

Study of attached gingiva space color according to gender and age in Caucasian population

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Abstract

Objective: To describe the color of the healthy attached gingiva adjacent to the maxillary incisors and to evaluate the effect of age and gender on CIELAB color coordinates.

Materials and Methods: The study included 216 Caucasian individuals (129 females and 87 males) divided into three age groups. A SpectroShade Micro spectrophotometer was used to register color coordinates at 2.5 mm apical of the zenith of the upper central incisors. Descriptive and inferential statistical analysis was performed.

Results: The minimum and maximum coordinates in which the CIELAB natural gingival space is delimited are: L* minimum 40.4 - L* maximum 61.2; a* minimum 17.0 - a* maximum 30.2; b* minimum 9.8 - and b* maximum 21.9. There are statistically significant differences between males and females for coordinates L*, a* and b* in the attached gingival area selected. Age had a significant effect on coordinate b* ($p = 0.000$).

Conclusions: Statistically significant differences were found between the L*, a* and b* color coordinates of the attached gingiva between men and women, although the color difference is below the clinical acceptance threshold. The attached gingiva takes on a bluish color as the patients get older, which means that the b* coordinate decreases.

Clinical Significance: With a prosthodontic approach, knowledge of the CIELAB natural attached gingival coordinates based on the patient's age and gender will facilitate the clinician's work in selecting the appropriate color. The CIELAB system values found can be used as a gingival shade guide reference.

KEYWORDS

CIELAB color space, gingival color shade matching, natural gingival color, spectrophotometry

1 | INTRODUCTION

Tooth color is the most relevant factor in the esthetic assessment of the smile,^{1,2} therefore it has been studied through subjective shade

guides, photography, colorimeters and spectrophotometers.³⁻⁶ Achieving a perfect color selection is a fundamental part of White Esthetics - dental esthetics, and Pink Esthetics - the esthetics of soft tissue, especially in the case of gingival recession and/or severe

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maxillary resorptions that require a dental and gingival prosthetic rehabilitation. Despite this, the number of studies focused on gingival color is considerably smaller.^{7,8}

Traditionally, the study of natural gingival color has been done through visual comparative methods using the Munsell color system.⁹ Nowadays, it is necessary to use “in vivo” objective methods, using color coordinates, to define the natural gingival space color.^{8,10,11} Gingival color is difficult to measure, due to its morphology and irregular elasticity.^{8,10} In addition, gingival color varies according to age,^{12,13} gender,⁸ ethnicity,^{14–16} thickness and degree of the keratinization of the epithelium,¹⁷ periodontal disease,¹⁸ and medication⁸ and even due to the dark color of metallic abutments and frameworks used in prosthetic procedures.¹⁹

Color coordinates that determine the natural gingival space color have not yet been defined.^{8,20–22} In 2004, Schnitzer et al. after a systematic review, concluded that it was impossible to compare and combine the results from the different studies in a reliable way, due to the variety of methods used in these studies.²² The subjective selection of healthy attached gingiva color adjacent to the maxillary incisors in prosthetic restoration is subject to limitations, namely: the small number of gingival shade guides,^{7,12,23–25} and a lack of information about the process manufacturers follow in the chromatic preparation of each shade tab.^{7,12,17} In vivo spectrophotometric analysis is an essential step in identifying and subsequently reproducing the natural gingival color in dental prosthetic restorations.

Quantification of space color is achieved using the CIELAB System. This system consists of three color coordinates, where L^* represents lightness and the color coordinates a^* and b^* are the chromatic axis: a^* is the green/red coordinates axis and b^* is the blue/yellow coordinates axis.²⁶

With this system, it is possible to calculate the difference between two colors in a quantitative way using the Euclidean formula: $\Delta E^*_{ab} = [(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2]^{1/2}$, as used in several other studies.^{27–29} Nevertheless, there are other formulas that measure color differences, such as CIEDE2000 (ΔE_{00}), recommended in 2001 by the International Commission on Illumination (CIE). Currently, this formula is considered the standard and it is also known to reflect the differences perceived by the human eye better than the Euclidean formula, even though recent studies concluded that both formulas are similar.^{29,30} This color difference allows us identify the thresholds of perceptibility (the value at which a color difference becomes perceptible to the human eye) and acceptability (at or beyond this value, a color difference is deemed to be clinically acceptable).³¹ Sailer et al. determined that the gingival color difference becomes perceptible at values of $\Delta E^*_{ab} = 3.1 \pm 1.5$ units: much lower than the published thresholds for dental color, but similar to the results found by Gómez-Polo et al.^{32–34}

