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RESEARCH ARTICLES

The effect of activated charcoal and bentonite toothpaste on extrinsic tooth discoloration

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ABSTRACT

Tooth discoloration is categorized into intrinsic and extrinsic types, with the latter caused by external staining agents such as pigmented beverages (e.g., black tea). Whitening toothpastes are commonly used to address extrinsic discoloration, though chemical-based formulations may lead to side effects. Consequently, natural alternatives, including activated charcoal and bentonite, are gaining attention as whitening agents. This study aimed to evaluate the effects of activated charcoal and bentonite toothpaste on extrinsic tooth discoloration. A control group pretest-posttest design was employed, involving 48 premolar teeth divided into four groups. Samples were stained by immersion in a black tea solution (400 mL water, 4 tea bags) for 4 hours daily over 13 days, simulating 7 months of tea consumption. Color measurements were conducted using a spectrophotometer before and after brushing. Brushing was carried out using an electric toothbrush with 0.5 g of toothpaste and 1 mL of distilled water for 2 minutes, twice daily, over 10 days. Repeated ANOVA analysis revealed significant differences in ΔE, ΔL, and ΔC values ($p < 0.05$). Activated charcoal toothpaste produced a marked lightening effect and increased color intensity, although no change was observed at the cervical region of the teeth. These findings suggest that activated charcoal may serve as an effective natural agent for managing extrinsic discoloration while further research is needed to clarify its long-term effects and clinical applications.

Keywords: activated charcoal toothpaste; bentonite toothpaste; discoloration; tooth discoloration

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INTRODUCTION

Tooth color, especially in the anterior region, plays a central role in aesthetics and self-confidence. Bright teeth are often associated with health and enhance self-esteem.[1] Research by Hadi et al. shows that teenagers in Medan have a high desire for white teeth,[2] supported by Nuryanti et al.'s study in Samarinda, where 57.8% of individuals complained about their teeth, including their color.[3] These findings reflect widespread concerns regarding tooth discoloration in Indonesia. Tooth discoloration, which negatively affects facial aesthetics and self-esteem,[4] is categorized as intrinsic or extrinsic.[5] Intrinsic discoloration is caused by developmental disorders of the teeth, antibiotics, metabolic diseases, or trauma,[6] and is difficult to eliminate because it involves stains on both enamel and dentin.

Extrinsic discoloration, by contrast, occurs on the tooth surface due to factors such as tobacco, mouthwash, pigmented foods and beverages (e.g., >400 mg/day tea consumption), and poor oral hygiene.[7] According to Aswin et al., the prevalence of extrinsic discoloration from tea and coffee is higher than intrinsic discoloration.[8] Brushing with toothpaste is the most accessible method of stain removal.[9] Conventional toothpaste formulations typically contain abrasive agents (e.g., calcium carbonate), humectants (e.g., glycerin), binders (e.g., carboxymethyl cellulose), preservatives, flavoring agents (e.g., menthol), and detergents (e.g., sodium lauryl sulfate).[10] Oral care products are increasingly marketed with a focus on whitening, as white teeth and a bright smile are associated with improved quality of life.[11]

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Whitening toothpaste is effective in removing extrinsic discoloration stains,[11] but many contain chemical agents such as hydrogen peroxide (3–6%), sodium citrate, or sodium pyrophosphate.[12,13] However, high concentrations of chemicals can cause side effects, including gum irritation, allergies, and sensitive teeth.[14] Hydrogen peroxide oxidizes stains at the tooth surface but carries risks of enamel damage with long-term use.[15] Therefore, natural ingredients are being considered as safer alternatives to prevent enamel damage.[16] Activated charcoal and bentonite have recently been introduced as natural whitening ingredients.[17,18] Activated charcoal, derived from materials such as coconut shells and bamboo, possesses high absorbency and abrasive capacity that can effectively reduce staining.[19] Bentonite, a natural clay containing minerals like calcium and magnesium, helps remineralize and strengthen tooth enamel.[20,21]

Both agents provide abrasive action capable of removing extrinsic stains without the potential enamel damage associated with chemical bleaching agents. Therefore, this study was conducted to examine the effects of activated charcoal and bentonite toothpaste on tooth color changes due to extrinsic discoloration. The findings are expected to provide insights into the efficacy of these natural agents in teeth whitening, inform dental education and clinical practice, and increase public awareness of their potential as safe and effective alternatives.

