with a mixture of pumice and water in order to keep the measurement surface clean and free from stains. Before the measurement procedure, a lip retractor was placed in the mouths of the individuals participating in the study.

The tooth shade selection was made using the Vita EasyShade Advance spectrophotometer (VITA Zahnfabrik GmbH, Bad Säckingen, Germany). All measurements were made under 112 cm wide Led Fluorescent lighting with a temperature of 6500°K and a color rendering index (CRI) of 95 (Philips & Co, Netherlands).

It is known that the spectrophotometer device has a fixed enhanced light source from fiber optic light at the measuring end, so the device can record tooth tones in any light beam. For this reason, the lighting conditions of the environment were ignored with the recommendation of the manufacturer.

The Vita EasyShade Advance spectrophotometer device, consisting of a base and a handpiece part, was calibrated using a ceramic calibration plate fixed to the device before data collection. The measuring handpiece part of the device was held on the ceramic plate prepared for the calibration of the device, and it was held until the sound indicating that the calibration was done was heard. Calibration was repeated before each tooth measurement.

Before each measurement, an infection protection barrier (VITA Easyshade Infection Control Shield, Vita Zahnfabrik, Bad Säckingen, Germany) was attached to the tip of the spectrophotometer to prevent cross-infection. The "Single Tooth Option" was selected from the color selection menu. The measuring tip of the device was placed at a 90° angle to the middle third of the labial surface of the tooth. Measurements were made in accordance with the manufacturer's instructions and attention was paid to the correct positioning of the measuring tip.

All measurements were made by the same investigator to ensure standardization. The average of three consecutive measurements from the middle third of the labial surfaces of the targeted teeth was taken, and the CIE L* a* b* values and the values of the Vita 3D Master scale were recorded. All obtained values were recorded on previously prepared forms.

2.3. Standardization of the Area to Take Portrait, Eye and Lip Photographs and Camera Settings

In order to standardize the environment before the photo shoot, a room in the Ege University Faculty of Dentistry was designed to be used in this study as described below. All the windows of the room were closed with opaque thick black covers in order to prevent any light from leaking in and it was ensured that it was isolated from all light sources. All portrait, eye and lip photos were taken in this room.

A non-reflective black screen was used as the background for the portrait photos. A stool was placed 75 cm in front of the background so that the dark tones in the hair of the people to be photographed could not be confused with the background. All shots were taken with the subject to be photographed sitting on a stool. Two speedlight overhead flashes (Godox TT685F, Fujifilm Compatible Top Flash, GODOX Photo Equipment Co., Ltd, Shenzhen, China) were used as light sources, angled 45 degrees in front of the person to be photographed. Two 10x10cm soft boxes were used to increase the light quality, to keep the light power standard and to provide a softer light spread. (Godox SB1010 10x10cm Flash Softbox, GODOX Photo Equipment Co., Ltd, Shenzhen, China) A randomly chosen ceramic block was fixed to a bracket on the end of a tripod to ensure its position remained the same across all photographs. A stationary system was designed by fixing the overhead flash on the other end of the bracket. The ceramic block was positioned to align the outer canthus of the subject's right eye for each portrait and eye photograph, and the right commissura labiorum for all lip photographs. External light sources and ambient conditions were kept constant for all individuals.

All photos were taken with NIKON D90 digital lens adjustable camera (Digital Single-Lens-Reflex, DSLR camera) and Nikon AF-S DX Micro NIKKOR 85mm f/3.5G ED VR lens. Before the photo shoot, ISO 200 (International Standards Organization), aperture f5/6, exposure time 1/125 sec. After the first photo was

taken with a gray card, the white balance settings of the ceramic block in the photos were applied to the other photos. A tripod was used to ensure that images can be taken from the same distance for all portrait, eye and lip photos and to keep the camera stable during shooting.

2.4. Taking Portrait, Eye and Lip Photographs

After checking the standardization of the area to be photographed, the volunteers participating in the study were asked to gently wash their faces with warm water to remove dirt and cosmetics. The volunteers were kept at room temperature for 20 minutes after face washing. Volunteers sat on a stool 75 cm in front of a black background; The axis of the camera lens was kept at eye level of the patient. Prior to the photo shoot, the volunteers were asked to remove photographic distractors such as hats, jewelry, and glasses. During the photographing process, the Frankfurt Horizontal plane of the individuals was positioned parallel to the ground, and the Midsagittal planes were positioned perpendicular to the ground.. Before taking the photo, the auto focus feature was turned off in the camera settings, and all the photos were taken from 1.5 meters where the desired data could fit into the frame in the clearest way. The first photograph was taken with the aid of a standard gray reference card (Original White Balance Reference; Michael Tapes Design) with known color values. The photograph was taken in high resolution, flash and raw data format (Fig. 1).