It is necessary to broaden our chromatic knowledge concerning the Pink Esthetic if we are to offer the patient ideal esthetic results, especially in anterior teeth where there are gingival recessions,³⁵ vertical and horizontal bone defects, bone reabsorption, or misplaced dental implants.³⁶ The limited chromatic variability of the “coral pink” offered by manufacturers compromises the ability of ceramic

restorations in gingival prosthesis to mimic the natural gingival color. The purposes of the present study were: (1) to describe the attached gingival color in the anterior teeth, using CIELAB color coordinates through spectrophotometry; (2) to evaluate if there are any significant differences in the color coordinates of healthy attached gingiva according to gender in the Caucasian population; and (3) to identify any differences in healthy attached gingival color between age groups defined according to gender, using the ΔE^*_{ab} and ΔE_{00} color difference formulas.

The research hypotheses tested in the present study, concerning color coordinates for healthy attached gingiva adjacent to the maxillary incisors, were: (1) that there would be statistically significant differences in attached gingival color according to gender; and (2) that there would be statistically significant differences in attached gingival color between the different age groups.

2 | MATERIALS AND METHODS

2.1 | Study design

This analytical cross-sectional study was approved by Bioethics Committee of the University of Salamanca (Spain). All of the participants signed an informed consent form based on the Helsinki Declaration and were verbally informed about the objectives of the study.

2.2 | Selection of patients

The study included 129 women (59.72%) and 87 men (40.28%): total sample = 216. The participants were divided into three groups: a first group of patients aged from 20 to 35 years old (Group 1, $n = 72$); a second group aged from 36 to 60 years old (Group 2, $n = 72$); and a third group aged from 61 to 90 years old (Group 3, $n = 72$). As inclusion criteria, all participants were Caucasians from Spain, with no relevant systemic diseases, a dental plaque index equal to or less than 25%, a gingival index of less than 10%,³⁶ no visible melanin pigmentation in the study area, a vestibular keratinized gingiva band greater than 2 mm, and no gingival recessions.⁸ Exclusion criteria were: pregnant women,³⁷ smokers,³⁸ visible signs of gingival inflammation, and patients who were taking any kind of medicine with side effects related to the soft tissue.

2.3 | Data collection procedure

Gingival color measurements were performed using an MHT Spectro-Shade™ Micro spectrophotometer. A single examiner (a 28-year-old woman with 5 years of experience), with prior theoretical and practical training in use of the spectrophotometer, performed all the measurements. All images were captured in a dental cabinet with ambient lighting calibrated with a Philips Master TLD 90 Delux 58W/965 ISL fluorescent light.^{8,39} Prior to patient measurement, the spectrophotometer

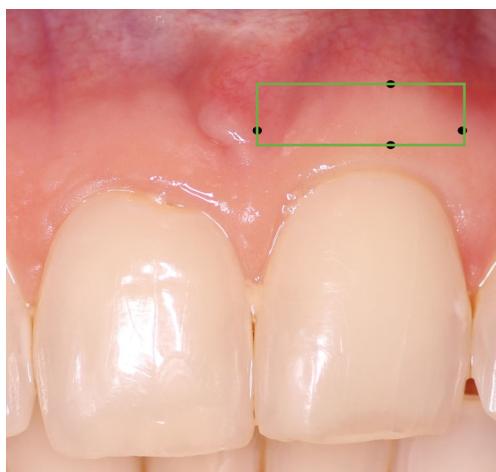


FIGURE 1 Color measurement area.

MHT SpectroShade™ Micro was calibrated following the manufacturer's instructions. The patients were seated with their head kept stable. Air was applied with the air and water equipment syringe at 15 cm distance for 3 s, thereby avoiding soft tissue dehydration in the study area and leaving the tissue relatively moist.¹⁰ The nozzle of the spectrophotometer was placed in the patient's mouth, pointing to the reference tooth, with the upper lip retracted and no pressure over the gingival area.²⁴ The image was captured once the instrument was centered in the yellow frame and the icon displayed on the device screen.

