Research Article

Quantitative Assessment of Gingival Inflammation in Patients Undergoing Nonsurgical Periodontal Therapy Using Photometric CIELab Analysis

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Visual inspection and gingival indices have been traditionally used for diagnosis of gingival inflammation. These methods are prone for subjective variability. Thus, the study is aimed at evaluating gingival inflammation quantitatively by using CIELab colour space value obtained from digital photographs. An experimental study was conducted with 27 patients each in group A (gingivitis) and group B (chronic periodontitis, CP). Preoperative and postoperative (1 month) photographs of maxillary anterior sextant were recorded to evaluate CIELab coordinate values. Simultaneously, clinical parameters such as bleeding on probing (BOP) and periodontal probing depth (PPD) along with indices such as plaque index (PI), gingival index (GI), and sulcus bleeding index (SBI) were evaluated before and after the nonsurgical periodontal therapy. Data was presented as the mean $\pm$ SD, and a paired *t*-test was used for the testing hypothesis with $p < 0.05$ considered as significant. Data analysis was carried out with Statistical Package for the Social Sciences (SPSS) version 21. A significant reduction ($p < 0.001$) is seen in all the clinical parameters and indices before and after the intervention in chronic periodontitis patients. Similar results were seen in gingivitis patients ($p < 0.001$) except for PPD. A significant ($p < 0.001$) reduction in postoperative values of the *a* * and *b* * coordinates was seen in CP patients; whereas, only the *a* * coordinate value reported a significant ($p < 0.001$) reduction in the gingivitis group of patients. The ΔE of the gingivitis and chronic periodontitis groups was 2.25 and 2.96, respectively. Within the confinements of the study, estimating the gingival colour with the help of CIELab values taken via digital photographs can be an excellent valuable tool to assess the gingival colour as a sign of gingival inflammation.

1. Introduction

Inflammation of the gingiva and supporting tissues of the periodontium is a common feature of periodontal disease. The primary local etiological agent for this inflammation in these tissues is dental plaque (DP), which is consistently present around the tooth near the gingival sulcus [1]. If the inflammation is not resolved with home or professional care

such as scaling and root planing (SRP), it will develop into gingivitis. Some of the cases may progress into periodontitis if left untreated. Periodontitis is caused by an imbalance between the host and bacterial interaction leading to clinical attachment loss and bone loss [2]. The bacteria residing in the biofilm of a periodontitis patient can enter the blood stream. This phenomenon possibly explains their role in causing systemic inflammation [3]. Once they enter into

the systemic circulation, the cascade of inflammatory mediators' initiates. There are many biomarkers which are helpful in evaluating the systemic inflammation [4]. Apart from systemic causes, there are certain predisposing factors which also facilitate the plaque accumulation such as orthodontic bands and brackets during orthodontic treatment will compromise the oral hygiene of patient leading to gingival inflammation [5]. During this inflammatory process, gingiva depicts various cardinal signs of inflammation [6]. Change in the colour of the gingiva is among one of them. Change in the gingival colour from red to pink can be a good indicator of healthy gingiva, thus showing the resolution of inflammation [7].

Around the 1950s, assessment of gingival inflammation was usually graded as good, medium, and poor [7]. Later, gingival and periodontal indices were introduced to assess the inflammatory changes of the gingiva, which eventually gained popularity in clinics as well as epidemiological studies [8]. Although indices are considered the gold standard [7, 9] and are considered essential to assess the clinical outcome, its subjective variability cannot be neglected. To the best of our knowledge, there are no direct indices for measuring colour changes of the gingiva.

Electronic measurements from spectrophotometer or colourimeter were used to assess the various shades of healthy gingiva, natural teeth, or dental restoration [10]. These methods are not used often because of the edge loss effect and invasive nature, respectively [11]. Later, digital photography technique was used to assess shade selection and gingival colour as it is reproducible, noninvasive, and inexpensive. Comparing the colour on digital photographs is again an area of subjective variability. Thus, to overcome the subjectivity, the output colour of the digital photograph can be calculated by mathematical formula applying CIELab colour space [12] on various software such as Adobe Photoshop or Gimp software. CIELab is a chromatic value colour space given by the International Commission on Illumination in 1976. This system has three components L^* , a^* , and b^* which measure lightness from black to white, green to red, and blue to yellow, respectively. Its working principles and working have been extensively elaborated by various authors [13, 14]. The $CIEL^*a^*b^*$ system is widely used in dentistry in shade selection criteria for dental restorative material as well as shade guide for tooth colour [15]. Concerning the soft tissue evaluation by using the CIELab colour space system, studies have been conducted on healthy gingiva [16–18], but not much explored on inflamed gingiva.

