Effects of 10\% and 15\% Carbamide Peroxide on Extrinsic Enamel Discoloration caused by Black Tea

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Abstract. To determine the effects of 10\% and 15\% carbamide peroxide on extrinsic enamel discoloration caused by black tea. Thirty-two extracted human premolars randomly divided into two groups were soaked in a black tea solution for eight days, then mounted in microwax. The specimens were subjected to 14 applications of bleach, each of seven-hour duration. Color changes after the 7th and 14th applications were measured using the CIE L*a*b* method with VITA Easyshade®. Independent t-tests showed no significant difference in the color change value between groups. The data showed there was no difference in the effectiveness of bleaching using 10\% or 15\% carbamide peroxide on extrinsic enamel discoloration caused by black tea.

1. Introduction
Tooth discoloration can affect the enamel surface alone or also other tooth structures such as the pulp. Many causes of tooth discoloration have been found, such as the consumption of the antibiotic tetracyclin during tooth development, excessive fluoride intake, or the physiological aging process. The main cause of discoloration of the enamel surface is the habitual consumption of foods or drinks that can stain the enamel surface [1]. Extrinsic discoloration could be due to agents present in drinks such as coffee, tea, wine, and soft drinks [2].

Tea is a beverage obtained by processing the leaves of the tea plant or Camellia sinensis, belonging to the family Theaceae. Tea is the second most frequently consumed drink after water [3]. In 2013, the domestic consumption of tea in Indonesia reached 6,153 kg per capita per year [4]. Therefore, the high consumption of tea in Indonesia could be one of the predisposing factors in tooth discoloration.

Several methods of tooth whitening have been developed and are currently available, including in-office bleaching performed by dentists and home bleaching performed by patients and supervised by dentists [5]. Home bleaching is preferred by patients because of its ease of use and affordability compared to in-office bleaching. Home bleaching most commonly uses carbamide peroxide [6]. Carbamide peroxide is a strong oxidizing agent that can break down stain molecules attached to the teeth [7], resulting in a whiter tooth color. However, carbamide peroxide can also affect the roughness of the enamel surface, decreasing enamel hardness and increasing tooth sensitivity to temperature, which may cause pain [8].

The concentration of carbamide peroxide as a bleaching agent considered safe and effective is 10–20\%. Some studies have shown that factors such as concentration, thickness of application, or
viscosity of carbamide peroxide may affect the outcome of tooth whitening [9]. However, the effects of different concentrations of carbamide peroxide used in home bleaching on extrinsic tooth discoloration caused by black tea are still unknown. To address this question, we studied the effects of 10% and 15% carbamide peroxide on extrinsic tooth discoloration caused by black tea.

2. Materials and Methods
This study was conducted from August to October 2014 at the Dental Material Laboratory, Faculty of Dentistry, Universitas Indonesia. Thirty-two extracted and caries-free human premolars were used in this study. First, the specimens were cleaned and immersed in saline solution, then colorless nail polish was applied on the root, from the cemento enamel junction to the apex. Two bags of Sosro® branded black tea (four grams) were dipped in a glass beaker containing 320 ml boiling water with a three-minute brewing time. The pH of the solution was measured by immersing pH indicator strips into the solution. Next, the black tea was poured into pots, making the volume up to 10 ml in each. The tooth specimens were immersed in the black tea solution for 24 h and then incubated at 37 °C. The black tea solution was replaced daily with an identical tea solution for eight consecutive days. The tooth specimens were randomly divided into two groups: one group was treated with 10% carbamide peroxide and the other with 15% carbamide peroxide.

The initial color was measured using the VITA Easyshade® device. In each measurement, teeth were mounted in microwax with the buccal surface facing up. Specimens were placed on white HVS paper layered with a rag. The color was measured once for each specimen using the tip of the VITA Easyshade® probe covered in plastic wrap. Then, it was placed perpendicularly and attached to the central one-third of the buccal surface to obtain L*₀, a*₀, and b*₀ data.