With a periodontal probe, a point was established at 2.5 mm apical of the zenith of the central incisor,¹⁰ and at the mucogingival line, forming a rectangle with the mesial and distal edges of the tooth (Figure 1). SpectroShade MHT software (MHT Optic Research AG, Niederhasli, Switzerland) was used to convert the spectral results obtained by the instrument into the L^* , a^* and b^* values for each measurement. The program offers the mean L^* , a^* and b^* color coordinates in the selected rectangular area of the attached gingiva. Gingival color coordinates were recorded in the attached gingiva surrounding one of the two central left (tooth # 2.1) or right (tooth # 1.1) maxillary incisors.

Three repeated measurements were performed on this same location to ensure spectrophotometer reliability, and the calculations were made with the arithmetic mean. Reliability was calculated through the intraclass correlation coefficient ($ICC = 0.9$).

2.4 | Statistical analysis

The color coordinates recorded were analyzed using statistics software (SPSS, SPSS Inc., version 22). The limits (minimum and maximum) of the color coordinates were calculated using descriptive analysis. Normal distribution of the data was checked through the Kolmogorov–Smirnov test. Later, the ANOVA and student's T tests were applied. P values <0.05 would be considered statistically significant.

TABLE 1 Gingival color differences between groups. M = men, W = women. G 1 = 20–35 years old, G2 = 36–60 years old y G3 = 61–90 years old.

Study groups	Color differences	
	ΔE^*_{ab}	ΔE_{00}
M vs. W	2.5 units	2.3 units
G 1 vs. G 2	1.5 units	1.3 units
G 1 vs. G 3	2.4 units	0.6 units
G 2 vs. G 3	1.1 units	0.8 units

3 | RESULTS





The total sample ($n = 216$) was divided into three different age groups including 72 subjects each – of 20–35 years (46 women, 26 men), 36–60 years (39 women, 33 men), and 61–90 years (44 women, 28 men) to prove its homogeneity in terms of age and gender. The Chi-square test ($X^2 = 1.277$; $p = 0.528$) for homogeneity showed that there are no statistically significant differences in age or in gender.

The healthy attached gingival space color studied is delimited between the following maximum and minimum coordinates. L^* : minimum 40.4 and maximum 61.2; a^* : minimum 17.0 and maximum 30.2; b^* : minimum 9.8 and maximum 21.9. The mean and standard deviation for L^* was 53.41 ± 3.37 , for a^* it was 24.06 ± 3.03 , and for b^* it was 15.58 ± 2.09 . With a significance greater than $p > 0.05$ in the Kolmogorov Smirnov test, we confirm the normality in the distribution of the data.

However, the Student's T test revealed that there are statistically significant differences between men and women for the three coordinates of the CIELAB system. For L^* , the mean coordinate was 52.16 ± 3.4 for men and 54.27 ± 3.1 for women (P value: 0.000); for a^* , the mean coordinate was 24.77 ± 2.9 for men and 23.58 ± 3.1 for women (P value: 0.004); and for b^* , the mean coordinate was 15.18 ± 2.2 for men and 15.86 ± 2.0 for women (P value: 0.020). Gingival color differences between men and women and between different age groups were calculated using the classic Euclidean formula (ΔE^*_{ab}) and CIEDE2000 (ΔE_{00}). According to the ΔE^*_{ab} value of 2.5 units, the difference between the gingival color of men and women is not perceptible, while the ΔE_{00} value of 2.3 units falls slightly above the perceptibility threshold, making the difference just perceptible according to the CIEDE2000 formula. Nevertheless, both values fall under the clinical acceptability threshold. Color differences between the age groups are minor: there is a just perceptible difference between group 1 and 3 (2.4 units according to ΔE^*_{ab} , 0.6 units according to ΔE_{00}), but the difference was smaller between groups 1 and 2 (1.5 units: ΔE^*_{ab} ; 1.3 units: ΔE_{00}), and groups 2 and 3 (1.1 units: ΔE^*_{ab} ; 0.8 units: ΔE_{00}) (Table 1).