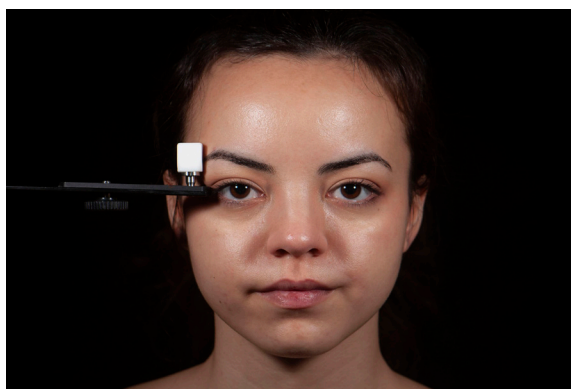


Figure 1. Portrait, eye, lip photograph taken with Nikon D90 adjustable camera with digital lens.

The camera stored the images in NEF format because the image data was not processed intact.

2.5. Color Analysis of Photographs

2.5.1. Skin Color Analysis from Portrait Photographs

After taking the portrait photographs of the volunteers participating in the study, all the images were transferred to the computer. In order to ensure standardization control for each portrait photograph taken, the CIEL*a*b* value of the intersection point of the lines drawn from the four outer corners of the ceramic block to the center of the rectangle in the first photograph taken with a gray card was measured with the Adobe Photoshop program (Fig. 2).

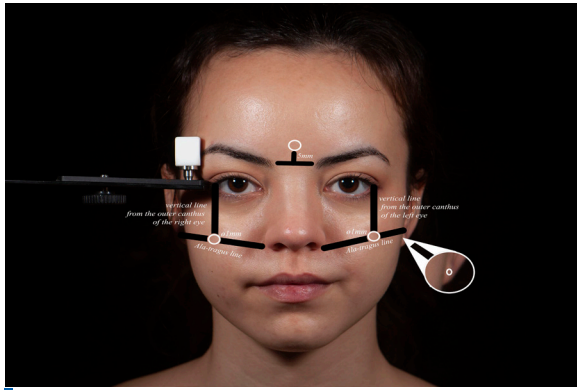


Figure 3. CIEL*a*b* value of ceramic block.

In order to ensure that the ceramic block, whose CIEL*a*b* value was measured as 94.0.0 with the spectrophotometer, gives this value for each photograph, the measurement point was selected using the white balance tool in the Adobe Photoshop program. The white balance values in all the photos were adjusted according to this point located in the middle of the ceramic block.

In order to standardize the skin color analysis of each volunteer participating in the study, four reference regions were determined in the portrait photographs (Fig. 3).

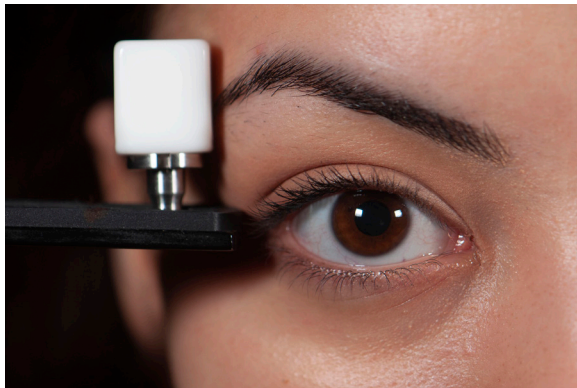


Figure 3. Reference regions for skin color measurement from portrait photographs.

For the first region, the circular region with a width and height of 1 mm, where the vertical descending line from the outer canthus of the right eye and the ala nasii-tragus line intersect on the right cheek was taken as reference. For the second region, the circular region with a width and height of 1 mm, where the vertical descending line from the outer canthus of the left eye and the ala-tragus line intersect on the left cheek, was taken as reference. For the third region, the circular region with a width of 5 mm above the nasal bridge and a height of 1 mm was taken as reference. For the fourth region, the circular region with a width and height of 1 mm at the midpoint of the left earlobe was taken as reference.