MATERIALS AND METHODS

This study was an in vitro experimental laboratory research using a control group pretest–posttest design. The research was conducted at the Dental Materials and Testing Core (DMT Core), Faculty of Dentistry, Trisakti University, between September and October 2024. The samples consisted of extracted first maxillary premolars from adults that met the following criteria: intact buccal surface, free of caries, no root fractures, no occlusion interference, no root perforations, and no anomalies. The sample size for each treatment was calculated using the Lemeshow formula:

$$n = 2\left(\frac{(z\alpha + z\beta)S}{x1 - x2}\right)^2$$

Description :

Za : Alpha value (1.96)
Zß : Beta value (0.84)
S : Standard deviation (13.664)
x1 - x2 : Minimum mean difference considered significant (30.533)

Based on this calculation, the minimum required sample size was four teeth per group. In this study, 12 teeth were used per group, giving a total of 48 samples. Group 1 was brushed with activated charcoal toothpaste, Group 2 with bentonite toothpaste, Group 3 with hydrogen peroxide toothpaste, and Group 4 with fluoride toothpaste.

This study has specific inclusion and exclusion criteria. Inclusion criteria were first maxillary premolars extracted for orthodontic purposes, with buccal surfaces free of cavities, fractures, fillings, perforations, or anomalies. Exclusion criteria were premolars with buccal surfaces containing cavities, restorations, or erosion. The research variables consisted of independent, dependent, and controlled factors. The independent variables were the types of toothpaste used, namely activated charcoal and bentonite toothpaste. The dependent variable was the degree of color change observed in the teeth. Controlled variables included tea immersion time (4 hours per day for 13 days), brushing frequency and duration (twice daily for 2 minutes over 10 days), the method of tea preparation, incubation temperature, the type of electric toothbrush, the composition of artificial saliva, the source of distilled water, the volume of immersion solution, the ratio of toothpaste to distilled water, the applied brushing force, and the method of color measurement.

The equipment used included a spectrophotometer (VITA Easyshade V), infrared thermometer (Sinocare AET-R1D1), electric toothbrush (KLAR Sonic Toothbrush 2 in 1), dropper, digital scale, protective equipment (masks, gloves), containers, 100 g weights, incubator, and universal table vise. Materials included 48 extracted premolars, black tea, and the following toothpastes: activated charcoal (Formula Charcoal, 160 g), bentonite (Closeup White Attraction Mineral Clay & Acai Berry, 100 g), fluoride (Pepsodent Pencegah Gigi Berlubang, 120 g), and hydrogen peroxide (Unpa Cha-cha Whitening, 100 g). Additional materials were clear nail polish, distilled water, tissue, double-sided tape, and artificial saliva containing NaCl, KCN, $NaHCO_3$, KCl, urea, Na_2HPO_4, and KH_2PO_4.

The procedure began with the preparation of 48 extracted premolars, divided into four groups of 12 teeth each. The roots and cervical areas were coated with clear nail polish to prevent tea penetration into dentinal tubules. The tea solution was prepared by boiling 400 mL of water to 100 °C, adding four black tea bags, and boiling for 3 minutes. After cooling, the solution was stored at room temperature. Teeth were immersed in the tea solution in an incubator for 4 hours per day, then transferred to distilled water to maintain moisture, repeated for 13 days. The tea solution was renewed daily. A 13-day immersion period was considered equivalent to 7 months of daily tea consumption (one cup/day for 15 minutes).