Therefore, the ANOVA test was used to compare the CIELAB values and the age groups. No statistically significant differences were found between age groups for the L^* (p -value: 0.432) or a^* (p -value: 0.452) coordinates, the means and standard deviations of which were as follows. L^* : 20–35 years: 53.84 (3.4); 36–60 years: 53.47

TABLE 2 Comparative table of the different studies that analyze the gingival chromatic space.

Methodology				Technique		Results	
Author	Population	Ethnicity	Study groups	Instrument	Measurement area	Color coordinate	Conclusions
Gómez-Polo et al. (2018)	N = 259	Caucasians	3 Groups: Less than 30 years (n:44), 30–59 years (n:133) and 60 years or more (n:82)	Spectrophotometer -ShadePilot MHT		Men L* 49.3 - a* 24.7- b*14.6/Women L* 51.3 - a*23.6 - b* 16.4	There are perceptible color differences within the keratinized gingiva band. These chromatic differences must be taken into account if the prosthetic characterization of gingival tissue is to be considered acceptable. There are significant differences between the color coordinates of the three sites studied in the keratinized gingiva of men and women.
Hyun et al. (2016)	N = 40	Koreans	2 Groups: Men (n:22) and women (n:18) de 25–36 years	Colorimeter – Shade Eye		Do not provide CIELab system color coordinate according to gender	The colorimetric values of AG and AM differ according to the area, possibly as a result of differences in anatomic and histologic distribution that influence optical properties.
Ho et al. (2015)	N = 238	African Americans, Asians, Caucasians, and Hispanics	4 Groups: 18–30 years (n:90), 31–45 years (n:65), 46–60 years (n:52) and more than 61 years (n:31)	Spectrophotometer - PR-670		Men L* 52.8 - a* 23.9- b*14.4/Women L* 53.0 - a*22.9 - b* 15.2	It was found that ethnicity and age had statistically significant influence on the color of human gingiva.
Calvo (2015)	N = 168	Caucasians	4 Groups: 18–29 years (n:46), 30–44 years (n:42), 45–59 years (n:40) and more than 60 years (n:40)	Spectrophotometer -ShadePilot MHT		Men L* 52.1 - a* 25- b*17.7/Women L* 54.1 - a*23.9 - b* 18.4	7 gingival color categories were obtained which can serve as a proposal for a clinical classification of gingival color and be useful as a guide for communication between dentists and dental technicians.

(Continues)

TABLE 2 (Continued)

Methodology				Technique		Results	
Author	Population	Ethnicity	Study groups	Instrument	Measurement area	Color coordinate	Conclusions
Sala et al. (2015)	N = 30	-	1 group. Between 20 and 30 years	Spectrophotometer - Spectroshade MHT		Do not provide CIE Lab system color coordinate according to gender	The repeatability and reproducibility of soft tissue shade measurements were almost perfect (ICC >0.9) under the examination conditions tested. The measurements were affected by pressure but not by ambient light.
Ito et al. (2014)	N = 120	White, black, Asian and other	5 Groups. 18–29 years, 30–39 years, 40–49 years, 50–59 years and 60–85 years	Spectrophotometer - PR-750		Do not provide CIE Lab system color coordinate according to gender	The study showed that L*a*b* was significantly affected by race and gender. Clustering analysis was able to identify clusters in 120 participants for three gingival tones.
Huang et al. (2011)	N = 362	Taiwanese	2 Groups. 18–35 years (n:261) and 65 to 86 years (n:101)	Spectrophotometer - custom device		Men L* 41.37 - a* 15.15 - b* 9.91/Women L* 45.44 - a* 14.99 - b* 9.58	The gingival color of females is lighter than that of males. The proposed color classification can be used as a gingival shade guide reference by dental laboratory technicians.
Heydecke et al. (2005)	N = 150	Caucasians	1 Group. No specific age	Visual - Munsell System		Do not provide CIE Lab system color coordinate according to gender	The color spectrum for the maxillary interincisal papilla is in the shades of yellow. For maxillary attached gingiva, Munsell shades are between 7/6 2.5 R and 8/4 10 R.