To determine skin color, the average CIEL*a*b* value of these four different regions in the portrait photograph of each volunteer was taken. The Adobe Photoshop (Adobe Inc., San Jose, CA, USA) program was used to determine the CIEL*a*b* value of four

different regions of the face. The average of the CIEL*, a* and b* values of four different reference regions was automatically measured from a total of approximately 10,000 separate points in the selected regions. By using this method, it was aimed to prevent changes in the skin such as skin spots, mild skin inflammations and sunburn, which may cause deviations in the measurement results.

In all photographs, the absence of clipping was checked on the histogram showing the exposure levels. It was also checked with histogram whether the reference regions for the analysis of skin color remained in the overexposure or underexposure areas. After making sure that the four reference regions were in the areas where the exposure value of the light was normal, the measurements were carried out.

2.5.2. Eye Color Analysis from Eye Photographs

After taking the eye photographs of the volunteers participating in the study, all the images were transferred to the computer. In order to ensure that the light and color values of all photographs are the same, it was checked that the selected ceramic block gave the same CIEL*a*b* values for each eye photograph. In order to standardize the eye color analysis of each volunteer participating in the study, the reference region to be measured in the eye photographs was determined with the Adobe Photoshop program.

The eye was divided into two equal hemispheres with a horizontal axis passing through the center of the pupil. By removing the pupil in the lower hemisphere, the iris in this hemisphere was taken as a reference for eye color analysis. Thus, the shadow areas formed by the eyelash in the upper hemisphere and the light reflections created by the ceramic block used for standardization were eliminated (Fig. 4).

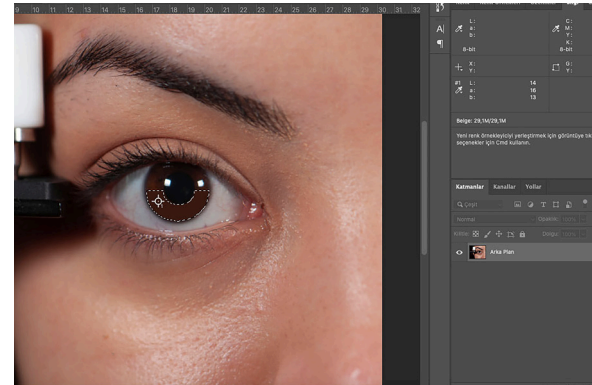


Figure 4. Determination of the reference region to measure eye color from eye photographs with Adobe Photoshop program.

The feature used to determine the average color value of a region in the Adobe Photoshop program was used for the selected reference region in all eye photographs. Thus, different pigmented areas in the iris were prevented from affecting the measurement alone. The CIEL*a*b* value of the region from which the average color value was taken was measured

using the Adobe Photoshop program and recorded on the pre-prepared forms.

2.5.3. Lip Color Analysis from Lip Photographs

All the lip photographs taken were transferred to the computer and it was checked that the ceramic block used to provide light and color standardization in all photographs gave the same CIE L*a*b* value for each photograph.

In order to analyze lip color from all lip photographs, a circular region with a width and height of 1 mm 2 mm below the philtrum was chosen as a reference (Fig. 5). CIE L*a*b* values of the selected reference region were measured with the Adobe Photoshop program and recorded on previously prepared forms.

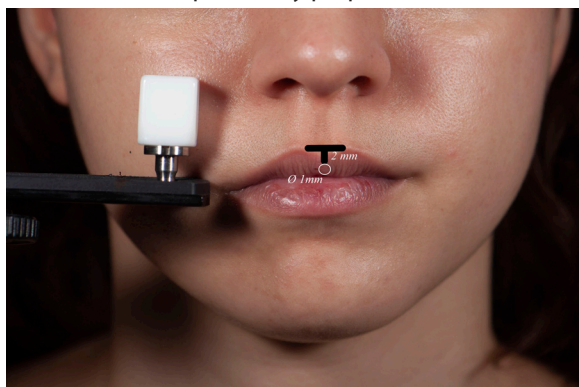


Figure 5. Reference region for lip color measurement from lip photographs.

