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ORIGINAL ARTICLE

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The color of human gingiva and mucosa: visual measurement and description of distribution

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Abstract No soft tissue shade guide is available for matching the color of denture resins to human intraoral soft tissues. To determine the color of both the gingiva and the alveolar mucosa, intraoral soft tissue colors of 150 men and women were assessed under standardized lighting conditions. Colors of the papilla, attached gingiva, and alveolar mucosa in the central incisor region of the maxilla and mandible were examined using Munsell color tabs and their corresponding notations (value, hue, chroma). Statistical evaluation was performed by using frequency tables and multiple regression (level of significance p=0.05). Color ratings for the maxillary interincisal papilla lay in the yellow hue spectrum. A high incidence of ratings was found between 7/6 2.5R and 7/4 5R (Munsell color notations). Two further peaks were identified for the colors 3/6 2.5 R and 8/4 10R. Five peaks with the highest frequency of ratings were present with regard to the color of the mucosa in the maxillary incisal region: 6/6 2.5R, 7/6 2.5R, 6/8 5R, 5/8 7.5RP, and 5/6 10RP. In the mandible, a similar pattern was found. Using the results from visual matching tests, five color frequency peaks were identified. They could be used to construct an intraoral soft tissue shade guide.

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Introduction

Patient ratings of masticatory efficiency, phonetics, and oral comfort are important determinants of patient satisfaction with dental prostheses [3], while clinician ratings of technical aspects of prostheses usually correlate poorly with patient satisfaction. Aesthetic appearance is essential for the acceptance of fixed and removable dentures; however, the individual evaluation of aesthetics is very subjective [38]. Nonetheless, patient expectations of dental aesthetics have been increasing continuously, particularly as they relate to the selection of tooth color [15].

Over the past years, a disparity between gingival colored and tooth colored aesthetics has been emerging. There is no doubt that a high degree of sophistication has been achieved in the realm of tooth-colored aesthetics. Three factors can be held responsible for this development: (1) the influence of highly skilled dental technicians, (2) the continuous refinement of manufacturing techniques, and (3) the improvement of dental materials [5, 17, 20].

In contrast, the individual characterization of the "gingival" portion of denture bases is lagging behind. This is primarily due to the small range of materials available for this purpose. The techniques employed for the manufacture of individualized "soft tissue" areas are not standardized because materials (tinted ceramics or resin materials) often need to be prepared specifically for a single use. This is a resource-intensive procedure which makes the manufacture of such restorations expensive. If a portion of a removable or fixed partial denture must match adjoining natural intraoral soft tissue, the transition between prosthetic replacement and soft tissue is typically apparent due to an inability of the material to mimic the natural color and texture of gingiva and mucosa.

Methyl methacrylate is currently the most frequently used acrylic resin for the fabrication of partial and complete removable denture bases [17]. Individual tinting of denture

base resins has been described using stain kits and other nonstandardized methods [21]. Hence, the development of a shade guide appears to be an essential tool for an improved and more predictable management of gingival color matching in removable prosthodontics. However, to date, a standardized shade guide does not exist. Colors in such a shade guide should be based on a representative selection of intraoral human soft tissue colors [2, 7, 12, 22].

The CIELAB color order system is commonly used in dental research. In this system, the location of a particular shade in the color space is defined by three coordinates: L^*, a^*, and b^*. Similarly, in the Munsell color system, a specific color is indicated by using three coordinates. The quantity L^* in the CIELAB color system serves as the correlate of lightness similar to the Munsell value. The a^* and b^* coordinates describe the chromatic components of perceived color but do not serve as direct correlates to the color attributes of Munsell hue and chroma. However, both the a^* and b^* numerals can serve to determine numeric correlates for those attributes. The fact that the Munsell system is arranged as a type of polar coordinate system and the CIELAB system as a Cartesian coordinate system allows for the translations to be made [39, 40]. The measure of the color difference between two objects is described by ΔE. Yet, the magnitude of ΔE gives no information of the character of the color difference between specimens because it does not indicate the quantity and direction of the individual CIELAB components.

The characterization of healthy gingival color ranges from pale pink [12] and pink [2] to dark red [7] or purple [22]. Munsell color notations from 10 R to 2.5 YR have been reported, with about 80% of the notations between 5R to 7.5R [23, 24, 26, 34]. A number of influences on gingival and mucosal pigmentation have previously been postulated: gender and age, location (left, right, mandibular, or maxillary) [24, 26, 34], skin type [14], melanin content [16] modulated by hormonal influences [6, 35], blood pressure [31, 42], and gingival inflammation [19, 27, 41]. External sources of gingival discoloration may be the type and location of prosthetic restoration [19, 41] as well as smoking [26, 31].

