Original Article

Creating A Gingival Color Database Among Thai Samples by Using Digital Images Processing

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Abstract

This research aims to analyze the digital color-coded values of clinical gingival color images and create a gingival color database using digital images to measure the clinical gingival color levels. Theories of RGB and HSB color models were applied in the present study. The research model was cross-sectional descriptive. There were two research methods: 1) Digital gingival color code analysis and 2) Digital gingival color reliability analysis. In the first part, photographs of the gingiva of 99 patients who were admitted to the dental hospital, Faculty of Dentistry, Naresuan University, were taken. Adobe Photoshop CS6 software was employed for digital color code analysis. The digital color codes of the gingiva collected from the 143 samples were then examined for their reliability. Data from the study exhibited the total numbers of digital areas from the gingival images were 3,700 areas, with slightly red being the majority, 35.51%, followed by pale pink, red, and bluish-red, for 27.46, 25.43, and 11.59%, respectively. The RGB and HSB color models revealed the frequency of one or two codes using the statistical mode. In contrast, the red code showing ten performed by the RGB model and more codes in the HSB model. The reliability analysis of digital gingiva was calculated with an alpha coefficient of 0.655, which is a moderate confidence level. The analysis of dental images in the present study shows the promising potential to create a database of gingival color. The digital image databases are created on the Windows operating system and Microsoft Access software that can display data such as frequency, percentage, gingival color code, and color samples. Performing the software, users can basically input data consisting of gingival images, color codes, filter inputs, and search the database of RGB and HSB color models.

Keywords: Digital image analysis, Gingivitis, Gingival color

Received Date: Aug 21, 2022 **Revised Date:** Oct 6, 2022 **Accepted Date:** Nov 18, 2022
doi: 10.14456/jdat.2023.9

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Introduction

Gingivitis and periodontitis are diseases caused by bacterial infection, which affects the periodontal organs due to antagonistic interactions between bacteria in the dental plaque and periodontal tissues via intracellular and vascular responses. The onset and progression of periodontitis are classified as immunopathogenesis with inflammation. It can be clinically demonstrated locally or generalized. In addition, supporting factors affecting pathogenesis include environmental and genetic factors.[1]

Inflammation causes the color of the gingiva to change from normal to pale pink, starting to redden with the degree of inflammation. If the inflammation is mild, it will be slightly red, and more inflammation will be red. Gingival discoloration is caused by an increased cellular and vascular response within the gingival tissue. If the inflammation persists for a long time, it will have a bluish-red color due to congestion of venous blood.[2]

In previous studies, digital image processing was performed to assess the importance of plaque adhesion conditions on the teeth, gingival swelling, and gingival color changes associated with inflammation in Gingivitis. The researchers observed that the change in gingival color from different levels of inflammation could indicate Gingivitis.[3-6] Usually, the gingival color assessment can be assessed by a dentist, but sometimes the color assessment may vary depending on the experience of each dentist. It can cause inaccuracies in the diagnosis of Gingivitis.[7] Building a database of digital gingival color values can help develop a tool to distinguish gingival color, which would help reduce the aberration of color vision and make the gingival color assessment more accurate with the same standard.

The RGB color model is based on the principles of color theory and color mixing that uses red, green, and blue light as the primary colors to mix different colors. The color reproduction mechanism on computer monitors uses the glow of red, green, and blue phosphor dots to mix the light into different colors. It will assign three numeric values, which are the value of R, the value of G, and the value of B. The program will set a number from 0 – 255. The number 0 indicates that the beam is not firing in that area, but the higher the number, the more increasing intensity of the light.[7]

The HSB color model (HSB) is a basic color system whose mechanism of color reproduction is similar to the human color perception process. This color system divides the color composition into three parts. The first part, hue (H), indicates that color is caused by the value of light waves that hit an object and are reflected into the human eye. Hue is arranged in a color wheel ranging from 0 to 360 degrees. The second part, Saturation (S), is the intensity and fade of the color. Determined by the proportion of gray that exists in that color, it ranges from 0% (much gray) to 100% (no gray). The third part, Brightness (B), is the lightness and darkness of a color. It ranges from 0% (black) to 100% (white). [7]

A 1975 study of Ibusuki's gingival color measuring Hue, Chroma, and Value found that the gingiva of the elderly had a more purplish-blue hue and a higher chroma value, while the Value was higher among adolescents.[8] In addition, the CIELAB color system model was used to study gingival color, such as in the study of Huang JW *et al.* 2010, to develop a shade guide for pink aesthetics and to create ten gingival color shades.[9] However, the RGB color model is used to view colors in images from a typical electronic device screen. The HSB model is closer to the human color perception process, with limited studies in gingival color separation. The RGB (Red, Green, Blue) and the HSB (Hue, Saturation, Brightness) color model theories and the concept of four clinical grades of gingival color classification: Pale pink, Slightly red, Red, and Bluish-red, were used to study and build a database. This study aimed to analyze the digital color code of the gingiva on the clinical inflammatory color scale, and to create a digital image database for clinical gingival color measurement.

