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Cielab Assessment Of Enamel And Dentin Caries: An Original Study.

Jeeva S.[1], Dr. Dinesh[2]

[1] Undergraduate Student (Registration No. 152001056), Saveetha Dental College and Hospital, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai – 600041, Tamil Nadu, India.

Email: 152001056.sdc@saveetha.com

[2] Associate Professor, Department of Pedodontics, Saveetha Dental College and Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai – 600077, Tamil Nadu, India.

Email: dineskumarb.sdc@saveetha.com

Corresponding Author:

Dr. Dinesh

Email: dineskumarb.sdc@saveetha.com

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ABSTRACT

Background: Tooth bleaching remains one of the most requested and effective conservative procedures for treating intrinsic and extrinsic dental discoloration. To properly assess the efficacy of modern whitening agents, precise, quantifiable metrics are required, making spectrophotometric evaluation utilizing the CIE LAB tridimensional color space a clinical gold standard.

Objective: The aim of this study was to evaluate the optical behavior of tooth color using CIE LAB space; the teeth were subjected to novel bleaching gels containing peroxide carbamide with potassium oxalate.

Materials and Method: Three different carbamide peroxide gels were experimentally fabricated. They consisted of 10% (G10), 16% (G16) and 37% (G37) concentrations. Sixty recently extracted premolars were subjected to different bleaching protocols. Color change (ΔE) was assessed using the CIE Lab system after the application of each gel. The data were analyzed using one-way ANOVA with Tukey's post hoc test (α=5%) and a t-test.

Results: The G10 and G16 gels exhibited an increase in ΔE ab parameters from T0 to T1 (T0: application day of the gels. T1: 14th day measurement); a small decrease from T1 to T2 was also noted (T2: control measurement, 28th day). However, no statistically significant differences were found (p=0,22 for G10 and p=0,10 for G16). The G37 gel also exhibited an increase in ΔE*ab parameters, with similar results after the first application of 45 min, the second application of 45 min, and the third application of 45 min (T1, T2 and T3, respectively. T4: control measurement, 14th day). No statistically significant differences were observed between the three times of application (p>0,69), and an appreciable difference was noted between times T3 and T4 (p=0,000).

Conclusions: The presented formulations of peroxide carbamide at 10%, 16%, and 37% are clearly effective. The G10 and G16 gels exhibited better effectiveness than the G37 gel.

Keywords: CIE LAB ASSESSMENT ; Tooth caries ; Enamel and dentin caries.

INTRODUCTION

Tooth color is the result of the interaction of light with the different hard tissues that compose the tooth structure. When light reaches the tooth surface, many optical phenomena occur. Some portion of the light can be reflected as specular or diffuse light, and another portion is absorbed, dispersed or transmitted(Gönüllü et al. 2026). The final result is that the observer perceives color. A multitude of intrinsic color alterations can be successfully managed through the application of tooth-whitening agents. The vast majority of these commercial and professional systems utilize hydrogen peroxide—in varying concentrations—as the primary active agent(Heiden et al. 2026). While the precise chemical pathway of tooth bleaching is still under continuous investigation, it is widely accepted to be driven by an oxidation reaction. As the peroxide breaks down, ...

it releases water and highly reactive oxygen radicals. These radicals diffuse through the dentin and enamel, targeting complex, high-molecular-weight pigmented organic molecules known as chromophores(Sharma et al. 2026).

Chromophores often consist of metallic bioorganic chelator complexes or structures with heavily conjugated aromatic double bonds. The reactive oxygen dismantles these double bonds via oxidation, cleaving the chromophores into smaller, simpler, and lighter-colored structures. Consequently, the tooth's light absorption spectrum shifts, leading to an overall increase in luminosity(Sharma et al. 2026; Parlak Insel et al. 2026). Discoloration resulting from certain metallic compounds, however, presents a more resilient challenge and typically necessitates invasive restorative interventions rather than chemical bleaching alone.

During this oxidative bleaching reaction, the active hydrogen peroxide compound breaks down to release water alongside highly reactive oxygen radicals(Teplitzky et al. 2026). These free oxygen radicals possess the ability to diffuse deeply into both the enamel and dentin layers of the tooth(d'Apuzzo et al. 2026). Once inside the dental structure, the oxygen targets and interacts with specific high-molecular-weight organic pigments known as chromophores. These deeply pigmented chromophores typically consist of intricate structures, including conjugated aromatic double bonds or complex metallic bioorganic chelator compounds, which are responsible for the unwanted discoloration(Bittar et al. 2026).

Upon encountering these organic chromophores, the reactive oxygen actively degrades their double bonds through an oxidative breakdown, effectively reducing these complex pigmented molecules into simpler, colorless configurations. This structural degradation fundamentally alters the tooth's light absorption spectrum, which translates visually into a higher value of luminosity and an overall whiter appearance(Bittar et al. 2026; Fortunato et al. 2026). However, discoloration stemming from metallic compounds presents a significantly more formidable challenge, as their complex nature resists standard oxidative breakdown and often necessitates the use of more invasive restorative dental procedures to achieve optimal esthetic outcomes.