(3.3); 61–90 years: 52.77 (3.4); a^* : 20–35 years: 24.31 (3.1); 36–60 years: 23.85 (2.9); 61–90 years: 24.07 (3.1). However, the differences in the b^* coordinate were found to be statistically significant ($p = 0.000$), with the following means and standard deviations: 20–35 years: 16.73 (1.8); 36–60 years: 15.30 (2.2); 61–90 years: 14.55 (1.4). Due to the statistical significance found in the ANOVA test between the b^* coordinate and the age of the participants, Tukey's post hoc test was applied, and it was determined that statistical significance was present between Groups 1 and 2, and between Groups 2 and 3 ($p = 0.000$). In other words, the older the person is, the bluer the attached gingiva becomes.

4 | DISCUSSION

The first hypothesis of this analytical cross-sectional study, predicting that there would be statistically significant differences between the CIELAB color coordinates of natural healthy attached gingiva adjacent to the maxillary incisors according to gender, was accepted, given that significant differences ($p < 0.05$) were registered between the L^* , a^* and b^* color coordinates for men and women. Despite being statistically significant, this color difference is below the threshold of acceptance in the gingival chromatic space.³³ These results agree with those of Ho et al.²⁷ who did not find a perceptible color difference between men and women either (ΔE^*_{ab} 1.3 units), but contradict those of Huang et al.¹⁰ who only found statistically significant differences between men and women for the L^* coordinate and determined that the color difference between the two genders surpassed the threshold of perceptibility (ΔE^*_{ab} 4.8 units). This threshold has been extensively studied for dental color ($\Delta E^*_{ab} = 3.7$ units),³¹ however, for gingival color few studies have obtained these data. Sailer et al.³² and Gómez-Polo et al.³³ found that the average threshold of perception for the gingival chromatic space is 3.1 units for ΔE^*_{ab} ,^{32,33} and 2.1 units for $\Delta E00$, respectively.³³ The difference in color between the genders in the present study is not perceptible by the human eye using the ΔE^*_{ab} formula, although with the CIEDE2000 formula, one could say that it becomes so. Pérez et al.³⁴ concluded that the CIEDE2000 color difference formula provided a better fit than the CIELAB formula in evaluating the color difference thresholds of human gingiva. An improved interpretation and understanding of the gingival perceptibility and acceptability thresholds has been provided by a recent publication on how each of the three dimensions of color (lightness, chroma and hue) influence color differences.³⁵ More attention needs to be given to these gingival thresholds in future research. These differences in color between the genders can be attributed to the amount of melanin, vascularization, gingival biotype and keratinization, which tend to vary between men and women.⁸

The study's second hypothesis, according to which the color coordinates of healthy attached gingiva adjacent to the maxillary incisors are related to age, should also be accepted, since there were statistically significant differences in the color coordinate b^* between the three age groups under study. With aging, there is a chromatic change in healthy attached gingiva, with an increased presence of the color

blue (the values for the b^* coordinate tend to decrease as age increases). Age and its relation to gingival color is another much-debated topic. The present study only found statistically significant differences ($p = 0.000$) in the values of the b^* coordinate for participants of different ages. Ho et al.²⁷ used a spectroradiometer to analyze the color distribution of healthy human gingiva in 238 subjects (of four ethnicities) divided into groups according to age (18–30, 31–45, 46–60, and over 61), finding that the gingiva becomes lighter as age increases. This study examined subjects of all four races in a combined manner: a method of data analysis which could result in misinterpretations when they are compared with results focused on one race alone. Calvo Box,³⁶ who determined the gingival color at 6 points on the gingiva, in a Caucasian population with age ranges similar to that of the present study, agrees that the b^* values are higher in young people, although many authors have not found differences regarding this issue.^{8,10,28,37} Thus, the difference in gingival color obtained between the age groups does not have clinical relevance, which is defined as an acceptance threshold, as described in Gómez-Polo et al.³³

Some studies have also examined the effect of gender and age on gingival color without obtaining consistent results.^{8–10,21,37} Heydecke et al.⁹ studied the color of the alveolar mucosa, attached gingiva, and mesial papillae in the central incisor region and identified small differences with respect to gender. In general, men's gingivae were lighter and less blue than they were in women.⁹ The present study also found statistically significant differences between the CIELAB coordinates according to the gender of the participants (87 men and 129 women). With the results obtained, it could be said that women have a lighter gingival color and in men it is slightly more bluish, as stated by several other studies.^{8,10,28,37}