After immersion, samples were rinsed with distilled water for 20 seconds, dried with tissue, and measured using the spectrophotometer against a white background. Measurements were taken at the center of each sample at a 90° angle to ensure consistent placement and light reflection.

Samples were divided into four treatment groups: Group 1 brushed with activated charcoal toothpaste, Group 2 with bentonite toothpaste, Group 3 with hydrogen peroxide toothpaste (positive control), and Group 4 with fluoride toothpaste (negative control). Brushing was performed using an electric toothbrush fixed to a table vise, with a 100 g weight attached to the brush head via double-sided tape. The toothpaste–water ratio was 1:2 (0.5 g toothpaste and 1 mL distilled water). Each sample was brushed for 2 minutes, twice daily, then rinsed. Treatments continued for 10 days, with samples stored in artificial saliva in the incubator when not undergoing treatment. After 10 days, samples were rinsed, dried, and their final color measured using the same protocol.

Data were analyzed using the Shapiro–Wilk normality test (appropriate for $n < 50$). If normally distributed ($p > 0.05$), repeated-measures ANOVA was applied. This study obtained ethical approval from the Ethics Committee of the Faculty of Dentistry, Universitas Trisakti, prior to commencement.

RESULTS

This study was conducted from September to October 2024 at the DMT Core Laboratory, Faculty of Dentistry, Universitas Trisakti, using a control group pretest–posttest design. Data were analyzed using the Shapiro–Wilk test for normality, followed by repeated measures ANOVA.

The color measurements for each sample group were obtained using the indicators ΔE, ΔL, ΔC, and ΔH. The research data were analyzed for mean and standard deviation, as presented in Tables 2–5..

Table 1 shows that in the activated charcoal group, the values of ΔE and ΔH decreased, while ΔL and ΔC increased after brushing. Table 2 shows that in the bentonite group, ΔE and ΔC decreased, while ΔL and ΔH increased after brushing. Table 3 shows that in the hydrogen peroxide group, ΔE, ΔC, and ΔH decreased, whereas ΔL increased after brushing. Table 4 shows that in the fluoride group, ΔE, ΔL, ΔC, and ΔH did not show significant changes after brushing.

Normality testing was performed to determine whether the data followed a normal distribution. Because the study involved fewer than 50 samples, the Shapiro–Wilk test was used. The results of the normality tests are presented in Tables 6 and 7.

Table 1. Average color changes values in the activated charcoal group

	Activated charcoal	
Value	Soaking	Brushing
ΔE	11.69 ± 0.742	9.35 ± 0.259
ΔL	1.71 ± 0.390	6.49 ± 0.475
ΔC	10.23 ± 0.673	10.31 ± 0.906
ΔH	-1.03 ± 0.723	-1.28 ± 0.754

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Table 2. Average color change values in the bentonite group

Value	Bentonite	
	Soaking	Brushing
ΔE	11.7 ± 0.63	8.57 ± 0.65
ΔL	2.09 ± 0.58	4.49 ± 0.61
ΔC	11.54 ± 0.24	4.47 ± 0.57
ΔH	-1.49 ± 0.73	1.26 ± 0.606

Table 3. Average color change values in the hydrogen peroxide group

Value	Hydrogen peroxide	
	Soaking	Brushing
ΔE	12.6 ± 0.73	10.65 ± 0.80
ΔL	1.49 ± 0.57	1.67 ± 0.46
ΔC	9.76 ± 0.36	9.44 ± 0.50
ΔH	-0.76 ± 0.44	-0.93 ± 0.38

Table 4. Average color change values in the fluoride group

Value	Fluoride	
	Soaking	Brushing
ΔE	11.38 ± 0.49	10.88 ± 0.58
ΔL	0.86 ± 0.97	0.74 ± 0.87
ΔC	10.32 ± 0.37	9.73 ± 0.45
ΔH	-0.95 ± 0.81	-0.83 ± 0.80