Materials and Methods

This study has been accredited by the Human Research Committee on Project Ethics. Naresuan University institution review board on February 27, 2019, No. COA NO.086/2019

This study was a cross-sectional descriptive of 99 Thai ethnic patients admitted to the Periodontology clinic, Faculty of Dentistry, Naresuan University, who were diagnosed with gingivitis or periodontitis. The exclusion criteria were the patient who has braces, has a metal component of a prosthesis, has a dental implant, or has hyperpigmented gingiva from the area of the second premolar to the anterior teeth onwards. The expert observers were dentists who work in periodontology and have at least five years of working experience. A Canon 700D digital camera was used to record gingival images. A tripod was used to control the distance and shooting position 80 cm away from the background wall. ISO sensitivity of 800, shutter speed (f) at f/18, exposure time of 1/40 sec, automatic white balance, and automatic head flash were set consistently. All patients were fixed at the position of the Frankfurt plane paralleling the floor. Images were taken from the frontal view. Adobe Photoshop CS6 was used to identify digital color codes. Color analysis software used in this study was newly developed by our research team. The study was conducted in two parts: 1) Digital gingival color code analysis and 2) Digital gingival color reliability analysis. For the digital gingival color codes analysis, three observers viewed images and selected the area representing the best pale pink, slightly red, red, and bluish-red from anywhere in each image (maximum of ten areas of each color). Selected areas were analyzed for the codes of RGB and HSB using Adobe Photoshop CS6. All code values were recorded and analyzed in the color analysis software. The data of frequency, percentage, highest value, lowest value, popular base, and range were described statistically. For digital gingival color reliability analysis, verifying the consistency of the representative color code values obtained from the first part is a procedure. Twelve new clinical images, (three pale pink, three slightly red, three red, and three bluish-red) selected by three experts, were used in the questionnaire, with four choices of both RGB and HSB color codes from the first part. The developed questionnaire was tested by periodontologists, general dentists, and dental students totaling 143 people. A sample of the questionnaire is shown in Figure 1. Internal reliability was analyzed using Cronbach's Alpha coefficient.

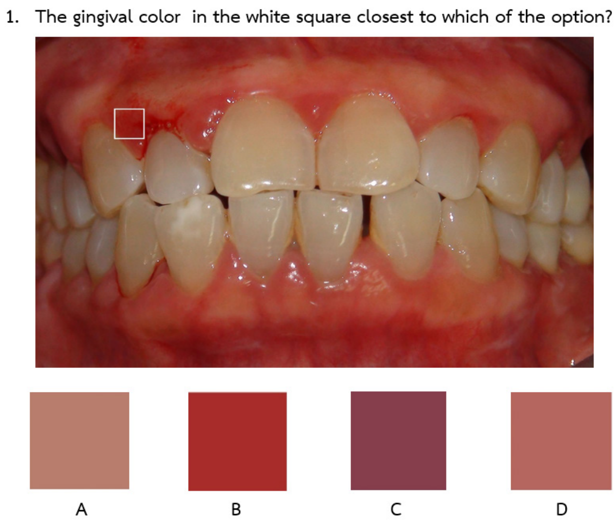

Figure 1 *Shows a sample of the questionnaire*

Results

1. Digital gingival color code analysis

All 99 participants were ethnic Thais. As for the other demographic data of the samples from this study, only the gingival images were collected in the early stages. As a result, only 31 participants could collect feedback on other sample demographic characteristics (Table 1).

The gingival images of 99 participants showed the total numbers of digital areas from the gingival images were 3,700 areas, with slightly red being the majority, 35.51 %, followed by pale pink, red, and bluish-red, for 27.46, 25.43, and 11.59 %, respectively (Table 2).

1.1 RGB color code classified according to the degree of clinical gingival color

RGB color code values classified according to the degree of clinical gingival color in the gingival images of 99 participants showed that the gingival color code is distinctly different for each clinical grade of gingival color (Table 3).