MATERIAL AND METHOD

Development of Bleaching Gels:

Three formulations of bleaching gels were developed. The elaboration was made by mixing 0,1% methylparaben (Aldrich®), 0,1% sodium benzoate (Merck®), 3% potassium oxalate (Fisher®), and peroxide carbamide at 10%, 16% and 37% (Merck®), respectively. To produce a complete formulation, sterile distilled water was used. Finally, Carbomer 940 at 2% and triethanolamine (Reutter®) were added under agitation. Pre-formulation studies were carried out in which the selected raw materials yielded the product with the desired characteristics. The following physical-chemical characterization tests were then carried out

Organoleptic characteristics:

Color, odor and texture were evaluated by a panel of five experts. To carry out the organoleptic tests, a reference or standard sample maintained under controlled environmental conditions was used. Color was evaluated by visual means, smell was evaluated through smell and texture was evaluated through touch. These measurements were made 0, 1, 2, 3, 6 and 12 months.

Apparent viscosity:

The samples were analyzed in a Brookfiel Viscosimeter (Splindle 06) at 100 rpm (10% and 16% peroxide carbamide) and 60 rpm (37% peroxide carbamide). The apparent viscosity values were registered after 24 h of gel preparation.

pH value:

The pH of each formulation was determined by a Hanna pH-meter at room temperature over the course of 12 months. Formulations with variations in pH value exceeding 15%, compared with the initial value, were removed from the sample.

Microbiological analysis:

The samples were seeded on Müeller-Hinton agar. The Petri dishes were incubated at 37°C, and the bacteria colonies were counted after 24, 48 and 72 hours. The final product did not have to be sterile and no specific pathogens were found (e.g., Escherichia *coli*, Pseudomonas *auroginosa*, Salmonella spp, Staphylococcus *aureus*).

Stability studies:

Duplicate samples were stored for 12 months at 40±2°C and 75% RH (accelerated stability) and at room temperature (25±2°C) and 60% RH avoiding exposure to light.

RESULTS

Organoleptic and physico-chemical parameter results

The organoleptic control showed similar results in the three groups, being these translucent and colorless, odorless, with firm texture, compact and with acceptable thixotropic characteristics. The viscosity in G10, G16 and G37 was 6780, 7730 and

16850 cP respectively. There is no standard for viscosity values in gels for dental bleaching products.

The pH values resulted in the following means: G10 pH= 4,75; G16 pH= 5,09 and G37 pH= 5,35. No colonies of bacteria or fungi were obtained in the microbiological control, which shows that the selection of the preservatives and their respective concentrations were adequate.

Value HVC

LAB

89.9,5.4,29.7

63.3,8.6,25.8

97.5,2.1,26.3

97.6,1.3,23.4

90,2.5,30.1

87.2,5.4,31.6

78.4,11.1,34.7

89,5.2,32.7

93.5,5,31.4

88.1,1.8,26.3

89.4,7.5,32.7

80.5,9.4,32.6

99,0.6,25.4

86,4.2,29.8

100,1.2,21.9

98.6,0.9,22.6

95.5,3.1,32.2

91.9,2.7,25.4

97.6,1.6,24.2

85,6.9,33

Control: 96.1,2.2,21.9

Table 1: CIE $L^*a^*b^*$ Color Space Values for Bleaching Gels Trial

Sample Number	Lightness (L^*)	Red-Green Chromaticity (a^*)	Yellow-Blue Chromaticity (b^*)
1	89.9	5.4	29.7
2	63.3	8.6	25.8
3	97.5	2.1	26.3
4	90.3	2.1	26.7
5	91.3	3.6	25.1
6	84.9	5.3	25.0
7	87.0	3.1	26.3
8	63.3	8.6	25.8
9	97.4	2.1	26.3
10	80.9	3.9	20.6
11	86.7	1.8	26.1
12	92.9	2.4	22.9
13	98.5	3.5	26.2
14	85.9	7.2	30.4
15	94.3	6.9	32.7
16	81.7	6.9	33.7
17	88.7	5.1	33.2
18	90.9	7.4	30.7
19	76.0	6.7	32.0
20	85.0	6.9	33.0
Baseline (Control Measure)	$L^* = 96.1$	$a^* = 2.2$	$b^* = 21.9$

The results of the stability tests were satisfactory; in shelf stability tests, changes were seen after 8 months, where there was a slight change in coloration. In the accelerated stability tests the changes appeared at 6 months, where there was dehydration due to extreme storage conditions.