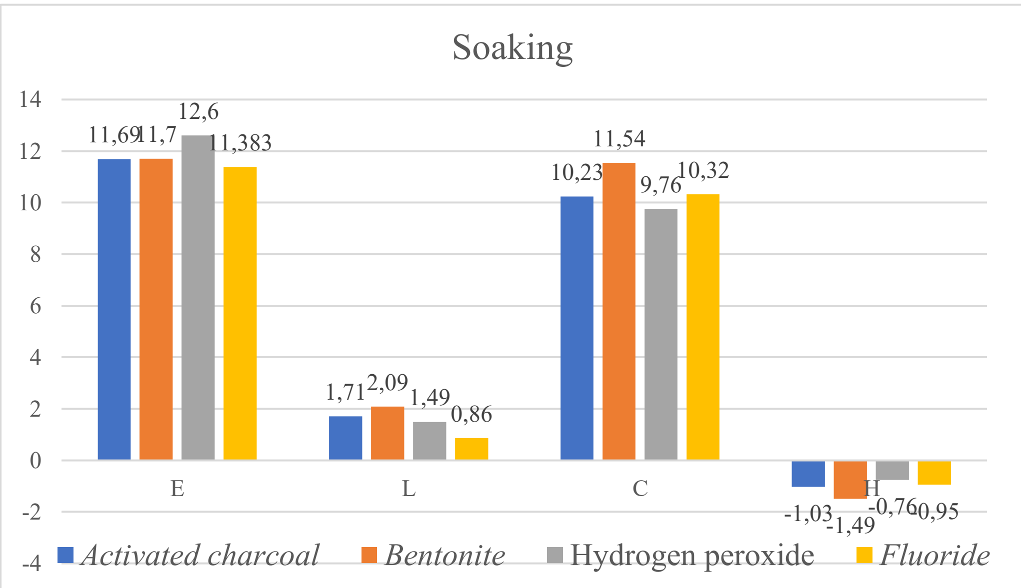

Figure 1. Graph of color measurement results after immersion in black tea

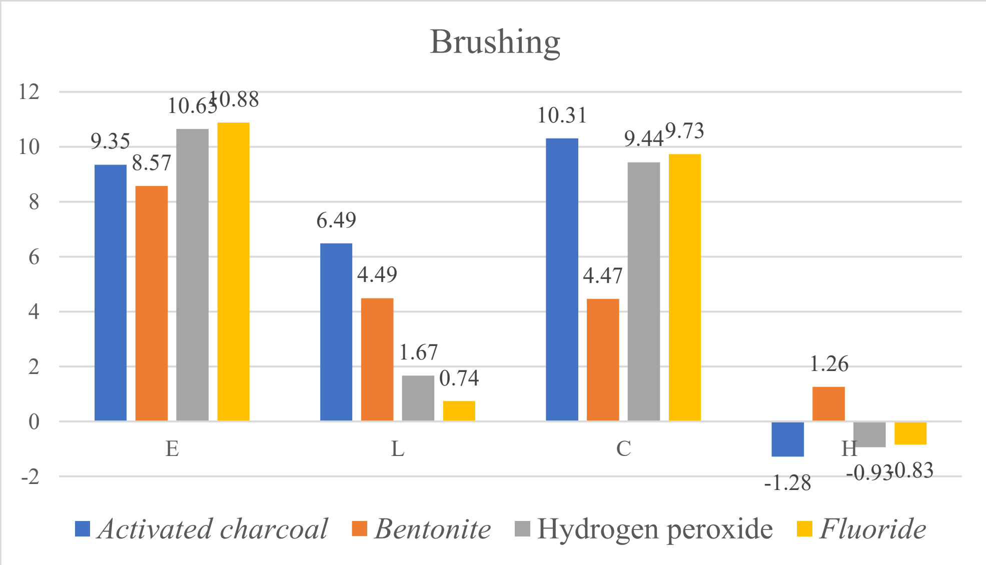

Figure 2. Graph of color measurement results after brushing

Table 5. Shapiro-Wilk normality test after immersion in the solution

Group	Variable	Shapiro-wilk		
		Statistic	df	p
Activated charcoal	ΔE	0.910	10	0.279*
	ΔL	0.942	10	0.575*
	ΔC	0.936	10	0.509*
	ΔH	0.987	10	0.991*
Bentonite	ΔE	0.854	10	0.065*
	ΔL	0.931	10	0.461*
	ΔC	0.958	10	0.764*
	ΔH	0.900	10	0.220*
Hydrogen peroxide	ΔE	0.958	10	0.768*
	ΔL	0.959	10	0.770*
	ΔC	0.948	10	0.645*
	ΔH	0.938	10	0.527*
Fluoride	ΔE	0.937	10	0.524*
	ΔL	0.920	10	0.360*
	ΔC	0.937	10	0.517*
	ΔH	0.980	10	0.966*

*Data is normally distributed if $p > 0.05$

In Table 5, the Shapiro–Wilk test showed $p > 0.05$, indicating that the data after immersion in black tea were normally distributed. In Table 6, the test also showed $p > 0.05$, indicating that the data after treatment were normally distributed. Since all data were normally distributed, repeated measures ANOVA was performed. The results of the ANOVA are shown in Table 7.

Table 6. Shapiro-Wilk normality test after treatment

Group	Variable	Shapiro-wilk		
		Statistic	df	p
Activated charcoal	ΔE	0.853	10	0.063*
	ΔL	0.863	10	0.082*
	ΔC	0.870	10	0.100*
	ΔH	0.883	10	0.143*