Thus, the study is aimed at quantitatively evaluating the gingival inflammation of patients before and after nonsurgical periodontal therapy by applying CIELab colour space obtained from the digital photographs. The null hypothesis states that “there is no difference in the CIELab values of maxillary anterior gingival tissue before and after nonsurgical periodontal therapy”.

2. Materials and Methods

2.1. Study Design and Population. Experimental nature of the study was planned in a hospital-based setting. Ethical

approval (15-03/41) was obtained from the local ethics committee. A total of 112 Saudi Arabian patients with thick gingival biotype who visited the dental clinics at the College of Dentistry, from December 2019 to January 2020, were screened (Figure 1). All the prospective candidates for the study were initially informed about the objective of the study. Later, verbal and written informed consent was obtained from all the subjects who voluntarily agreed to participate in the study. Seven (7) patients did not give consent for the same and hence were not considered part of the study. Considering the inclusion and exclusion criteria (Table 1), 81 subjects were recruited in the study. Based on the diagnosis of periodontal health, 39 patients were allocated to group A (gingivitis) and 42 patients into group B (chronic periodontitis). Although the decision of recruitment of patient into the study group was based on the clinical diagnosis, the patient was blinded about it, as they are given a chit with code written “A” or “B”. During the follow-up period, 4 and 11 patients were lost in groups A and B, respectively, thus making 27 patients available in each group for the final analysis.

2.2. Study Protocol. The patients in both groups were recorded with bleeding on probing (BOP) and periodontal pocket depth (PPD) along with indices, namely, gingival index (GI) [19], plaque index (PI) [20], and sulcus bleeding index (SBI) [21] at the initial visit. There were few patients in both groups, who declined to undergo the intervention, and so were dropped from the study. Followed by which are supra- and subgingival scaling that were carried out. Postintervention, patients were given oral hygiene instructions (OHI) and were informed about the follow-up visit after one month. Personal reasons were cited by a few patients in both groups, who did not turn up for the follow-up visit and hence were no longer remained part of the study. On the follow-up visit, the clinical parameters BOP, PPD, and indices GI, PI, and SBI were rerecorded.

2.3. Digital Clinical Photographs and Photometric Analysis with CIELab Colour. As a part of the study protocol, the intraoral picture of labial gingiva in the maxillary anterior sextant was taken with digital single-lens reflex camera (Canon EOS 60D) with a ring flash (Dual Macro LED Ring Light). The specification was kept as a shutter speed of 1/200 s, ISO 200; aperture: F 20; white balance; and 18% grey colour shade. The patient was asked to sit straight in a room lit with 16 tube lights with no exposure to daylight. The resultant image was processed in Adobe Photoshop 7.0 to get the $L^*a^*b^*$ values by assessing the maxillary right lateral incisor as described by Mayer et al. (2017) [22]. On the follow-up visit, the clinical photographs of the same region were repeated and compared using CIELab colour space (Figure 2).

In dentistry, this colour space is widely used because the colour difference measured by this method can be correlated with visual perception. Colour difference is represented by the Greek symbol, ΔE (delta), which is calculated by using the traditional mathematical formula (with steps) given below.

FIGURE 1: Flow chart of study design.

$$\Delta E = \sqrt{(L_{\text{Post}} - L_{\text{Initial}})^2 + (a_{\text{Post}} - a_{\text{Initial}})^2 + (b_{\text{Post}} - b_{\text{Initial}})^2}, \text{ (Step 1)}$$

$$\Delta E = \sqrt{(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2}, \text{ (Step 2)}$$

$$\Delta E = \sqrt{|\Delta L|} + |\Delta a| + |\Delta b|, \text{ (Step 3)} \quad (1)$$

where L^* , a^* , and b^* are the three coordinates in CIELab colour space. The ΔL , Δa , and Δb are calculated by getting the difference of the particular coordinate by subtracting the preintervention value from postintervention value. In order to get the absolute value ($|\Delta|$) of each coordinate's Δ , the square is calculated. Finally, by adding the absolute values, the ΔE is calculated.

2.4. Interexaminer and Intraexaminer Reliability. An attempt was made to eliminate the examiner's bias in the study. Firstly, two experienced periodontists were selected to perform the clinical examination and record the clinical values as well as indices. To eliminate the interexaminer variability, both periodontists had standardized their assessment methods by undergoing focused theoretical and short clinical training sessions. Two orthodontists were selected to take the clinical photographs and later performed the assessment for the same. Individual examiners of either group were blinded

about the study group or assessment values of their contemporary. Secondly, 10 repeated measures (excluded from the analysis of the study) of clinical parameters and CIELab colour space were taken, and test-retest reliability was performed. The inter- and intraexaminer reliability was found to be 0.87 and 0.94, respectively, which shows a strong level of agreement.

