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RESEARCH ARTICLE

Tooth Lightness Changes with Listerine Healthy White after Application of Tooth-Coloring-Inducing Foods

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Background: The purpose of this study is to investigate the tooth whitening effect of Listerine Healthy White and provide effective management of extrinsic discoloration by comparing the whitening effects of existing whitening products.

Methods: The included study four groups: those using whitening gel, whitening toothpaste, and Listerine Healthy White and a control using artificial saliva. Each group received 40 bovine tooth specimens, which were stained with commonly consumed tooth-coloring-inducing foods; black tea, black coffee, and instant noodles for 72 hours. The specimens were treated with tooth whitening materials for 5 weeks, after which the lightness (L*) was measured weekly using a spectrophotometer.

Results: There was a significant difference in lightness among the groups between the 1st and 5th week of treatment for all tooth-coloring-inducing foods ($p<0.05$). When comparing the changes in lightness values from before whitening to the 5th week of whitening for all tooth-coloring-inducing foods, the order of change was as follows: whitening gel, whitening toothpaste, Listerine Healthy White, and artificial saliva. Listerine Healthy White showed a significant whitening effect for all tooth-coloring-inducing foods ($p<0.05$). Particularly, changes in lightness values for specimens stained by black tea after 5 weeks of whitening were in the following order: whitening gel (21.72), whitening toothpaste (14.89), Listerine Healthy White (12.91), and artificial saliva (3.85). For specimens stained by black coffee, the changes in lightness values were in the following order: whitening gel (12.99), whitening toothpaste (9.66), Listerine Healthy White (7.91), and artificial saliva (3.12). Lastly, changes in lightness values for specimens stained by instant noodles were as follows: whitening gel (10.84), whitening toothpaste (9.85), Listerine Healthy White (7.71), and artificial saliva (2.61).

Conclusion: Listerine Healthy White exhibits continuous whitening effects over time, and for consumers seeking convenient ways to achieve tooth whitening effects at home, consistent use of Listerine Healthy White is recommended.

Key Words: Colorimetry, Mouthwashes, Tooth bleaching, Tooth discoloration

Introduction

1. Background

With the advancement of modern medical technology, the aesthetic standards of patients have been elevated, leading to an increase in the number of patients seeking cosmetic treatments. As a result, the use of teeth whitening procedures and over-the-counter (OTC) whitening products in dental practice are on the rise[1)]. The causes of tooth discoloration, which require teeth whitening procedures, can be categorized into intrinsic and extrinsic factors. Intrinsic discoloration originates from within the tooth, often caused by tetracycline medication intake during pregnancy and dental trauma. Conversely, extrinsic discoloration is caused by external factors, typically resulting from prolonged smoking and consumption of heavily pigmen-

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ted food and beverages, such as coffee, and curry[2]. Previous research on tooth discoloration has focused on various beverages, including red wine, coffee, and black tea, revealing their potential to cause discoloration of teeth and dental resin materials[3,4].

To address tooth discoloration, oral prophylaxis, cosmetic restorations, and tooth whitening procedures using hydrogen peroxide are available[5]. Among these, tooth whitening procedures aim to increase the lightness (L*) of teeth by oxidizing the stained tooth structure and remove stains, restoring them to their original color[6]. Vital tooth whitening procedures can be broadly categorized into three methods. In-office professional whitening is performed by applying whitening agents containing 30% to 50% hydrogen peroxide, followed by light exposure. At-home whitening is performed using individual trays with 10% to 15% hydrogen peroxide. Finally, OTC whitening products with low concentration that can be easily purchased online are available for at-home use[7]. Furthermore, the interest in tooth whitening among modern-day individuals extend beyond teeth whitening procedures to everyday oral care products, such as toothpaste and mouthwash, which have added whitening functions. Nam and Choi[8] confirmed that low-concentration hydrogen peroxide that is included in whitening toothpaste is safe for whitening and tooth cleaning actions. Tavares et al.[9] observed an increase in lightness of teeth when a whitening-agent-mixed toothpaste was applied to teeth for 4 weeks. Kim et al.[6] also reported approximately 2.3 times higher color change values in the group using whitening toothpaste for 4 weeks compared with the group using regular toothpaste. Color measurements are represented by three values, L*, a*, and b*, in line with the guidelines of the International Commission on Illumination. L* represents lightness on a scale of 0 to 100, where values closer to 0 indicate black and values closer to 100 indicate white. a* and b* represent the degrees of red-green and yellow-blue, respectively[10]. Kim et al.[11] found that the most pronounced change in tooth color, following whitening treatment of the first premolar tooth, was observed in the L* value, indicating that tooth lightness change is the most significant measurement factor.