Visual color matching is an established clinical procedure. Compared to photometrical measurements, it has a number of advantages (lower costs, greater practicability), although recent studies suggest that spectrophotometric tooth shade analysis is more accurate and reproducible as compared to human visual shade assessment [33]. In fact, a large portion of the substantial variation in visual gingival color measurement [4, 8] has been attributed to the "human factor," i.e., intergender features, age, and color vision problems such as red–green weakness [9, 10, 28, 30, 36]. There are a number of external influences that may affect the perception of color by the human eye, such as light condition, metamerism, and distracting factors (make-up) [29, 43]. However, there are important limitations to instrumental assessment of gingival color. No colorimetric or spectrophotometric device has been validated for measuring intraoral gingival color, and the difficulties associated with measuring translucent samples have not been dissolved.

Previous studies on color assessment of human gingiva and mucosa were not sufficient for the development of a shade guide. No representative selection of soft tissue colors has been published (for a systematic review, see Schnitzer et al. [37]). Thus, further investigations of color assessment of human gingival and mucosal tissues are needed. Knowledge about the distribution of different gingival and mucosal shades is almost equally important since both are crucial for the individual configuration of denture base color.

The aims of the present study were, therefore:

To assess the color of human attached and papillary gingiva and oral mucosa in Caucasians by visual color matching using the Munsell color system [1, 34, 40]
To describe factors that influence soft tissue colors
To evaluate the interindividual rater variance of the measurement
To provide a preliminary selection of soft tissue colors for a potential shade guide

Materials and methods

Study sample

A total of 150 participants (48% males, 52% females) were enrolled in this study. Subjects were recruited as a convenience sample from staff and students of the School of Dentistry, University Hospital, Freiburg, Germany. A self-administered questionnaire was used to collect information on age, gender, skin color (four grades [18]), fluoride intake, oral hygiene habits, presence and type of prosthetic restorations, and eating habits (vegetarian food, coffee consumption, acid intake; see Table 1).

Measurements

All color measurements were carried out in a windowless and air-conditioned room. The room was illuminated by two daylight neon lights with a color temperature of 6,500 K, a color rendering index of 97, and a lightness of 1,000 to 1,600 lx (Biolux L58/72, Osram, Munich, Germany), which is very close to standard light "C" with a color temperature of 6,774 K. A single investigator (S.S.) rated the gingiva and mucosa of all 150 participants. The rater had been examined and calibrated for normal color vision in the Department of Ophthalmology of the University Hospital, Freiburg, Germany.

The Munsell color system (*Munsell Book of Color*, glossy finish, Gretag MacBeth, Munich, Germany) was used for the present investigation. In a pilot study, which had been carried out prior to this investigation under identical conditions, 28 color tabs had been selected from the more than 800 tabs of the complete Munsell system;

Table 1 Demographic data, eating habits, and oral hygiene of the 150 participants

	Gender			
	Male		Female	
	Mean	SD	Mean	SD
Age	45.7	13.1	44.4	15.7
	n	%	*n*	%
Total	78	52.0	72	48.0
Skin type[a]				
I			1	100.0
II	27	56.3	21	43.8
III	50	51.0	48	49.0
IV	1	33.3	2	66.7
Prosthetic restorations				
No	45	51.7	42	48.3
Yes	33	52.4	30	47.6
Smoking				
No	61	57.5	45	42.5
Yes	17	38.6	27	61.4
Frequency of tooth brushing				
1/day	1	20.0	4	80.0
2/day	43	46.7	49	53.3
3/day	24	66.7	12	33.3
Fluorides				
Missing	10	58.8	7	41.2
Often	2	15.4	11	84.6
Occasionally	23	67.6	11	32.4
Rarely or never	53	51.5	50	48.5
Vegetarian				
No	62	46.6	71	53.4
Yes	16	94.1	1	5.9
Coffee				
No	3	25.0	9	75.0
Yes	75	54.0	63	46.0
Acid intake				
Frequently	12	40.0	18	60.0
Occasionally	26	47.3	29	52.7
Rarely	34	60.7	22	39.3
Never	6	66.7	3	33.3

[a]For grading, see text

they were subsequently rank-ordered by their Munsell hue notation. Munsell color codes were converted into L^*, a^*, and b^* notations with the help of the Munsell conversion tool (Table 2). The L^*, a^*, and b^* system reflects human color vision by using the vertical axis L^* for describing lightness (or value), and the two horizontal axes a^* for red–green and b^* for yellow–blue [39, 40]. (For a detailed introduction into the Munsell color system and other color order systems see Sproull [39, 40]).