Bentonite	ΔE	0.962	10	0.810*
	ΔL	0.930	10	0.450*
	ΔC	0.956	10	0.734*
	ΔH	0.934	10	0.487*
Hydrogen peroxide	ΔE	0.919	10	0.351*
	ΔL	0.971	10	0.902*
	ΔC	0.887	10	0.157*
	ΔH	0.963	10	0.819*
Fluoride	ΔE	0.934	10	0.493*
	ΔL	0.949	10	0.658*
	ΔC	0.879	10	0.126*
	ΔH	0.951	10	0.679*

*Data is normally distributed if p > 0.05

Table 7. Repeated ANOVA test

Indicator	Group	Mean ± SD	p
ΔE	Activated charcoal	9.35 ± 0.259	0.003*
	Bentonite	8.57 ± 0.65	
	Hydrogen peroxide	10.65 ± 0.80	
	Fluoride	10.88 ± 0.58	
ΔL	Activated charcoal	6.49 ± 0.475	0.006*
	Bentonite	4.49 ± 0.61	
	Hydrogen peroxide	1.67 ± 0.46	
	Fluoride	0.74 ± 0.87	
ΔC	Activated charcoal	10.31 ± 0.906	0.000*
	Bentonite	4.47 ± 0.57	
	Hydrogen peroxide	9.44 ± 0.50	
	Fluoride	9.73 ± 0.45	
ΔH	Activated charcoal	-1.28 ± 0.754	0.211
	Bentonite	1.26 ± 0.606	
	Hydrogen peroxide	-0.93 ± 0.38	
	Fluoride	-0.83 ± 0.80	

*p < 0.05 = Significant difference

Table 7 indicates that the repeated measures ANOVA revealed the highest mean ΔE in the fluoride toothpaste group, with significant differences between groups ($p \leq 0.003$). The highest mean ΔL and ΔC were observed in the activated charcoal group, both showing significant differences ($p \leq 0.006$ and $p \leq 0.000$, respectively). However, ΔH did not show a significant difference between groups ($p \geq 0.211$).