Table 1 *Demographic data of the sample (N=31)*

Demographic characteristics	Frequency	Percentage
sex		
Male	12	38.70
Female	19	61.30
Age (years)		
< 30	26	83.88
31 – 49	3	9.67
>50	2	6.45
Average = 28.16 SD = 8.97 Highest = 56 Lowest = 23		

Table 2 *Summarizing the number of areas and percentage of each gingival color chosen by the expert*

Gingival color	Area	Percentage
Pale pink	1,016	27.46
Slightly red	1,314	35.51
Red	941	25.43
Bluish-red	429	11.59
Total	3,700	100.0

Table 3 *Shows the summary of RGB color code and gingival color*

Gingival color	Min.	Mode			Max.	Range
Pale pink	109,75,39		184,125,108		204,212,150	95,137,111
Slightly red	121,52,48		181,102,94		209,166,157	88,114,109
Red	73,9,25	160,44,42	160,44,49	160,44,75	197,149,136	124,140,111
		160,48,42	160,48,49	160,48,75		
		167,44,42	167,44,49	167,44,75		
		167,48,42	167,48,49	167,48,75		
Bluish-red	91,27,6		135,62,76		199,143,130	108,116,124

The red code is especially the most different (Range = 124,140,111), while the slight red code was the least different (Range = 88,114,109). In addition, the visible colors are different when comparing the color vision at all four levels of gingival color by considering only the Mode value. Pale pink is lighter than slightly red and red. The bluish-red color looks darker than purple.

However, it is worth noting that the Mode value of the red grade has up to 12 values. Looking at the color of the eyes, it can be seen that all colors are very close. It can be divided into two types of vision: reddish-orange and reddish-pink.

1.2 HSB color code classified according to the degree of clinical gingival color.

HSB color code values classified according to the degree of clinical gingival color in the gingival images of 99 participants showed that the gingival color code is distinctly different for all gingival colors, and there are 1-2 specific codes for each gingival color (Table 4).

Table 4 Shows the summary of the HSB color code and gingival color

Gingival color	Min.	Mode		Max.	Range
Pale pink	0°,19,32	13°,39,72		359°,59,80	359,40,48
Slightly red	0°,4,48	8°,45,68		359°,72,82	359,68,34
Red	0°,31,5	0°,47,66	0°,55,66	359°,92,78	359,61,73
Bluish-red	0°,24,5	4°,39,51	4°,39,52	359°,75,78	359,51,42

When considering only the Mode value, the visible color difference is noticeable. Pale pink looks lighter than slightly red and red, while bluish-red is the darkest.

2. Digital gingival color reliability analysis.

The sample group used to examine the reliability of the test consisted of 143 persons, including specialists, general dentists, dental students, and dental personnel. Demographic characteristics data are shown in Table 5. Cronbach's Alpha Coefficient found that when all 24 tests were taken into the analysis, the reliability score was 0.612, with the reliability value of the whole text being between 0.556 – 0.638. However, when the three low correlation tests were eliminated, the reliability value was increased to 0.655. Therefore, the visual and color-coded tests were moderately confident, with a confidence level greater than 0.610. As mentioned earlier, the exam can be used as a digital gingival color database.

Table 5 Demographic characteristics of the sample

demographic characteristics	Frequency	Percentage
Sex		
Male	45	31.46
Female	97	67.83
no answer	1	0.69
Age (years)		
20 - 29	75	52.44
30 - 39	60	41.95
40 - 49	6	4.19
>50	1	0.69

Table 5 *Demographic characteristics of the sample (cont.)*

demographic characteristics	Frequency	Percentage
no answer	1	0.69
Average = 29.13 SD = 5.93 Highest = 50 Lowest = 22		
expertise		
Specialized dentist	37	25.87
General dentist	64	44.76
Dental student (Class year 5-6)	37	25.87
Other dental personnel (Dental assistant)	3	2.10
no answer	2	1.40

3. Creating a Gingival color database

The color analysis program is a newly created software by our research team for collecting color-coded gingival color data in RGB and HSB models. It is run through the Microsoft Access runtime Version 2010 on Windows 8.1 and above (Windows Version 8.1). A total of 32,750 records can be recorded. The program can display frequency, percentage, gingival color code, and color samples. Using the software, users can input data consisting of gingival images, color codes, filter inputs, and search the database of RGB and HSB color models.