In the maxilla and mandible of the participants, one quadrant each was randomly selected because previous investigations had shown no evidence for left/right color differences [34]. In each quadrant, the color of the alveolar mucosa, the attached gingiva, and the mesial papilla was measured in the central incisor region.

Table 2 Rank order of the preselected Munsell color tabs and their corresponding L^*, a^*, and b^* values

Code	Munsell color	L^*	a^*	b^*
1	3/6 2.5 R	30.8	28.9	8.2
2	3/8 2.5 R	30.8	38.3	10.6
3	4/6 2.5 R	41.2	27.2	8.6
4	5/6 2.5 R	51.6	25.8	9.0
5	6/6 2.5 R	61.7	24.6	9.3
6	7/6 2.5 R	71.6	23.6	9.2
7	4/8 2.5 R	41.2	36.0	11.2
8	5/8 2.5 R	51.6	34.4	12.0
9	8/6 2.5R	81.4	23.7	9.5
10	5/6 5 R	51.6	25.3	13.0
11	5/8 5R	51.6	33.7	17.6
12	6/6 5 R	61.7	24.2	12.8
13	7/4 5 R	71.6	15.0	8.1
14	7/6 5 R	71.6	23.2	12.6
15	6/8 5R	61.7	31.8	16.9
16	5/6 7.5 R	51.6	24.4	16.9
17	6/6 7.5R	61.7	23.1	16.5
18	7/4 7.5 R	71.6	14.8	10.8
19	7/6 7.5R	71.6	22.4	16.7
20	8/6 7.5 R	81.4	22.7	17.5
21	6/6 10 R	61.7	21.4	21.6
22	7/6 10 R	71.6	21.1	21.7
23	7/4 10 R	71.6	13.8	14.0
24	8/4 10 R	81.4	13.9	14.3
25	8/6 10 R	81.4	21.1	22.4
26	5/8 7.5 RP	51.6	35.0	1.8
27	3/6 10 RP	30.8	29.3	3.9
28	5/6 10 RP	51.6	26.0	5.5

Interrater variance

In the second test, the interindividual difference between color ratings obtained by 11 dentists, 6 dental technicians, and 10 dental students (Table 3) in the Department of Prosthodontics, School of Dentistry, University Hospital, Freiburg, was assessed. All 27 judges rated the color of the interincisal gingiva, mucosa, and frenum between the two central incisors of a single participant.

Table 3 Demographic data of the 27 raters by qualification

	Gender (*n*)		Age (years)	
	Male	Female	Mean	SD
Total	16	11	29.4	5.1
Qualification				
Dentist	7	4	33.4	3.1
Dental student	5	5	24.6	3.2
Dental technician	4	2	29.8	3.7