2.6. Statistical Analysis

The average of 3 measurements made from the middle third of the labial surfaces of 11 and 21 was recorded in the excel table. The average CIE L*a*b* value of 4 regions measured on the skin from portrait photographs was recorded as skin color, eye color obtained from eye photographs, and lip color obtained from lip photographs saved in same excel table. IBM SPSS Statistics for Windows, Version 25.0 package program 2017 (IBM Corp., Armonk, NY, USA) and Microsoft Office Excel 2019 (Microsoft

Office Excel 2019®, Redmond, WA, USA) were used for all statistical analysis. The conformity of numerical variables to normal distribution was examined using the Kolmogorov-Smirnov Test. The linear relationship between the color values measured on the teeth and 18 independent variables from 6 different regions on the face was examined by the Spearman rank correlation analysis. Since the normal distribution harmony could not be obtained in the color variables obtained in the study, the Friedman Test was first applied for the multi-group difference in comparing the L, a and b levels between different regions. Dunn's test with Bonferroni correction was used for pairwise comparisons, since the difference between regions was found to be significant as a result of this test. All hypothesis checks were performed at the 0.05 significance level.

3. RESULTS

According to the Spearman Rank Correlation made between tooth measurements and face measurements shown in Table 1; A positive, very weak and statistically significant correlation was found between the b measurement of tooth number 11 and the measurement of Y3.a with a correlation coefficient of 0.213, between the measurement of tooth no. 21 and the measurement of Y3.b, with a correlation coefficient of 0.187 ($p < 0.05$). A positive, very weak and statistically significant correlation was found between the a measurement of tooth number 11 and the measurement of Y3.b with a correlation coefficient of 0.179, and the measurement of a tooth of tooth 21 and the measurement of Y3.b with a correlation coefficient of 0.187 ($p < 0.05$). A positive, very weak and statistically significant correlation was observed between the L measurement of tooth 11 and the measurement of Y4.L, 0.203, with a correlation coefficient of 0.238 between the L measurement of tooth 21 and the measurement of Y4.L ($p < 0.05$).

Table 1. The relationship between the measurements taken from the face and the measurements taken from the teeth.

		11. Teeth			21. Teeth3		
		L	a	b	L	a	b
Y1.L	Rho	0.036	-0.092	-0.195	0.185	-0.003	-0.099
	p	0.662	0.265	0.017*	0.023*	0.967	0.227
Y1.a	Rho	0.015	0.126	0.085	-0.044	0.084	0.038
	p	0.853	0.124	0.303	0.593	0.304	0.641
Y1.b	Rho	-0.142	0.098	0.084	-0.131	0.082	0.048
	p	0.083	0.231	0.310	0.109	0.321	0.564
Y2.L	Rho	0.143	-0.150	-0.198	0.244	-0.091	-0.128
	p	0.081	0.068	0.015*	0.003*	0.267	0.118
Y2.a	Rho	-0.020	0.167	0.140	-0.095	0.114	0.070
	p	0.812	0.041*	0.087	0.250	0.165	0.397
Y2.b	Rho	-0.171	0.184	0.170	-0.128	0.110	0.079
	p	0.036*	0.024*	0.037*	0.119	0.180	0.335

Y3.L	Rho	0.134	-0.200	-0.278	0.272	-0.129	-0.234
	p	0.103	0.014*	0.001*	0.001*	0.115	0.004*
Y3.a	Rho	-0.095	0.185	0.213	-0.163	0.136	0.180
	p	0.247	0.023*	0.009*	0.046*	0.097	0.028*
Y3.b	Rho	-0.195	0.179	0.175	-0.190	0.187	0.124
	p	0.017*	0.028*	0.033*	0.020*	0.022*	0.131
Y4.L	Rho	0.203	-0.057	-0.086	0.238	-0.072	-0.009
	p	0.013*	0.491	0.297	0.003*	0.383	0.915
Y4.a	Rho	0.202	-0.010	0.022	0.075	-0.050	-0.021
	p	0.013*	0.908	0.791	0.361	0.547	0.803
Y4.b	Rho	0.007	-0.005	-0.069	0.023	0.039	-0.060
	p	0.930	0.953	0.405	0.776	0.634	0.463
Yt.L	Rho	0.135	-0.140	-0.226	0.272	-0.064	-0.134
	p	0.101	0.087	0.005*	0.001*	0.438	0.103
Yt.a	Rho	0.037	0.178	0.177	-0.073	0.119	0.105
	p	0.653	0.030*	0.030*	0.374	0.146	0.200
Yt.b	Rho	-0.166	0.129	0.091	-0.144	0.118	0.051
	p	0.043*	0.115	0.266	0.078	0.150	0.535

*p<0.05

According to the Spearman Rank Correlation made between tooth measurements and eye measurements shown in Table 2, it was found that there were correlations between the L*a*b* measurements of

tooth number 11 and the L*a*b* measurements of the eye; no statistically significant relationship could be obtained between the measurements of tooth number 21 and any eye measurement.