Discussion

The RGB color model accurately recognized the clinical gingival color with almost every color except red. The analysis showed that the RGB color code's mode was found in only one value for each of the three gingival colors. These were pale pink (Code 184,125,108), slightly red (Code 181,102,94) and bluish-purple (Code 135,62,76). The red gingival color was found to have up to 12 color code base values. Red gingival classification by RGB color system has many central tendency values; therefore, red gingival diagnosis may be inaccurate. The results supported the weakness of the RGB color model, namely its sensitivity to uneven illumination, and the difference between colors is not linear. It may cause an aberration of human color vision.[11] Another reason may be that the chances of seeing red light are higher than in other colors. Humans can generally see the light or waves of different colors, with a wavelength range of 390 – 780 nm. Different wavelengths produce different colors. For example, blue has a length of 455-492 nm; green is 492-577 nm, etc. Compared to red, with a wavelength of 622 - 780 nm, it is found that red light has a significantly longer wavelength than other colors[12], so professionals have a greater chance of seeing red than any other color.

As a result, the nominal values are more multivalued. The findings provide a better understanding of using the RGB color model in clinical gingival color diagnosis. In the case of red gingiva, the dentist may need to review or confirm the results in conjunction with the HSB color model or another color instrument. To make the diagnosis more accurate, Seshan H and Shwetha M[13] used Serif plus-6 software to help compare the differences in swelling and red gingiva before and after treatment. Alternatively, the red representing inflamed gingiva, may be compared with the alveolar mucosa, characterized by red tissue near the gingiva. More accurate confirmation of gingival inflammation was obtained by looking at the gingival color and the hemorrhages from the insertion of a periodontal probe.[14]

The HSB color model can accurately identify clinical gingival colors at all color levels. The HSB system, which analyzed four levels of gingival color, found that there were only 1-2 values for the color codes that experts agreed on: pale pink and slightly red, with only one color code: 13°, 39, 72, and 8°, 45, 68, respectively for red and bluish-red to purple with two values each. These findings show that gingival color classification by the HSB color model has very low aberrations. Therefore, this color model can be used in clinical studies or diagnoses of gingival color. The main reason that most experts see the same color is probably because the HSB system is a primary color system consisting of Hue, Saturation, and Brightness, which is the mechanism of color reproduction that isclose to the process of receiving knowing the human color.[9] So it can be seen that the HSB color model has been used in various contextual studies; for example, a 2011 study by S. Khairunniza-Bejo and S. Kamarudin used the HSB color model to determine the sweetness of Chokanan mangoes. The study used a Keyence Machine Vision system to capture mango images with an HSB color model and then used a Digital AR2008 Abbe refractometer to obtain the sweetness to the set threshold.[15] Although the HSB color model has not been ever used for clinical gingival color analysis, there is the potential to apply it as a knowledge base to develop tools or methods for measuring and evaluating gingival color and creating a future database of gingival color.

However, a 2018 study by Edgar Chavolla[16] looked at the ability to distinguish and detect colors by different color systems using clustering and fragmentation techniques. It was found that different color systems were able to identify different colors. Each color system has different advantages and disadvantages. It was found that the RGB color system is a color system with vast color space, enabling a wide range of colors close to what the human eye sees and is compatible with electronic devices without different adjustments and can interpret mathematical results accurately.[16] Nevertheless, the system has a discrete nature within the color space, so that mistakes are easy to make when grouping and separating colors. The RGB system has no luminance processing, resulting in shadows or noise in the image and the color processing of images is easy to distort. In a color system with a separate H (Hue) value, such as HSB, HSV, or HSL, there is a discrepancy in the color values at the 0° and 360° region if a set of correction commands are inserted into these color systems. It will be able to group and separate colors well.[16] Therefore, in preparing the database, the researcher gathered information on gingival color codes for both RGB and HSB systems, as both systems have different advantages and disadvantages.

The gingival image and color code reliability in the RGB and HSB color models was within acceptable levels in most images. The alpha coefficient reliability analysis found that the value was 0.612 obtained from 24 images, indicating that the color codes from the RGB and HSB color models showed moderate or adequate reliability (an alpha coefficient greater than 0.6[10]); the tool can be used as a gingival color database. However, due to time and resource constraints in this study, only 24 items were included in the analysis, which was one reason for the low reliability. Increasing the number of questions is one way to increase the confidence score[17], where the rule of thumb must be 0.7 or higher. The higher the value, the more consistent the instrument was created.[10,18] Therefore, in order to increase the confidence in the gingival color image in the future, the number of gingival image exams should be increased. In addition, the confidence analysis can be modified with new methods such as test-retest, parallel forms, and confidence among evaluators (Interrater reliability), etc.[19], to comply with the context and limitations of the research. It will help develop tools to be more reliable.