2.5. Sample Size Calculation. Post hoc power estimation was done using software GPower 3.1.9.2 (Heinrich Heine Universität Düsseldorf, Germany) at confidence interval (α) of 0.05 for the two-tail test. It was computed by considering the difference between two dependent means (matched pairs), effect size (f) of 0.05 and a sample size of 54. The statistical power of the current study is 0.95.

2.6. Statistical Analysis. The data was collected in a specially designed extraction sheet. It included the patient's identification, clinical examination data, and values of CIELab colour space. Later, all data were entered in MS Excel spreadsheet for the necessary editing and coding of data. Data was presented as data in percentages and mean with standard deviation. For testing the hypothesis, a dependent t -test was used for comparing means between the study groups. The independent t -test was used with respect to the baseline variable.

TABLE 1: Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Common	General factors
(i) Patient with age range of 18–60 years visiting dental clinic at the College of Dentistry	(i) Patient aged below 18 years
Group A (gingivitis)	Systemic factors
(i) Patient diagnosed clinically with chronic gingivitis as per the criteria given by the American Academy Periodontology (AAP, 1999)	(i) Patients with underlying systemic conditions affecting the gingival pigmentation
Group B (chronic periodontitis)	(ii) Pregnant women
	Local factors
	The following are the gingival conditions affecting the maxillary anterior sextant:
(i) Patient diagnosed clinically with chronic periodontitis as per the criteria given by American Academy Periodontology (AAP, 1999)	(i) Drug-induced gingival enlargement
	(ii) Gingival pigmentation
	(iii) Red or white lesion
	(iv) Benign or malignant tumors

FIGURE 2: This figure depicts the preoperative and postoperative clinical photographs of maxillary anterior gingiva of gingivitis patient. (a) Extracting the CIE Lab values from preoperative photograph using Adobe Photoshop software. (b) Arrows showing gingiva of the maxillary right lateral incisor region are selected for the calculation of CIE Lab values. (c) Derived Lab values for preoperative clinical photograph. (d) Extracting the CIE Lab values from postoperative photograph using Adobe Photoshop software. (e) Arrows showing gingiva of the maxillary right lateral incisor region are selected for the calculation of CIE Lab values. (f) Derived Lab values for postoperative clinical photograph.

For correlation analysis, Pearson correlation was performed. All the statistical analysis was performed using version 21 of the Statistical Package for the Social Sciences (SPSS IBM, Chicago, IL, USA).

3. Results

In the current study, two study groups, namely, gingivitis and chronic periodontitis, were considered with each group having 27 (twenty-seven) subjects. The two groups were matched with respect to age and gender (Table 2).

3.1. Inferential Analysis of Clinical Parameters. The subjects of both study groups were subjected to supra- and subgingival scaling as an intervention considered in the current study. The clinical and CIELab parameters were measured before and after the intervention. A highly significant ($p < 0.001$) reduction (improvement in the clinical picture) in all the clinical parameters was observed in the periodontitis group after the intervention. On the other side, the gingivitis group managed to show a significant ($p < 0.001$) reduction in all clinical parameters after the intervention, except the periodontal probing depth ($p > 0.05$) (Table 3).

3.2. Inferential Analysis of CIELab Parameters. Concurrently, the CIELab parameters were recorded before and after the intervention. In the gingivitis group, the a^* coordinate showed a significant ($p < 0.001$) reduction, whereas L^* showed a nonsignificant increase after the intervention. Also, a nonsignificant ($p > 0.05$) reduction was noted with respect to the b^* coordinate (Figure 3). Unlike the gingivitis group, the periodontitis group showed a significant reduction in both the a^* ($p < 0.001$) and b^* coordinates ($p < 0.01$). The L^* coordinate was found to show a nonsignificant ($p > 0.05$) increase after supra- and subgingival scaling (Figure 4).

3.3. Inter-group Comparison of ΔE . Another crucial parameter, ΔE , was initially calculated by using the traditional mathematical formula (Equation (1)). It was found to be 2.256 ± 2.614 and 2.961 ± 1.895 for the gingivitis and chronic periodontitis groups, respectively. Although on comparing the ΔE between the groups was nonsignificant ($p > 0.05$) but both the groups had it within the human eye threshold value of $\Delta E 3.7$ which is perceivable by the naked eye.