Carbamide peroxide treatment was performed on the buccal surface of the teeth, and a brush with ±0.5 mm bristle thickness was then used to flatten them. All specimens were covered using a drug strip attached to the tooth surface, placed in a tray, then incubated at 37 °C for seven hours. Next, the specimens were removed from the incubator, cleaned using tissue, and rinsed with aquadest until no more carbamide peroxide remained. All specimens were then placed in a dry pot. The color was measured after the 7th application to obtain L*₁, a*₁, and b*₁ data, and after the 14th application to obtain L*₂, a*₂, and b*₂ data. The color was measured following the same procedure used in the initial color measurement.

All L*, a*, and b* data were processed to obtain the values of ∆E*, ∆L*, ∆a*, and ∆b* in each group. Statistical analyses were performed using independent sample t-tests with normally distributed and homogeneous data, to determine the differences in color changes between the groups. The ∆E*, ∆L*, ∆a*, and ∆b* values in each group at different applications were analyzed using paired sample t-tests with normally distributed data, to determine the differences in color changes between the 7th and 14th applications. Because the color change value (ΔE*) could not help determine the direction of color change, the mean values of L*, a*, and b* were analyzed using repeated measures ANOVA to determine the direction of the color changes.

3. Results
Visual observations showed that after immersion in a black tea solution, the color of all teeth became dark and brownish. After the 7th application of bleach, the tooth color in both groups became lighter and whiter. Further, the tooth color in both groups after the 14th application of bleach was lighter and whiter than that after the 7th application of bleach.
The average values of $\Delta E$ after the 7th and 14th applications of bleach are shown in Table 1.

**Table 1.** The mean values of color change ($\Delta E^*$)

|                  | 7th application | 14th application |
|------------------|-----------------|-----------------|
| 10% Carbamide Peroxide | 23.25           | 28.47           |
| 15% Carbamide Peroxide | 24.65           | 27.64           |

Both groups showed increases in $\Delta E$ after the 7th and 14th applications of bleach, with paired sample t-tests confirming that either 10% or 15% carbamide peroxide resulted in a significant increase. The mean $\Delta E$ values in the 15% carbamide peroxide group after the 7th day of application were higher than those in the 10% carbamide peroxide group. However, after the 14th day of application, the $\Delta E$ values in the 15% carbamide peroxide group were lower than those in the 10% carbamide peroxide group. These values were then analyzed using independent sample t-tests and no significant difference was found between them.

The mean values of $L^*$ after the 7th and 14th applications of bleach are shown in Table 2.

**Table 2.** The mean values of $L^*$

|                  | After discoloration | 7th application | 14th application |
|------------------|---------------------|-----------------|-----------------|
| 10% Carbamide Peroxide | 67.04              | 85.99           | 90.69           |
| 15% Carbamide Peroxide | 68.25              | 88.41           | 90.71           |

Both groups showed an increase in the mean value of $L^*$ after the 7th and 14th applications of bleach compared to that immediately after discoloration, with repeated measures ANOVA confirming a significant difference.

The values of $\Delta L^*$ after the 7th and 14th applications of bleach are shown in Table 3.

**Table 3.** The mean changes in values of $L^*$ ($\Delta L^*$)

|                  | 7th application | 14th application |
|------------------|-----------------|-----------------|
| 10% Carbamide Peroxide | 18.95           | 23.65           |
| 15% Carbamide Peroxide | 20.16           | 22.46           |

Independent sample t-tests showed no significant difference between the two bleaching groups. Paired sample t-tests showed significant differences in $L^*$ value change after the 7th and 14th applications in both groups.
The mean values of $a^*$ after the 7th and 14th applications of bleach are shown in Table 4.