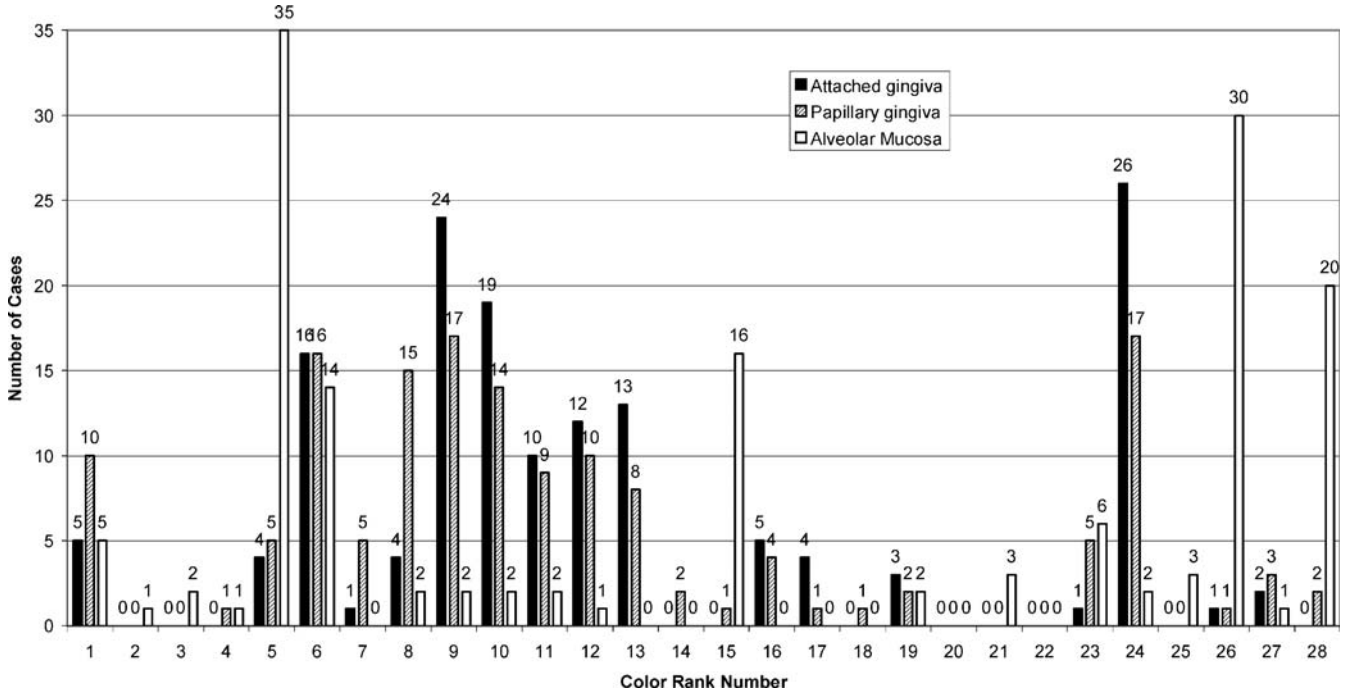

Fig. 1 Color frequencies in the maxillary incisor area by color rank order number (see Table 2)

Analyses

The Munsell colors were arranged in ascending order by (1) hue, (2) value, and (3) chroma (Table 2). The distribution of colors within the different soft tissue areas of the 150 subjects was described with frequency tables using the number ranks from C1 to C28. A stepwise multiple regression was chosen to model the influence of the different hypothesized influential variables (age, gender, skin color, fluoride intake, oral hygiene, presence and type prosthetic restorations, eating habits) on the L^*, a^*, and b^* color components for ratings of the maxillary

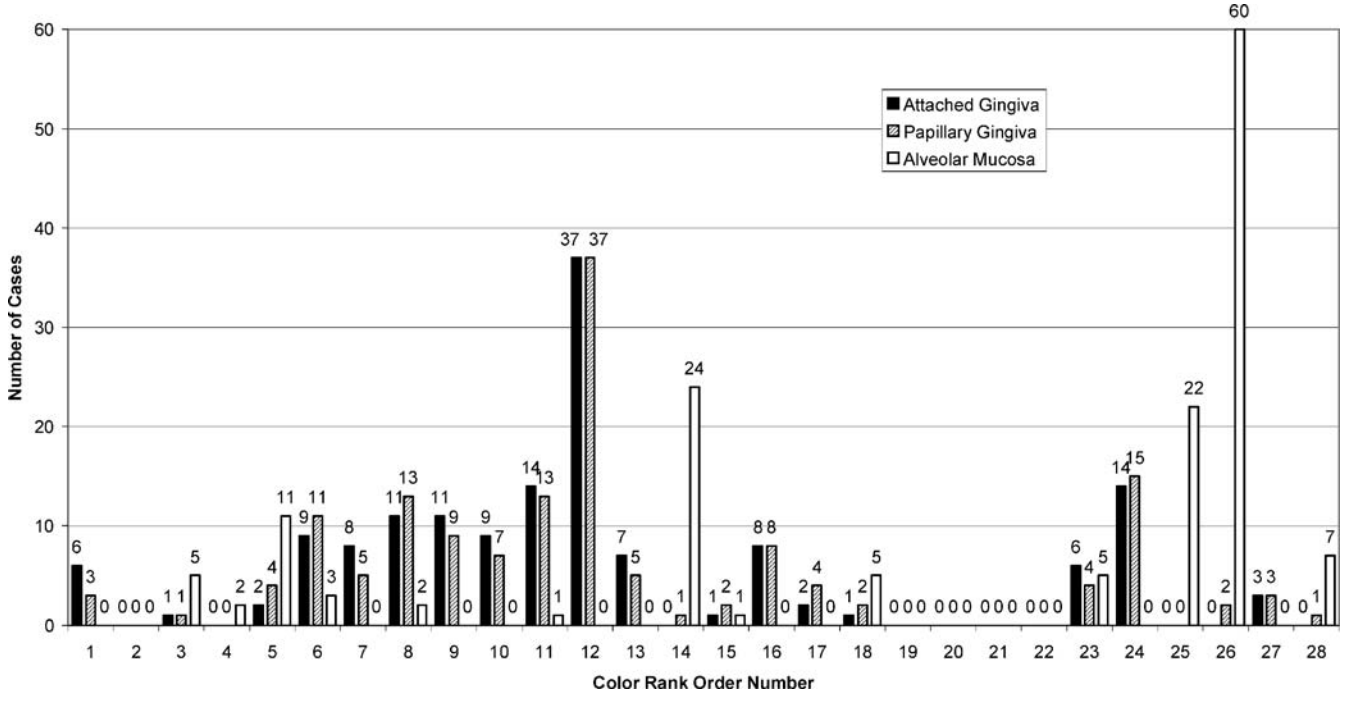

Fig. 2 Color frequencies in the mandibular incisor area by color rank order number (see Table 2)