3.4. Causal Analysis with the Clinical and CIELab Parameters. Further exploration was considered for the significant results seen in the inferential analysis. In the gingivitis group, a strong positive correlation was found between the a^* coordinate with all clinical parameters (except PPD), namely, BOP ($p < 0.01$; $r = 0.840$), SBI ($p < 0.05$; $r = 0.704$), GI ($p < 0.05$; $r = 0.699$), and PI ($p < 0.01$; $r = 0.592$). On the contrary, in the periodontitis group, significant, weak positive correlation ($p < 0.05$; $r = 0.240$) was found between the a^* coordinate with gingival index (GI) only (Table 4). The criterion used for interpreting the strength of correlation coefficient (r) was adopted from Boslaugh and Watters [23].

TABLE 2: Sample characteristics.

Variable	Response	Study group		p value
		Gingivitis	Periodontitis	
Sample size		27	27	—
Gender, n (%)	Male	14 (51.9)	12 (44.4)	0.586
	Female	13 (48.1)	15 (55.6)	
Age (mean $\pm$ SD)		32.44 $\pm$ 10.059	37.67 $\pm$ 11.222	0.078

n : no. of participants; SD: standard deviation.

4. Discussion

Resolution of inflammation is considered as an utmost end-point for the success of nonsurgical periodontal therapy. By convention, it is subjectively assessed by the clinical examination or based on various indices. The present study attempts to objectively and quantitatively assess the colour of the gingiva aided by digital photograph which in turn is a cardinal sign of gingival inflammation. In the present study, we have found that the CIELab colour space value obtained from digital photographs was able to differentiate the pre- and postoperative colour changes of gingiva after nonsurgical therapy in both the gingivitis and chronic periodontitis groups.

On exploring the literature regarding improvement of gingival tissue with supra- and subgingival scaling, evidence can be traced way back in 1970s [24]. Since then, clinical parameters such as BOP, PPD, and various indices such as GI, PI, and SBI have been used to assess the effect of scaling [25]. Similar pattern was shown by the gingivitis patients of the current study, where the clinical parameters (except PPD) and all indices showed a significant reduction postoperatively. Unlike group A, chronic periodontitis patients showed significant decrease in all clinical parameters as well as indices postoperatively. This can be validated by the established fact that since the etiological agent such as plaque and calculus once removed, the gingival inflammation will resolve [26].

The a^* coordinate in the CIELab colour space, which is a positive value (+) in the gingivitis group, depicts red colour. It was found to be significantly reduced postoperatively, as there was a change in the gingival colour (Figure 3). The a^* coordinate has shown significant positive correlation with all indices and BOP. Incidentally, these results are not consistent with previous study [22]. This deviation can be attributed to the racial variation among the study populations considered in the given studies. The impact of race on the constitutional makeup of gingival tissue is a well-known fact. Also, the variation in results can be due to varied degree of gingival inflammation in patients recruited in different studies. It will be helpful in arresting the disease progress, when the gingival inflammation is identified and managed in its early stages. Although the recruitment of patients in the current study was randomized, but due attention was made to include majority of mild to moderate cases. The intention was to see the applicability of digital photography in the early stage of gingivitis. There are several other studies where they have estimated the decrease in the redness using

TABLE 3: Intragroup comparative analysis of clinical parameters before and after the intervention.

Study group	Variable	Intervention		<i>p</i> value
		Preoperative	Postoperative	
Gingivitis	Plaque index	1.266 ± 0.493	0.644 ± 0.277	<0.001
	Gingival index	1.277 ± 0.529	0.629 ± 0.360	<0.001
	Sulcus bleeding index	1.637 ± 0.906	0.892 ± 0.579	<0.001
	Bleeding on probing	43.222 ± 19.881	17.185 ± 10.648	<0.001
	Periodontal probing depth	2.125 ± 0.629	1.455 ± 0.578	0.064
Chronic periodontitis	Plaque index	2.400 ± 0.345	1.166 ± 0.517	<0.001
	Gingival index	2.107 ± 0.381	0.992 ± 0.426	<0.001
	Sulcus bleeding index	2.963 ± 0.801	1.922 ± 0.771	<0.001
	Bleeding on probing	68.777 ± 11.342	26.703 ± 11.148	<0.001
	Periodontal probing depth	4.203 ± 0.774	2.974 ± 0.832	<0.001

$p < 0.05$: statistically significant. Values are presented as the mean ± standard deviation.

FIGURE 3: Intragroup comparative analysis of photometric parameter in the gingivitis group. $p < 0.05$: statistically significant.

FIGURE 4: Intragroup comparative analysis of photometric parameter in chronic periodontitis group. $p < 0.05$: statistically significant.

RGB scale after periodontal therapy and their results are consistent with the findings of present study [6].