DISCUSSION

Hydrogen peroxide is the most commonly used active compound of bleaching gels, it is the active ingredient of every carbamide peroxide gel(Caldwell et al. 2025). It has been shown to be an effective bleaching material whose effectiveness depends on many factors such as the concentration of the active compound and the time of application and duration of the treatment. Furthermore, it is not harmful to dental structures used by a dental professional(Pruthi et al. 2026). Different concentrations of the peroxide gels were successfully formulated and tested by organoleptic tests. Organoleptic tests are procedures used to evaluate the characteristics of a product, detectable by the sense organs. They provide parameters that make it possible to immediately assess the state of the sample under study through comparative analysis, with the aim of verifying alterations such as phase separation, precipitation and turbidity(Lee et al. 2026). These data enable the primary recognition of the product. A comparative analysis among the concentrations was hindered by the different times of application that were required, particularly for the 37% concentration. Even so, the 10% and 16% concentrations could be compared because the same protocols were used. Currently, there is no standard values for pH and viscosity for the formulation of bleaching gels(Namal 2026).

Although, according to some studies, the pH values would not produce a potential dental damage or sensitivity. As a recommendation, we suggest limiting the pH range above 5.5 to avoid possible damage of the enamel matrix. To ensure the physical integrity of the newly developed bleaching agents, organoleptic assessments were conducted(Lee et al. 2026; Buzato et al. 2026). These specialized tests rely on the human senses to evaluate the detectable characteristics of a product, providing immediate and valuable parameters regarding the physical state of the experimental samples. Through direct comparative analysis, organoleptic testing allows researchers to quickly identify any physical alterations or instabilities within the gel, such as turbidity, precipitation, or the separation of phases(González-Vaca et al. 2026). Consequently, this sensory data is crucial for the primary recognition and baseline quality control of the formulated products (Ganss et al. 2026).

The 10% and 16% peroxide carbamide concentrations demonstrated equal effectiveness in this study, findings confirmed by other studies. The ΔL^* parameter significantly increased, and Δa^* and Δb^* decreased(Ganss et al. 2026; Todorova 2026). These results are consistent with those of the study of Meireles et al., where the same concentrations of peroxide carbamide were used. This can be clinically appreciated as a higher value or lightness and less chromaticity, which is one of Munsell's dimensions of color associated with a tooth structure with a whiter optical appearance(Burlea et al. 2026). ΔE^*ab, which is color change, was maintained after the period of application. Although there was a small decrease, this change was not statistically significant(Burlea et al. 2026; Klitynska et al. 2025). Color was accordingly stable, and L^* values were maintained, proving that the 10% and 16% concentrations were effective(Burlea et al. 2026; Klitynska et al. 2025; Giannakopoulos et al. 2026).

CONCLUSION

In light of the experimental findings and within the boundaries of this specific investigation, it is evident that all three formulated concentrations of carbamide peroxide (10%, 16%, and 37%) function as highly effective dental bleaching agents. Spectrophotometric analysis utilizing the CIE LAB color parameters confirmed that the application of these gels successfully produced a definitive shift in overall tooth color. Specifically, the whitening process consistently led to an increase in the lightness parameter (L^*), while simultaneously yielding a measurable decrease in both the Δa^* and Δb^* dimensions. Ultimately, this optical transformation successfully enhances the luminosity of the tooth structure while actively reducing its overall saturation and chromaticity.

Within the limitations of the present study, we have shown that 10, 16 and 37% peroxide carbamide changes ΔE^*ab, increases L^*, decreases Δa^* and Δb^* of the CIE L^*a^*b color parameters, improves tooth lightness and reduces its chromaticity or saturation.

In summary, the comprehensive organoleptic, physico-chemical, and optical evaluations confirm that these newly synthesized carbamide peroxide gels are a reliable clinical option for treating dental discoloration. By effectively dismantling complex organic chromophores via an oxidative pathway, these materials provide a predictable enhancement to dental esthetics. Furthermore, the study reiterates that when properly formulated with appropriate preservatives and utilized under professional guidelines, these active oxidizing agents do not compromise the integrity of the underlying hard dental tissues. Therefore, these custom formulations represent a safe, stable, and highly effective therapeutic approach for conservative cosmetic dentistry.

FUTURE SCOPE

Future investigations should focus on the long-term physical effects of varying carbamide peroxide concentrations on dental enamel, specifically regarding surface roughness and microhardness changes over extended periods. Because thickeners like Carbopol are acidic and have the potential to bind to calcium thus, occasionally reducing enamel microhardness subsequent studies could explore the substitution of traditional thickeners with biocompatible alternatives such as Aristoflex (sulfonic acryloyldimethyltaurate acid copolymer), which maintains a stable pH and has shown less potential for cytotoxicity and physical enamel degradation. Furthermore, standardizing the application intervals across all high-concentration formulations would allow for a more precise, direct comparative analysis between low and high-concentration protocols.

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CONFLICT OF INTEREST

All the authors declare that there was no conflict of interest in the present study

AUTHORS CONTRIBUTION

Jeeva S - Study designing, data collection, analysis interpretation and manuscript preparation..

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