Table 4 Characteristics of the final models after stepwise multiple regression of the L^*, a^*, and b^* color values of the maxillary incisor area

Area	L^*				a^*				b^*			
	R^2	Coefficients	B	p	R^2	Coefficients	B	p	R^2	Coefficients	B	p
Maxillary incisor												
Attached gingiva	0.061			0.01	NS				0.031			0.031
		Constant	64.854	0.000						Constant	18.987	0.000
		Oral hygiene	2.708	0.025						Skin type	−1.245	0.031
		Smoking	−2.943	0.030								
Papillary gingiva	0.047			0.008	NS				0.085			0.002
		Constant	64.253	0.000						Constant	11.404	0.000
		Male	4.141	0.008						Male	1.638	0.013
										Oral hygiene	1.296	0.043
Mucosa	0.041			0.007	NS				0.006			0.006
		Constant	43.225	0.000						Constant	9.425	0.000
		Oral hygiene	3.886	0.007						Oral hygiene	1.204	0.039
										Fluoride use	−0.942	0.042
Frenum	0.17			0.000	0.058			0.013	0.127			0.000
		Constant	68.106	0.000		Constant	25.947	0.000		Constant	11.510	0.000
		Age	−0.254	0.000		Smoking	1.598	0.025		Oral hygiene	1.670	0.021
		Male	7.792	0.000		Oral hygiene	−1.246	0.048		Age	−6.086E-02	0.015
										Male	1.642	0.026
Mandibular incisor												
Attached gingiva	0.13			0.000	0.05			0.007	0.17			0.000
		Constant	75.128	0.000		Constant	22.607	0.000		Constant	20.012	0.000
		Age	−0.213	0.000		Male	−1.315	0.007		Age	−8.626E-02	0.000
		Acid intake	2.022	0.010						Male	2.458	0.000
Papillary gingiva	0.09			0.001	0.03			0.034	0.25			0.000
		Constant	73.486	0.000		Constant	19.021	0.000		Constant	19.998	0.000
		Age	−0.203	0.000		Skin type	1.164	0.024		Male	3.367	0.000
		Acid intake	2.060	0.024						Age	−0.104	0.000
Mucosa	NS				NS				0.07			0.006
										Constant	9.425	0.000
										Oral hygiene	1.204	0.039
										Fluoride intake	−0.942	0.042
Frenum	0.25			0.000	0.01			0.004	0.23			0.000
		Constant	72.327	0.000		Constant	23.498	0.000		Constant	19.804	0.000
		Age	−0.484	0.000		Male	−1.839	0.010		Age	−0.159	0.000
		Male	8.529	0.001		Age	5.733E-02	0.025		Male	3.478	0.000

NS Not significant

incisor region. The distribution of the color ratings by the 27 examiners was analyzed with box plots. An alpha level of 0.05 was accepted for significance.

Results

Distribution of soft tissue colors

In Fig. 1, the area of the maxillary incisors is presented as an example of the data. Most of the color ratings lay between C6 and C13, with another peak for C24 for the attached gingiva of maxillary incisors. This corresponds with Munsell colors between 7/6 2.5R and 8/4 10R (C24). Color ratings for the maxillary interincisal papilla were located more towards the yellow hue spectrum. A higher incidence of ratings was again found between C6 and C13, which corresponds to Munsell color codes from 7/6 2.5R and 7/4 5R. Two further peaks at C1 (Munsell notation, 3/6 2.5 R) and C24 (8/4 10R) were also identified. Five peaks with the highest frequency of ratings were identified for the color of the mucosa in the maxillary incisal region: C5 (6/6

2.5R), C6 (7/6 2.5R), C15 (6/8 5R), C26 (5/8 7.5RP), and C28 (5/6 10RP). Thus, one third of the ratings were in the red–purple hue spectrum (Fig. 1).

In the mandible, a similar pattern was found. Most interincisal color ratings for the attached gingiva were recorded between C6 and C13, with another peak for C24 for attached gingiva of maxillary incisors. This corresponds with Munsell colors between 7/6 2.5R and 7/4 5R and 8/4 10R (C24). These values also apply to the papillary area. For the mandibular mucosa, no accumulation in any area was evident. Instead, four peaks with the highest frequency of ratings were present: C5 (6/6 2.5R), C14 (7/6 5R), C25 (8/6 10R), and C26 (5/8 7.5RP). Again, more than one third of the ratings lay within the red–purple hue spectrum (Fig. 2).