When CIELab values were compared within the CP patients, the a^* and b^* coordinates showed a significant postoperative reduction in their values, thus validating the change in the gingival colour (both in red and yellow). The third coordinate, L^* , showed a nonsignificant increased postoperative value and was comparable to previous studies [22]. The changes seen in the a^* and b^* coordinates are more in the chronic periodontitis group; it can be said because the tissues might be more inflamed in this group and a better resolution of inflammation is seen. Considering

the significant results of the a^* and b^* coordinates, correlation analysis was performed. Statistically significant positive correlation was observed between the GI and a^* coordinate.

The ΔE value represents the complete shift of colour represented by the L^* , a^* , and b^* colour coordinates. It is estimated that the normal permissible limit to detect any colour change of a naked eye is $\Delta E = 1.2$ [17, 27]. A study done by Saller et al. (2014) by photographic method to evaluate gingival colour was found an acceptability threshold of $\Delta E^* = 3.1$ [24]. Whereas, in another study, the ΔE threshold was 3.7 [22]. In the present study, the ΔE for the gingivitis group and periodontitis group was found to be 2.25 and 2.96,

TABLE 4: Correlation analysis between the clinical parameters and CIELab coordinates for both study groups.

Clinical parameters	Study group (with the CIELab values)		
	Gingivitis <i>L</i> * coordinate	<i>a</i> * coordinate	Chronic periodontitis <i>b</i> * coordinate
Plaque index	0.009** (0.592)	0.955 (0.011)	0.988 (0.003)
Gingival index	0.024* (0.699)	0.025* (0.240)	0.757 (0.063)
Sulcus bleeding index	0.014* (0.704)	0.292 (0.292)	0.640 (0.094)
Bleeding on probing	0.003** (0.840)	0.282 (0.215)	0.961 (0.010)
Periodontal probing depth	0.536 (0.012)	0.092 (0.331)	0.942 (0.015)

Values are presented as the *p* value (*r*: correlation coefficient). **p* < 0.05; ***p* < 0.01.

respectively, which is within the agreed threshold of both the studies. This could be attributed by the fact that the various gingival factors such as degree of keratinization and gingival biotype might have an influential role for observation of these differences.

In the CIELab colour space value, the positive value of the *a* * coordinate represents the redness of an object under evaluation. In the current study, due importance is given to the *a* * coordinate as it assesses the change in the colour of the gingiva before and after supra- and subgingival scaling. The *a* * coordinate value in gingivitis and periodontitis after one month postoperatively was in a range of 23.93 and 25.86, respectively, compared to preoperative value of 27.14 and 29.07. Whereas, in another study, the *a* * value for health gingiva was in the range of 20.4-24.8 [17]. This could be attributed with the fact that the assessment method tool used in the study was a spectrophotometer and the assessment was done on healthy gingiva.

We reject the null hypothesis, as the CIELab colour space coordinates taken for the anterior maxillary gingival tissue show variation between the pre- and postoperative values. The results of the present study suggest that the digital photographic images can be an acceptable and reliable method to measure the gingival redness (colour). Since colour is a cardinal sign of gingival inflammation, hence, digital photographs can be an effective tool in determining the gingival inflammation in pre- and postoperative nonsurgical periodontal therapies.

5. Limitations and Future Directions

There are few limitations of the study as well. As the photographs are taken in the maxillary anterior sextant, it cannot evaluate the inflammation in the posterior region or as a full mouth assessment. Various gingival biotypes and variations among the population and different races can also have a significant effect on estimating the colour difference.

Since the advent of digital era, the dental clinics are well equipped with digital technologies involved in diagnosis and various treatment modalities. Pre- and postoperative photographs are excellent means for educating the patients as well as maintaining records. Analysis of these photographs via using Adobe Photoshop for assessing gingival inflammation can be a suggested alternative. This method can be used in assessing the colour matching in periodontal plastic sur-

gery in anterior region as well as to differentiate between the different stages and grades of periodontitis.

6. Conclusions

Within the limitations of the current study, it can be concluded that the pre- and postoperative CIELab colour space values taken from digital photographs of gingivitis and chronic periodontitis patients undergoing nonsurgical periodontal therapy were able to assess the colour changes, which in turn reflects the gingival inflammation. Considering the above observation, digital photographs can be possibly used as a valuable tool for assessing the gingival inflammation in the maxillary anterior sextant.

Data Availability

The data set used in the current study will be made available on reasonable request from Dr. Deepti Shrivastava (sdeepti20@gmail.com).

Conflicts of Interest

The authors declare that they have no conflicts of interest to report regarding the present study.

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