Table 2. The relationship between the measurements taken from the eye and the measurements taken from the teeth.

		11. Teeth			21. Teeth3		
		L	a	b	L	a	b
G.L	Rho	0.191	-0.183	-0.195	0.1445	-0.082	-0.089
	p	0.020*	0.025*	0.017*	0.079	0.318	0.281
G.a	Rho	0.110	-0.12	-0.163*	0.079	-0.074	-0.059
	p	0.181	0.139	0.046	0.334	0.368	0.474
G.b	Rho	0.163	-0.164	-0.174	0.100	-0.093	-0.063
	p	0.046*	0.045*	0.033*	0.225	0.258	0.447

*p<0.05

According to the Spearman Rank Correlation used to examine the relationships between lip measurements and tooth measurements shown in Table 3, a negative, very weak and statistically

significant correlation was found between the b measurement of tooth number 11 and the D.L measurement with a correlation coefficient of -0.173 (p<0.05).

Table 3. The relationship between the measurements taken from the lip and the measurements taken from the teeth.

		11. Teeth			21. Teeth3		
		L	a	b	L	a	b
D.L	Rho	0.064	-0.065	-0.173	0.181	0.071	-0.088
	p	0.434	0.432	0.035*	0.026*	0.390	0.282
D.a	Rho	0.176	0.063	-0.178	0.190	-0.045	-0.129
	p	0.031*	0.442	0.029*	0.020*	0.583	0.116
D.b	Rho	-0.089	0.103	-0.037	-0.084	0.159	0.003
	p	0.279	0.209	0.655	0.306	0.052	0.971

*p<0.05

A positive, very weak and statistically significant correlation was found with a correlation coefficient of 0.176 between the L measurement of tooth number 11 and the D.a measurement ($p < 0.05$). A negative, very weak and statistically significant correlation was observed with a correlation coefficient of -0.178 between the b measurement of tooth number 11 and the D.a measurement ($p < 0.05$). A positive, very weak and statistically significant relationship was found with a correlation coefficient of 0.181 between the L measurement of tooth number 21 and the D.L measurement ($p < 0.05$). A positive, very weak and statistically significant correlation was obtained with a correlation coefficient of 0.190 between the L measurement of tooth number 21 and the D.a measurement ($p < 0.05$).

4. DISCUSSION

The hypothesis of this study was the presence of a correlation between tooth color and the soft color of the face. According to the results obtained from our study, it was observed that there was a correlation between skin and lip color and tooth color, but there was no significant correlation between tooth and eye color. Therefore, the hypothesis that there would be a correlation between tooth color and soft tissue color of the face was partially accepted. The differences between the results of our study and similar subjects reported in the literature may be due to the fact that the color matching procedures were mostly performed with the help of visual methods in previous studies. Unlike other studies, a ceramic block was used in our study to ensure that all photographs were in standard color and light values. The fact that the color values of the ceramic block are the same for each photograph has been very supportive that we use a more standard and objective method.

Since it is often accepted that the concept of aesthetics determines the character of a person in modern societies, it has become a very important issue [5]. Through aesthetic dentistry, the physician can make the patient's smile more beautiful while giving a younger appearance [29]. Accepting the smile as aesthetically compatible requires a perfect integration of the hard and soft tissues of the face and the teeth and gums. A smile aesthetics should always include evaluation and analysis of both facial and tooth formations [7,30].

Today, while tooth color can be better defined with developing technologies, it is difficult to define skin tone due to the lack of a well-categorized reference scale or guideline [31]. Most studies in the literature have categorized skin color visually [31–33]. In some studies in the literature, skin color was classified according to different cosmetic indices used to compare with samples such as NIVEA, LAKME or L'Oreal [34–36].