Influence of demographic variables and habits

These observed trends, however, appear to be largely independent of each other. Few of the hypothesized confounding variables were significant in the regression models of L^*, a^*, or b^* for the oral tissues of maxillary incisors. Overall, the variance explained by these models was very small, with R^2 values not higher than 0.25. The effects of the confounders were also small, except for male gender, which had a moderate effect on frenular color (Table 4).

Lightness (L^*) appears to be influenced by smoking (darker color) and oral hygiene (lighter). Frequency of tooth brushing also has a lightening effect on mucosal color. Males have lighter papillary gingiva. Males also had lighter mucosal color, while increasing age demonstrated the opposite trend.

None of the models for the a^* color axis of attached and papillary gingiva or mucosa were significant. Smoking resulted in higher a^* values (↑red, ↓green), while oral hygiene led to lower a^* values (↓red, ↑green) of frenular mucosa.

On the b^* axis, darker skin type was associated with lower b^* values (↓yellow, ↑blue). Frequency of tooth brushing predicted higher b^* values (↑yellow, ↓blue) for papillary gingiva, mucosa, and frenum. Male gender also had an effect of higher b^* values for papillary gingiva and frenular mucosa. Fluoride use had a very small effect on mucosal color as had age on the frenum; both led to lower b^* values (↓yellow, ↑blue; Table 4).

Associations of soft tissue colors in the mandible were similar. Acid intake was significantly associated with lightness (L^*) of attached and papillary gingiva. Male gender and skin type were significant predictors of a^* values of attached and papillary gingiva, respectively.