The use of mouthwash prevents dental caries, remineralizes early carious lesions, and manages oral diseases such as periodontal diseases. In addition, it is known to be effective in reducing and eliminating halitosis and contributes to tooth whitening[12]. In particular, mouthwash containing hydrogen peroxide produced by Listerine is known to have tooth whitening properties for extrinsic discoloration. A study by Yazdi et al.[13] confirmed a significant color recovery of composite resin stained by coffee when Listerine Healthy White was applied. Furthermore, Lima et al.[14] demonstrated that mouthwash products with whitening ability typically contain low concentrations (1～2%) of hydrogen peroxide. They verified the tooth whitening effects of mouthwash products containing hydrogen peroxide, such as Listerine Whitening and Colgate Plax Whitening.

2. Objectives

While there has been considerable research on the tooth whitening effects of whitening gels and toothpaste products, research on mouthwash products containing whitening properties is relatively limited. Therefore, in this study, we aimed to confirm the tooth whitening effects of Listerine Healthy White, based on previous research on the effects of whitening toothpastes. Additionally, we sought to provide a basis for more effective removal and management of extrinsic discoloration, enabling consumers to make informed choices when comparing existing whitening products.

Materials and Methods

1. Ethic statement

This study did not require institutional review board approval because we did not use materials of human origin.

2. Materials

1) Tooth-coloring-inducing-foods

Tooth-coloring-inducing foods with a high tooth staining index, such as black tea, black coffee, and instant noodles, that are available in the market and most commonly consumed were purchased for the experiment. All products used had an expiration date of over 1 year, and

their characteristics are summarized in Table 1.

2) Whitening products

Self-whitening products including Listerine Healthy White, mouthwash, as well as widely used whitening gel and whitening toothpaste, were chosen for the experimental group. Artificial saliva was selected as the control group. A total of four products were used in this study, and their characteristics are summarized in Table 2.

3. Study design

1) Specimen preparation

Sound bovine permanent incisors without caries were selected, and after removing calculus and washing the surfaces, they were stored in a saline solution. For specimen preparation, bovine teeth were cut into 7×7×3 mm pieces using a cutting disc (Saejong Ind., Siheung, Korea). To obtain a flat surface, the bovine teeth were gradually sanded using Sic-paper on a grinder (Struers LaboPol-5, Type 05206133; Struers, Ballerup, Denmark). A total of 120 specimens were prepared.

2) Specimen staining

The sanded specimens were randomly distributed into black tea, black coffee, and instant noodles groups, with 40 specimens each, for the experiment. Black coffee and instant noodles were prepared according to the manufacturer's instructions, whereas black tea was made by soaking each disposable tea bag in 50 ml of boiled water for 30 seconds. The specimens were immersed in the solutions for 72 hours, and the solutions were changed every 24 hours. After immersion, the specimens were removed, rinsed with distilled water, and stored.

3) Measurement of specimen lightness (L*) after staining

A spectrophotometer (SP62 400-700nm; X-rite, Grand Rapids, MI, USA) was used to measure the lightness after staining.