In most studies in the literature, eye color was determined by visual methods as well as skin color. In the study of Krasniqi et al. [37] in 2018 to determine a possible relationship between tooth color and skin color and eye color, and in the study of Hassel et al. [38] in 2008 evaluating the probability of predicting tooth color in the elderly according to hair, eye, face color and gender, eye color was determined visually, categorized as brown, green, blue and dark brown. In the study of Lagouvardos et al. [18] investigating the relationship between teeth, skin, hair and color in the Greek population, eye color measurement was made by matching the iris with the colors in the iris color scale suggested by Franssen et al. [39]. It is very difficult to standardize any visually determined classification. Since these subjective methods can vary from person to person, they cannot produce reproducible and reliable results.

The focus of our study is to investigate the existence of a possible relationship between $L^*a^*b^*$ values obtained from teeth by spectrophotometer and $L^*a^*b^*$ values obtained from face, eye and lip photographs using the Adobe Photoshop program. Previous studies in the literature on this subject do not have sufficient scientific information or reports that are in harmony. As a result of the findings obtained in our study, it was observed that the L^* value was quite close for teeth 11 and 21. L^* values taken from the malar areas of the face are close to each other, but it was found that the L^* values taken from the earlobe had lower L^* values, unlike the other measurement regions on the face, and the L^* values taken from the forehead region were higher than the other measurement regions on the face. It is an expected result that the L^* value is lower than the other measurement regions, since the earlobe is located in the background of the other parts of the face, and the L^* values are higher, since the forehead region is located ahead. At the same time, a positive, very weak but significant relationship was obtained with the L^* value of the teeth, the L^* values obtained only from the earlobe region, and the b^* values obtained from the forehead region of the face, so a negatively, very weak but significant relationship was observed. It was observed that there was a positive, very weak but statistically significant relationship between the a^* values of the teeth and the b^* values of the forehead region of the face, and the b^* values of the teeth and the a^* values of the forehead region of the face. The results obtained from our study are compatible with recent studies on this subject [25,38,40–45].

In the study of Jahangiri et al. [35], it was stated that there was an inversely proportional correlation between teeth and skin color. The methodology in this study was completely different from our study, and both tooth and skin color were measured by visual methods. In the study of Esan et al. [41], both tooth and skin color were measured by visual

methods, but no significant difference was found between tooth color and skin color. In 2018, Lila et al.'s study [44], which measures tooth color with a spectrophotometer but categorizes skin color according to visual perception, did not find a relationship between tooth color and skin color. The limitations in visual color selection may have affected the results of studies that matched colors using visual methods. In our study, digital methods were preferred when measuring both tooth and skin color and the effects of subjective factors were minimized. In the study of Haralur et al. [46] examining the relationship between teeth and skin color between different ethnic groups, skin color was measured with the help of digital cameras, similar to our study. In this study, which takes a few points as a reference when determining skin color, changes in the skin such as skin spots, mild skin inflammations and sunburn may have caused deviations in the measurement results. In our study, the mean CIEL*a*b* values of regions with a width and height of 1 mm in anatomical landmarks to be used as a reference for color measurement were measured. Thus, by measuring the average of approximately 10,000 points in these regions, it is aimed to reduce the effect of changes in the skin that will cause deviations in the measurement results. In the literature, there is no scale that categorizes skin tone as a standard. While the spectrophotometer device used in our study can convert the spectral reflectance measured on the tooth into CIEL*a*b* values, the color values measured with the help of imaging analysis used to measure skin color can also be expressed in terms of CIEL*a*b*. The existence of a standard color space in which colors are expressed by both methods provides more consistent and reliable results between the regions compared. According to the results obtained in our study, it was observed that there was a harmony between tooth and skin color parameters. Although this fit is considered statistically significant, it is thought to be useful for a rough color estimation since it ranges from very weak to weak.

While the relationship between tooth color and skin color has been the subject of research in most of the studies in the literature, the number of studies investigating the relationship between tooth color and eye color is very little. In existing studies investigating the possible relationship between tooth color and eye color, eye color was measured by visual methods. In our study, a reference region was created from all eye photographs to create a standard in the measurement of eye color with the help of the Adobe Photoshop program. Based on the findings in our study, it was observed that the L* values measured from the eye had the lowest median among the L* values measured from the other soft tissues of the face, and the a* values of the eye had potential endpoints. The distribution