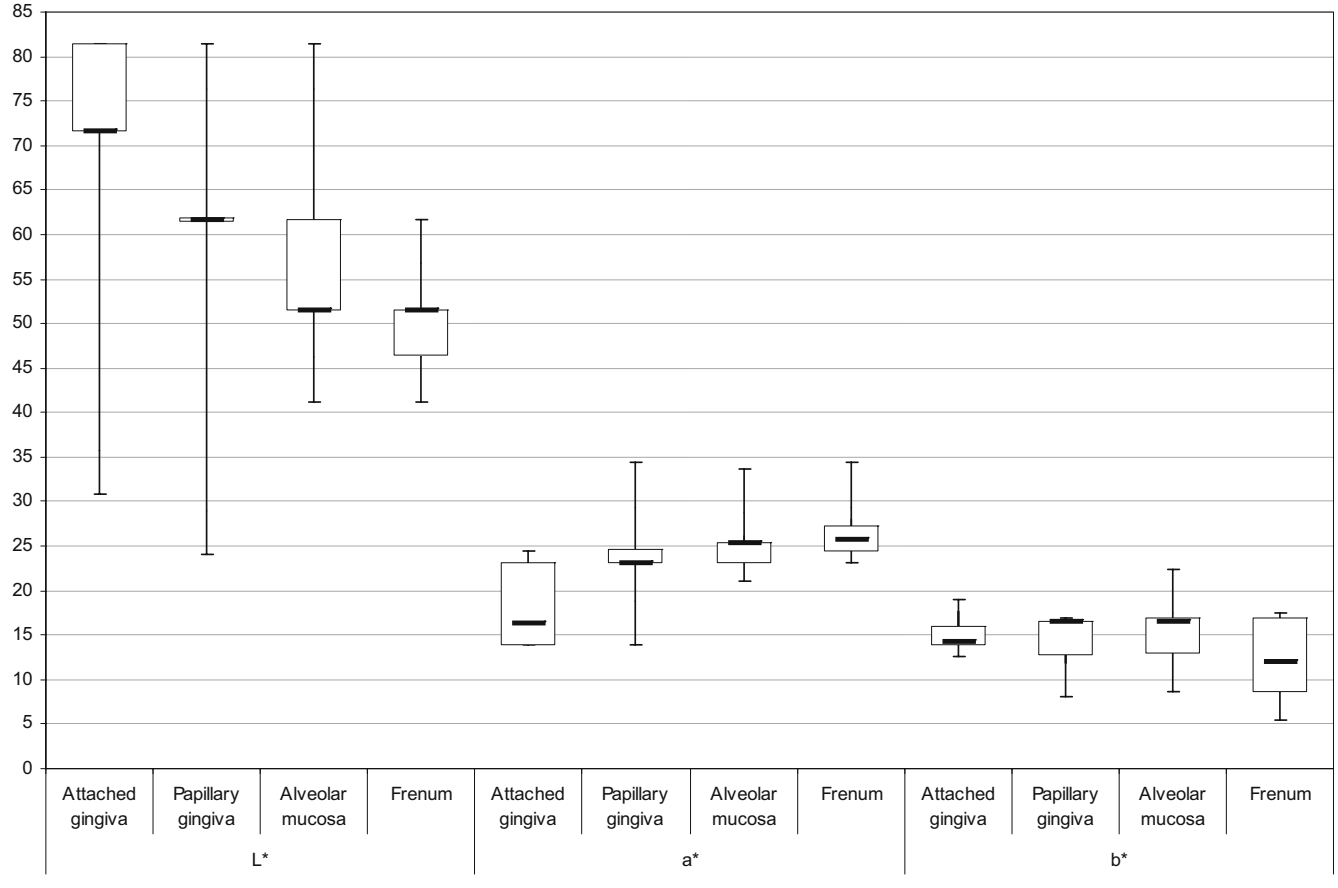

Fig. 3 Box plot of the variance of the color evaluation of a single patient (maxillary incisor area) by 27 raters. Note the larger variance on the L^* axis as compared to a^* and b^*

Table 5 Color differences (ΔE) between selected Munsell color tabs for gingival and mucosal color

Attached gingiva				
Color order number	6	9	11	13
9	9.8			
11	23.9	32.4		
13	8.6	13.1	29.0	
24	14.7	10.9	35.9	11.6
Mucosa				
Color order number	5	6	15	24
6	10.0			
15	10.5	15.0		
24	23.0	14.7	26.8	
28	10.9	20.5	16.4	33.3

Darker skin type was a predictor of higher a^* values (↑red, ↓green) for papillary gingiva. Male gender also predicted higher b^* values (↑yellow, ↓blue) for all soft tissue areas.

Interrater variance

The summarized results from the 27 examiners shown in Fig. 3 illustrate that, in general, lightness (L^*) decreases from the attached gingiva to the frenum with an intermediate value for mucosa. While b^* is almost constant, the a^* value increases for mucosa and the frenular area, indicating a more reddish color in these regions. The observed variance was large, especially for L^*. For the attached gingiva with a median value of 72 (rounded), the minimal and maximal values range from 31 to 81.4. For the papillary gingiva, the min/max variance is even larger, but the interquartile range is smaller.

Based on the maximum frequency of ratings, the colors with order numbers 6, 9, 11, 13, and 24 were selected for a proposed shade guide for the attached gingiva in the maxillary incisal region. For maxillary mucosal color, the colors with numbers 5, 6, 15, 24, and 28 were chosen. The color differences between these selected tabs were calculated using the formula

$$\Delta E = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2}.$$

The results are presented in Table 5. The color differences (ΔE) in all cases exceeded the smallest clinically detectable value [25] of ΔE=3.7.

Discussion

This paper reports on the results of a clinical study in which (1) the color of intraoral soft tissues was visually measured using the Munsell color system [1] and (2) the influence of explanatory variables such as skin color, gender, and age on gingival and mucosal color was assessed.

The Munsell system is the most popular and, due to its wide selection of colors, the best suited system for soft tissue color assessment. In dentistry, its use has been documented many times [39, 40]. Although Munsell color tabs are easy to use, their lack of translucency and especially the glossy surface color limit their usability. Furthermore, since the Munsell notations define a non-euclidic color room, values need to be converted to L^*, a^*, and b^* values to be able to calculate and report color differences.

As a rule, Munsell colors are often an approximation of the actual gingiva or mucosal color. At most, they represent the base color since gingiva and mucosa never have a uniform color. The appearance of oral soft tissues is modulated by their anatomical structure, such as stippling and capillary blood vessels [23, 24].

The distribution of the colors found in this study was very similar to that from previous reports [23, 24, 34]. Like these earlier investigations, there were only small influences of gender and age [23, 24, 26] on gingival and mucosal color. Male gingiva and mucosa were significantly lighter and less blue, but more yellow than female gingiva. There was also a weak association of gingival color with skin color, confirming existing reports [14]. Darker skin type was associated with more bluish and reddish attached/papillary gingiva. Skin pigmentation is directly related to the melanin content in the skin [35]. In a study by Becker [6], a melanotic pigmentation of alveolar mucosa was microscopically confirmed in 74% of the cases, although no pigmentation was clinically evident. In future studies, the investigation of melanin-stimulating hormone (MSH) and adrenocorticotropic hormone (ACTH) as well as beta-lipoprotein should be considered.

Regular tooth brushing had some influence on gingival and mucosal color, too. Patients who brushed more than twice per day had lighter gingiva that contained smaller amounts of red and blue—both factors could be associated with less capillary perfusion.

There was also a small influence of smoking: attached gingiva was darker in smokers than in nonsmokers [26]. It is known that, in smokers, the local influence of nicotine and tar increases vascular tone and blood pressure and results in reduced tissue circulation [31]. Yet, only small effects were evident in our investigation, paralleling the finding that, even in elderly subjects suffering from arteriosclerosis, there is no influence of the increased vascular tone on soft tissue color [42].