**Table 4. The mean values of red-green chroma ($a^*$)**

| After discoloration | 7th application | 14th application |
|---------------------|-----------------|------------------|
| 10% Carbamide Peroxide | 17.98           | 5.88             | 3.71             |
| 15% Carbamide Peroxide | 17.03           | 4.81             | 3.53             |

When the $a^*$ degree was initially measured, immediately after the teeth were immersed in the black tea solution, the mean value of $a^*$ was high. After the 7th and 14th applications, the mean values of $a^*$ in each group were at the $+a^*$ coordinates, which lie in the red region. Repeated measures ANOVA showed a significant difference in the mean value of red-green chroma ($a^*$) between the groups. A decrease in the mean value of red-green chroma indicates a color closer to neutral.

The values of $\Delta a^*$ after the 7th and 14th applications of bleach are shown in Table 5.

**Table 5. The mean values of red-green chroma change ($\Delta a^*$)**

| 7th application | 14th application |
|-----------------|------------------|
| 10% Carbamide Peroxide | −12.09           | −14.27           |
| 15% Carbamide Peroxide | −12.23           | −13.50           |

Table 5 shows the differences in the values of red-green chroma changes ($\Delta a^*$) in the groups. Independent sample $t$-tests showed no significant difference between the two bleaching groups. Paired sample $t$-tests showed significant differences (decreases) in red-green chroma values after the 7th and 14th applications in both groups.

The mean values of $b^*$ after the 7th and 14th applications of bleach are shown in Table 6.

**Table 6. The mean values of yellow-blue chroma ($b^*$)**

| After discoloration | 7th application | 14th application |
|---------------------|-----------------|------------------|
| 10% Carbamide Peroxide | 41.14           | 41.09            | 36.96            |
| 15% Carbamide Peroxide | 39.96           | 37.51            | 34.56            |

In each bleaching group, the mean initial value of $b^*$ was at the $+b^*$ coordinates, which indicates that all specimens were in the yellow chroma. After the 7th and 14th applications, there were decreases in the mean value, but these were still in the yellowish range. Repeated measures ANOVA showed significant differences in the yellow-blue chroma values ($b^*$) between the groups, but pairwise comparisons showed no significant decrease between the initial measurement and the measurement after the 7th application.
The values of $\Delta b^*$ after the 7th and 14th applications of bleach are shown in Table 7.

|                | 7th application | 14th application |
|----------------|-----------------|------------------|
| 10% Carbamide Peroxide | −0.05           | −4.18            |
| 15% Carbamide Peroxide  | −2.45           | −5.40            |

Table 7 shows the differences in the values of yellow-blue chroma change ($\Delta b^*$) in the groups. Independent sample t-tests showed no significant difference between the two bleaching groups. Paired sample t-tests showed significant differences (decreases) in yellow-blue chroma values after the 7th and 14th applications in both groups.

4. Discussion
After the immersion of teeth specimens in a black tea solution and the formation of stains on their buccal surface, both groups showed a low $L^*$ value, indicating low brightness level (darker color) of the specimens. The $a^*$ and $b^*$ values lay in the positive and high ranges in both bleaching groups, indicating that the color of the teeth became more reddish and yellowish [10]. These reddish and yellowish changes are related to pigments in black tea: thearubigins (red), theaflavins (yellow) [11], and tannins (dark brown) [12]. The attachment of pigments to the tooth surface leads to low brightness ($L^*$) due to light being absorbed by the pigments [13].

After bleach applications, all color components ($L^*$, $a^*$, $b^*$) changed in both the groups ($L^*$ increased, and $a^*$ and $b^*$ decreased). Carbamide peroxide thus succeeded in reducing the black tea stains on the tooth surface by oxidation. H2O2 (in carbamide peroxide) breaks down into HO2 and O; HO2 binds to black tea stain pigment molecules (tannins), interfering with electron binding and altering energy absorption by the organic molecules in enamel, and forming simple molecules that do not reflect light. Consequently, the brightness of the teeth increases in clinical measurements [1,14].

The present study found that after the 7th application of bleach, significant color changes ($\Delta E$) occurred in both bleaching groups. The mean values of $\Delta E$ in the 15% carbamide peroxide group were higher than those in the 10% carbamide peroxide group. However, statistical analysis showed no significant differences between these values, indicating that both concentrations had the same effectiveness in teeth whitening. After the 14th bleach application, the mean $\Delta E$ values in the 15% carbamide peroxide group were lower than those in the 10% carbamide peroxide group, but statistical analysis showed no significant differences.