However, in this work, three gingiva-colored images were removed. After removing the images, the confidence value rose from 0.612 to 0.655, indicating that the truncated images had a low correlation with the other images. It may be because the image that had been removed has a slightly unclear color. Understanding this point suggests future developments in gingival color measurement instruments. In measuring instrument development, especially the test, the analysis of difficulty (p) and discrimination power (r) is essential in addition to making the test quality. It also helps to check the basic properties of the tool before applying the statistical analysis in the next step.[20] However, due to the limitations of resources and the researcher's experience, only 24 initial exams (items) were created, and the difficulty and discriminant powers of the test were not checked. Therefore, it is not possible to find confidence by other methods or other statistics such as Pearson Correlation Coefficient, Paired *T*-test, etc.

The developed RGB and HSB color databases can be used for clinical gingival color diagnosis. One of the objectives of this research is to create a digital image database to measure the level of gingival color in normal and inflamed gingiva. The created database is stored in the color analysis software. It can save data in a database, manage data, search data, and display color-coded data as users want, such as charts, frequencies, etc. The initial usage involves importing new data into a new database of images, and RGB and HSB color codes. Gingival color code range values from this present research helped to separate new codes and imported into data for each color (pale pink, slightly red, red and bluish-red). As the database grows larger, distinguishing between gingival color code range values becomes more precise and more accurate. It can potentially be used for software that could analyze the color of the gingiva from the whole image. The development of an application to analyze the color of the gingiva from the images in the smartphone may provide preliminary diagnosis and treatment recommendations for people. For example, pale pink can indicate healthy gingiva, slightly red can indicate mild gingival inflammation requiring a dentist to assess gingival health, red can indicate severe gingival inflammation needing urgent treatment and bluish-red indicates the gingiva are chronically inflamed, may have a sub-calculus and need to be treated by a dentist. In terms of clinical teaching, image databases and gingival color codes can be used in dental teaching, especially on gingival color inflammation issues. However, this newly created database has limitations in many ways. The subject needs future development, especially the ability to interpret color codes before saving the data.

In saving the gingival color into the database, it is also necessary to save the image in a room or place where the light must be controlled for the image to be equally qualified. After that, points or image color spaces are imported into Adobe Photoshop CS6 to analyze color codes in both the RGB and HSB color systems and then saved in the database. Doing so requires knowledge and programming skills as well as user time. Therefore, to save data and analyze the color of the image more efficiently. In the future, functions in the database should be developed to manipulate images and color codes independently.

The initial usage involves importing new data into a new database of the initial assessment of gingivitis, which is only part of the evaluation of gingiva inflammation. In order to accurately diagnose gingivitis and assess its severity, additional clinical examinations are required, such as measurements of bleeding on probing, probing depth, clinical attachment loss, radiograph, etc. All data obtained will be processed for diagnosis and lead to the correct course of treatment.

Conclusion

The RGB and HSB color codes classified by the clinical grade of the gingival color showed that when considering the Minimum Mode and Maximum statistics of each gingival color level, the gingival color codes were significantly different across all gingival color levels. Considering only the Mode values, there was a noticeable difference in the colors. However, it is worth noting that up to 12 of the red gingiva's mode values are in the RGB color model. Nevertheless, all the colors within the red group are very similar, so the HSB model is suitable for diagnosing accurate color separations. Although the RGB color model's color separation accuracy is less than the HSB, it is compatible with electronic devices.

The reliability of the gingiva image and the color code in the RGB and HSB color models were acceptable for almost all images in the initial instrumentation development. Therefore, the development of increased confidence and database functions to increase their potential is a plan that further research should be developed to increase accuracy and performance. When the database is accurate, and the database size is more extensive, it can be developed into an artificial intelligence system in the future.

This new research on gingival color database construction uses RGB and HSB color models to analyze the color codes to create a criterion for distinguishing pale pink, slightly red, red, and bluish-red color ranges. They are used to assess the color of gingiva in the Thai population. Nevertheless, color-coded values, especially red, still have a wide range, and the reliability is not very high. In future studies, if larger database sizes result in more accurate color-coded values, further reliability studies of this research may need to be designed to provide higher reliability.

Acknowledgements

The authors would like to thank Assist.Prof.Dr. Panwadee Bandhaya, Assoc.Prof.Dr. Danai Reabsakul, Chanoknutpha Therapong, Kanthika Phangkariya, Nuttharee Sanunchatwanich, and Wanida Muangthong.

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