The presence of prosthetic restorations, such as fixed partial dentures, had no impact on gingival color. This observation contradicts the widely held assumption that fixed prosthodontic work with subgingival margins induces a color change through trauma of the free marginal gingiva (violation of the biological width [19]) or by causing infection (gingivitis, periodontitis). In cases where restoration margins impart a grayish shade on a thin marginal gingiva or the papilla, no change of color occurs in the attached gingiva [41]. Knowledge of these possible reasons

for gingival discoloration is important for diagnostic purposes [27]; however, no such discoloration was statistically significant in the present study. Nonetheless, one of the limiting factors within this study was that only one area was measured within each participant's mouth. To further investigate the influence of discolorations as a consequence of fixed restorations, future measurements should be compared to contralateral unrestored teeth.

The visual color measurement of gingival color in the three intraoral regions per arch resulted in a large variation of the results from the 27 examiners. Most likely, this variation is a consequence of interindividual differences in color vision due to age, gender, and color vision competence. These factors have also been described by other authors [28, 36]. Males suffer more often from red–green color vision defects than females (9.5 vs. 0.25%) [10], which may cause problems with shade matching [30]. In addition, color vision is affected by age [9]. These aspects need to be considered when colors are measured by different raters using a visual technique.

Less than adequate reliability of shade matching in dentistry has been described previously [4, 8]. Although a recent study reports more accurate and reproducible results for a spectrophotometrical method than for visual shade assessment, it has to be considered that the matched areas in that study were human teeth and not gingiva or mucosa [33]. Another article reported a promising interrater agreement of 92% [34] for visual color assessment; however, this could not be reproduced in our investigation. Because the variance was large, the calculation of percent agreement was not a viable option; thus, the variance was reported using box plots. This finding also emphasizes that results obtained by a single investigator need to be interpreted with great caution concerning their general applicability.

Wright [43] tested different methods (spectrophotometrical, fiber-optical, visual) for skin and intraoral tissue color measurement. He concluded that with regard to the high degree of variation of texture, light sources, and backgrounds, the visual technique gives the best results in the majority of cases. However, more recent studies on the color assessment of scar tissue show that instrumental techniques (r<0.7) are far superior to visual techniques (r=0.35) when it comes to reliability [11]. With regard to tooth color measurement, somewhat better reliability has been described (r=0.6) [32]. Thus, for future investigations, colorimetric assessment should be considered. As an alternative, images from a calibrated digital camera could be analyzed.

There is also a marked influence of the light source. In one study, a color measurement of intraoral soft tissues was performed. The use of two different types of light, standard light C and fluorescent light, led to different results in 54% of the cases [34]. One of the causes for this variation is metamerism: the change of the spectral composition of light results in a different color appearance of the same sample [29]. This effect is particularly strong when comparing artificial and natural light conditions. Thus, the use of standardized conditions for color measurements and shade matching is crucial. Optimal light conditions for shade matching have been described as daylight around noon without direct sunlight (northern light). Since these conditions are difficult to reproduce, standard light C was used for this investigation because its spectrum is very similar to northern daylight, with only a slight difference in color temperature. Intraoral color assessment is further complicated by the anatomical variation of the oral cavity. Therefore, it is very difficult to standardize measuring conditions such as lighting. However, due to its simplicity (no special equipment is required), visual color assessment remains the standard method in clinical practice.

In future studies of intraoral soft tissue color measurement and matching, the discussed factors should be considered and, whenever possible, standardized. In addition, the intensity of melanogenesis, the degree of epithelial cornification, the depth of epithelization, and the arrangement of gingival and mucosal vascularity should be taken into account [13]. For this purpose, spectrophotometrical measurement of melanin concentration could be performed. Results from this noninvasive technique are promising and correlate well with histologically obtained data [16]. In addition, higher precision and reliability in comparison to visual techniques are achieved [33].

While the aim of creating a representative shade selection was not accomplished with the data from this study, the proposed shades selected from the frequency tables could serve as guideline for the clinician.

Conclusions

The interrater variance of intraoral color measurement was high. Therefore, the following conclusions have to be considered within the limitations of this study:

Most of the color ratings for maxillary attached gingiva lay between Munsell colors 7/6 2.5R and 8/4 10R. Color ratings for the maxillary interincisal papillae were located more towards the yellow hue spectrum (7/6 2.5R and 7/4 5R).

The Munsell colors 7/6 2.5 R, 8/6 2.5, R5/8 5R, 7/4 5 R, and 8/4 10 R were selected as representative for maxillary attached gingiva.

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