Other studies have shown that 15% carbamide peroxide yielded the same final color change as did a concentration of 10% after 14 days of application [15]. However, 15% carbamide peroxide has been shown to provide a faster color change than 10% [15,16].

Both concentrations of carbamide peroxide resulted in a change in the $\Delta E$ value after the 7th and 14th days of application. The $\Delta E$ value was the difference in each color component ($L^*$, $a^*$, $b^*$) between the initial status and after bleach application. The mean $\Delta E$ value after the 14th day of bleaching was higher than that after the 7th day of bleaching at both peroxide concentrations with statistically significant differences, indicating that both concentrations were more effective after the 14th application than after the 7th application. The continued application of carbamide peroxide reduced the black tea stain pigments attached to the tooth surface ($\Delta E$ decreased) [14]. The decrease in the $\Delta E$ value is due to reduced pigmented organic compounds [1]. During the initial bleaching of pigmented compounds, carbon ring bonds are broken and transformed into simpler and less light-reflecting chemical bonds [1]. As the bleaching process continues, the compounds will attain saturation and become ineffective [1]. Thus, timing is an important factor in tooth whitening. As more
bleaching material is applied to teeth, tooth color becomes brighter, but as the bleaching process continues, the bleaching material will become saturated and ineffective.

Both bleaching groups showed significant changes in color in terms of all three components (L*, a*, b*). The value component (brightness level) was higher in both the 10% and 15% carbamide peroxide groups after the 7th and 14th days of application, indicating that both concentrations were equally effective at stain removal by oxidation [1]. This value is expected to increase as the amount of light reflected increases [17]. If color pigments were accumulated on the tooth surface, the amount of light reflected would be less because the light would be absorbed by the pigments, causing a darker tooth color [13]. As oxidation by peroxide continues, more color pigments are oxidized and removed from the tooth surface, causing more light to be reflected and a brighter tooth color. However, the L* values did not differ significantly between the 10% and 15% concentration groups, indicating no significant increases in the tooth brightness level.

The chroma components (a* and b*) decreased in both the 10% and 15% carbamide peroxide groups after the 7th and 14th applications. The ability of bleaching materials to oxidize color pigments causes this decrease in chroma values [1]. The chroma value increases when the number of reflected wavelengths increases [17]. In the present study, the chroma value decreased, indicating that the number of reflected wavelengths decreased, causing a reduction of reddish and yellowish chroma of the teeth to a more neutral color.

The mean a* value decreased to a range of 4.81–5.88 after the 7th application, and to a range of 3.53–3.71 after the 14th application, which lie in the neutral color range [18]. The mean a* values in each group were at the +a* coordinates, which are in the reddish region, although more toward a neutral color. Thus, the process of tooth whitening causes teeth to become less reddish.

The mean b* value decreased after the 7th application, but this was not statistically significant. However, at the end of the 14th application, the b* value decreased significantly until it reached a range of 34.56–36.96, which still lies in the yellowish range because it lies within the +b* coordinates. This is due to red stain pigments (thearubigins) being more abundant than yellow stain pigments (theaflavins) in black tea [12]. Tooth whitening causes teeth to become less yellowish. However, there was no significant difference between 10% and 15% carbamide peroxide in chroma degradation, because the measured values of a* and b* did not differ between the groups.

Based on the results of this study, it can be concluded that there is no difference in effectiveness between 10% and 15% carbamide peroxide treatment of one or two weeks in whitening extrinsic tooth discoloration caused by black tea.

5. Conclusion
In conclusion, the present study evaluated carbamide peroxide bleaching of black tea-induced extrinsic enamel discoloration, and found that color changes toward a lighter level after 7 and 14 days of 10% or 15% carbamide peroxide application. Further, there was no difference between the effectiveness of 10% and 15% carbamide peroxide.

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