Gingival color in esthetic prosthetic restorations is important in dentistry, given that about 80% of the population show part of the gingiva³⁸ when they smile. This creates a challenge for dentists in clinical situations where the gingiva must be replaced prosthetically, since there are currently no reliable gingival shade guides that allow the color of the gingiva to be reproduced artificially and thereby enable the prosthetic restoration to mimic the soft tissue successfully.^{38,39} Research on gingival color has been published, but there is still not enough information to determine the color of the attached gingiva and gingival papillae, and these studies fail to address the color of the gingiva when it is inflamed.^{7,8,39}

Visual comparative methods have been used clinically to select gingival color.^{9,16,22} However, this method presents difficulties when it comes to obtaining reliable and concordant results since it depends on factors such as: the examiner's characteristics,^{9,21} ambient lighting,^{9,12,40} uniformity in shade guides, and so forth.^{7,8,18} For these reasons, spectrophotometry has become the most reliable method for measuring gingival and tooth color in dentistry.^{41,42} Although it is true that spectrophotometry is the method with the greatest validity and reliability for dental color measurement, it would be beneficial for future studies to address validity and reproducibility in natural gingival color measurement.^{8–10,27,28,37} Color data obtained with electronic devices have greater repeatability^{42,43} and reliability, with values ranging from 0.8 to 0.9,⁴⁴ which are interpreted as excellent and superior

to subjective visual methods.^{8,39,41} While spectrophotometry can present certain drawbacks, such as the light source,⁴³ inconsistent measurement angles, discrepancies with the degree of humidity, “edge loss” due to the morphology of the gingiva and its resilience during color measurement,¹⁰ it was possible to minimize the impact of such issues in the present study with the methodology used.

The limitations of this study include the fact that only the Caucasian ethnic group was studied. Although few studies compare the gingival color of different ethnic groups, Ho et al.²⁷ and Ito et al.³⁷ concluded that there are significant differences between different ethnic groups (African Americans, Asians, Caucasians, and Hispanics/others) and that this may be due to the degree of melanotic pigmentation. Additionally, in a cross-sectional study, this is a valid methodology for identifying associations between variables, which is the primary aim of this research. It is also worth noting that most published research^{10,27,37} shares the present study's focus on the central part of the keratinized gingiva adjacent to the central maxillary incisors, given that this is the most representative gingival area. This makes it hard to extrapolate the results to other gingival regions, such as the free gingival margin, the gingival papillae, or the mucogingival line. However, other studies, also conducted on a Spanish Caucasian population, recorded gingival color in different gingival locations^{8,36} (examining six such locations) and identified similar color coordinates to those described in the present study (Table 2). In contrast, for the variables identified in the study by Huang et al.¹⁰ the color coordinates were significantly greater. This difference may be because the participants¹⁰ were Taiwanese, added to the fact that different models of spectrophotometer were used.

In future studies, the samples should be expanded, considering other factors such as ethnicity, medication, smoking, gingival biotype, degree of keratinization, degree of pigmentation, vascularization, and other factors. In addition, longitudinal studies should be carried out to understand the behavior of gingival color over time and thus obtain more consistent data regarding the age of the participants.

Taking into account the variables mentioned above, and the acceptability and perceptibility thresholds for the gingival chromatic space,^{12,32,33} it would be wise to create gingival color shade guides that adapt to the chromatic reality of the entire gingival color space, with mathematical criteria. This would enable clinicians to perform prosthetic gingival reconstructions that are much more esthetically successful, mimicking soft tissue through subjective visual selection.

5 | CONCLUSIONS

Within the limitations of this study, the following conclusions were reached regarding healthy attached gingiva adjacent to the maxillary incisors:

1. The color lies between the following values for the CIELAB coordinates. L*: 40.4 to 61.2; a*: 17.0 to 30.2; b*: 9.8 to 21.9. These color coordinates may be useful for producing well-designed gingival color guides.

2. Color differences between men and women are clinically irrelevant, gingival color in women being slightly lighter.
3. It takes on a bluish color, as patients get older.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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