DISCUSSION

The selection of black tea was based on research by Kasihani et al., who found that 96% of 45 respondents from Kampung Bali, Tanah Abang, consumed tea daily.[22] The high tannin content in black tea (65.157 mg/g) leads to tooth discoloration because tannins contain dark pigments, unlike white tea, which has the lowest tannin content (46.040 mg/g).[23,24] Pigments from black tea can penetrate the enamel structure and cause staining.[25] In this study, black tea was prepared with 400 mL of water and four tea bags, boiled for three minutes. The samples were soaked for four hours per day, following the method of Felicia et al., to simulate tea consumption over seven months.[26]

Color measurements of the upper first premolar samples were performed using the VITA Easyshade V spectrophotometer with the CIELCH system, evaluating ΔE, ΔL, ΔC, and ΔH. Here, ΔE represents total color deviation, ΔL indicates brightness, ΔC shows color intensity, and ΔH reflects the base hue.[27] The results demonstrated an increase in ΔL and ΔC in the activated charcoal group, indicating that the samples became brighter after brushing. This finding is consistent with Tomas et al., who reported that activated charcoal, derived from natural materials with large pores, effectively absorbs stains from colored beverages. The concentration of activated charcoal in toothpaste typically ranges from 7.5% to 30%, with this study employing concentrations of 15–20%.[28]

Lestari et al. reported that toothpaste with 12% palm kernel–based activated carbon effectively removes stains and plaque.[29] Pertiwi et al. highlighted the role of abrasives such as hydrated silica in scrubbing stains,[30,31] while Hartono et al. noted that sodium lauryl sulfate contributes to stain removal.[32] The decrease in ΔH in the activated charcoal group indicates no major shift in the base tooth color, in line with Priyanto et al., who found that activated charcoal toothpaste can abrade enamel and expose dentin.[33] In contrast, the bentonite group showed an increase in ΔL and ΔH, suggesting brighter teeth. Bentonite contains montmorillonite, kaolinite, and illite, which function as stain absorbers and abrasives.[34,35]

The reduction in ΔC in this group indicates that bentonite toothpaste may lead to darker discoloration because its mild abrasives are less effective at cleaning, consistent with the findings of Ruskandi et al.[36] The increase in ΔL in the hydrogen peroxide group confirms its whitening effect, consistent with the oxidative action of reactive oxygen species that break down tooth pigments, as described by Vaz et al.[37,38] However, the concurrent decrease in ΔC and ΔH suggests no major shift in the base tooth color, possibly due to enamel damage from the strong chemical action of hydrogen peroxide, as reported by Yuniarti et al.[39]

In the fluoride group, ΔL, ΔC, and ΔH showed no significant improvement after brushing. Fluoride (F^-) contributes primarily to caries prevention and enamel strengthening through compounds such as sodium fluoride and stannous fluoride.[40] It promotes remineralization but does not whiten teeth, as confirmed by O'Mullane et al.[41] Fluoride substitutes hydroxyl groups in hydroxyapatite with fluorapatite, which is more resistant to acid attack.[42]

The effectiveness of brushing also depends on technique. Budirahardjo et al. found that electric toothbrushes reduce plaque more effectively than manual ones.[43] Clarence et al. explained that electric toothbrushes employ vibration or rotation, with speeds ranging from 2,400 to 2,400,000 movements per minute, using durable nylon bristles.[44] For color assessment, Guy et al. emphasized that spectrophotometers are more accurate than shade guides, though they are costly and sensitive to environmental conditions.[45,46] A limitation of this study is the reliance on expensive instruments, which restricted sample size.

Future studies should explore the biomolecular mechanisms of active toothpaste compounds to better understand their effects.

CONCLUSION

This study concludes that activated charcoal and bentonite toothpastes are effective in reducing extrinsic discoloration caused by black tea immersion (4 hours/day for 13 days). Activated charcoal showed the greatest effect, producing brighter teeth and enhanced color intensity due to its strong abrasive properties, although no change was observed in the base tooth color. Future research is recommended to investigate the biomolecular mechanisms underlying the action of toothpaste compounds to provide a deeper understanding of their effects on dental tissues.

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Conflict of interest

The authors declare no conflicts of interest related to this study.

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