of the b* values of the eye was quite wide. The fact that the L*a*b* values of the eyes are generally concentrated in an average range can be explained by the fact that most of the individuals participating in the study have darker eye colors. In the studies of Lagouvardos et al. and Hassel et al., it was stated that there is no linear relationship between tooth color and eye color, which is consistent with our study [38,43]. In the studies of Lila et al. and Krashniqi et al., it was concluded that there is a correlation between the upper central teeth and eye color, but there is no correlation between the color of the lateral and canine teeth and eye color [37,44]. There is no consistency between the results of the studies, since there is no accepted standard method to determine eye color and the determination of eye color in studies is based on subjective perception. In the statistical results obtained in our study, it was found that there were correlations between L*a*b* measurements of tooth number 11 and L*a*b* measurements of the eye but no statistically significant correlation was found between the measurements of tooth number 21 and any eye measurement ($p>0.05$). Although we did not reach the conclusion that there is a clear linear relationship between tooth color and eye color in our study, it is thought that some associations found may give an idea to dentists.

There is no study in the literature investigating the relationship between tooth color and lip color. According to the findings obtained in our study, the measurement of a* values in the lip has the highest and the measurement of b* values has the lowest median value compared to other variables. The fact that the lip color is more reddish than the color of the other soft tissues of the face explains the higher a* values and lower b values. When the analysis between the color measurements taken from the lip photographs and the color measurements taken from the teeth is examined, it is seen that there is a statistically significant positive correlation between the L* values of the upper central teeth and the a* values of the lip. According to this result, it is understood that the teeth of individuals with more reddish lips are brighter. According to the results obtained from our study, there is a partial relationship between the L* values and b* values of the lip and the upper central teeth.

The lack of literature to compare the results of our study, the limited skin color range of the individuals participating in the study, the low number of individuals with light-colored eyes, the measurement of tooth color only in the upper central teeth, are the points of the study that should be supported by other studies in this sense. More clinical and evidence-based studies can be done to detect the presence of a more precise, reliable relationship. In further studies, with the correlations between tooth color and soft tissue color of the face, the

color of the teeth can be easily determined with the double-stage calibration photographic technique used in our study, using macro software that can be developed.

5. CONCLUSION

The results in the present study are summarized as follows.

1. Within the limitations of the current study, significant correlations were found between tooth and skin color for CIEL*a*b* values. When the components of skin and tooth color are evaluated separately, it was observed that there was a higher correlation between L* values of teeth and L* and b* values of skin compared to other relations. The results showed that CIEL*a*b* parameters of skin color can be used in the selection of tooth color in case of loss of natural teeth or discoloration of existing teeth.

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2. According to the statistical results obtained in our study, a definite correlation could not be established between tooth and eye color. It is thought that some associations between these two parameters can give an idea to dentists.

3. When the analysis between the color measurements taken from the lip photographs and the color measurements taken from the teeth was examined, it was seen that there was a statistically significant positive correlation between the L* values of the upper central teeth and the a* values of the lip.

CONFLICT OF INTEREST

The authors have no financial interest in any of the companies whose products are used in this study.

AUTHOR CONTRIBUTIONS

DO: conceptualization, methodology, software, writing - review& editing. **MEÇ**: investigation, visualization. **MS**: supervision, software.

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Questions

1. Which of the following was used to determine tooth color in the study?

- a. Classic color guides;
- b. Spectrophotometer;
- c. Colorimeter;
- d. Digital camera.

2. Which of the following programs was used to determine skin, eye and lip color in the study?

- a. Canva;
- b. Adobe Photoshop;
- c. PhotoScape;
- d. GIMP.

3. Which of the following is a conclusion that can be drawn from this study?

- a. The standardization of the color matching process with the help of digital cameras provides very objective data in the analysis of the results;
- b. It has been shown that CIEL*a*b* parameters of skin color can be used in the selection of tooth color in case of loss of natural teeth or discoloration of existing teeth;
- c. Within the limitations of the present study, no significant correlations were found between tooth and skin color for CIEL*a*b* values;
- d. Spectrophotometer is not a successful device to measure tooth color.

4. What is the purpose of the study named "Evaluation of the relationship of teeth color and soft tissue color of the face"?

- a. Choosing artificial tooth color in fully and partially edentulous patients by evaluating the relationship between the color of the soft tissues of the face and the color of the teeth;
- b. Understanding of artificial tooth alignment in edentulous and partially edentulous cases;
- c. Comparison of the different eye, lip and skin color in the society;
- d. Examination of the relationship between lip, skin and eye color.



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