4) Whitening procedure

Forty specimens stained with black tea were distributed to

Table 1. Characteristics of the Tooth-Coloring-Inducing Foods Used in This Study

Tooth-coloring-inducing food	Commercial name	Ingredient	Manufacturer
Black tea	Lipton	Orange pekoe, pekkoe cut black tea	Unilever, Englewood Cliffs, NJ, USA
Black coffee	Maxim Arabica	Coffee beans 100% (Peruvian 40%, Brazilian 35%, Colombian 25%)	Dongsuh Foods Co., Incheon, Korea
Instant Noodles	Nongshim Shin Ramyun	Wheat flour/semolina (USA, Australian), potato starch (German), palm oil (Malaysian), modified starch, calcium lactate, refined salt, vegetable flavor extract, alkaline agent for noodles (acidity regulator), mixed agent (acidity regulator), olive and green tea flavoring extract, vitamin B2, soup mix/soup base, refined salt, beefflavor base, refined sugar, broth flavor enhancer base, stir-fry seasoning powder, seasoned amino acid soy sauce flavor, seasoned beef powder, 5'-ribonucleotide disodium, soybean paste powder, garlic flavor base, soy sauce powder, seasoning powder, seasoned red pepper powder, ground black pepper, spicy seasoning powder, mixed seasoning powder, fermented dried oak mushroom seasoning powder, pumpkin sodium acid, pepper flavor powder, oak mushroom powder, onion flavor powder, roasted garlic seasoning powder, seasoned yeast powder, freeze-dried garlic powder, caramel powder (caramel color, syrup powder), ginger extract powder, soy protein (meat flavor, dried scallion, dried bok choy, dried oak mushrooms, dried carrot, dried chili pepper	Nongshim, Seoul, Korea

Table 2. Characteristics of Tooth Bleaching Materials Used in This Study

Group	Brand name	Ingredient	Manufacturer
Experimental group			
Whitening gel	2W	Carbamide peroxide, methylparaben, dipotassium glycyrrhizinate, glycerin, polyvinylpyrrolidone, ethanol, polypoxyl 40 hydrogenated castor oil, sodium saccharin, peppermint oil, eucalyptus extract, rosemary extract, flavors, purified water	JN Pharm Co., Pyeongtaek, Korea
Whitening toothpaste	Tosowoong	35% Hydrogen peroxide solution, tocopheryl acetate, colloidal silicon dioxide, D-sorbitol solution, L-menthol, green tea extract, matricaria extract, flavor (citrus mint flavor), eucalyptus extract, grapefruit seed extract, xylitol, purified water, carboxymethylcellulose sodium, sodium cocoyl glutamate, peppermint oil, polysorbate 20, hydroxyapatite	Sangleaf Pharm Co., Seongnam, Korea
Listerine Healthy White	Listerine	Active: sodium fluoride 0.02% (0.01% w/v fluoride ion), Inactive: water, alcohol (10.5%), sorbitol solution, hydrogen peroxide, PEG40 hydrogenated castor oil, flavors, poloxamer 407, sodium saccharin, phosphoric acid, disodium phosphate, sucralose	Johnson & Johnson Co., New Brunswick, NJ, USA
Control group			
Artificial saliva	Biotene	Water, glycerin, xylitol, sorbitol, propylene glycol, poloxamer 407, sodium benzoate, hydroxyethyl cellulose, methylparaben, propylparaben, flavor, sodium phosphate, disodium phosphate	Warren, Somerset, NJ, USA

the experimental groups: whitening gel, whitening toothpaste, Listerine Healthy White, and a control group which is artificial saliva, with ten specimens each. Specimens stained with black coffee and instant noodles were distributed in the same manner. The whitening experiment was conducted as recommended by the manufacturers. The whitening gel was applied using a brush, with half of it used to ensure an even thickness. It was applied for 30 minutes, twice a day. The whitening toothpaste was applied to the enamel surface of the teeth with a thickness of 1 mm for 3 minutes, three times a day. Specimens in the experimental groups using whitening gel and whitening toothpaste were placed on a gauze soaked in water during the experiment to prevent specimen drying. Specimens in the Listerine Healthy White group were immersed in 10 ml of the product for 1 minute, twice a day. Specimens in the control group, immersed in artificial saliva, had the solution replaced three times a day. After the whitening procedure, the specimens were rinsed with sterile distilled water to ensure no residual whitening agent and were stored in artificial saliva. This process was repeated for a total of 5 weeks.

5) Measurement of specimen lightness (L*) after whitening

To observe periodic changes in lightness post-whitening, the specimens were dried, and their lightness was measured five times using a spectrophotometer at 1-week intervals.

4. Statistical analysis

Results of the lightness change in the specimens were analyzed using IBM SPSS Statistics ver. 25.0 (IBM Corp., Armonk, NY, USA). At a significance level of 5%, the Kruskal–Wallis test was performed for the intergroup significance verification of whitening treatments among each group. The Wilcoxon signed rank test was conducted to analyze the difference in lightness values before and after the whitening experiments.

Results

1. Changes in lightness (L*) by whitening during the 5 weeks

In this study, we measured the lightness value six times in the experimental and control groups before whitening and after applying the whitening product for 5 weeks. There was no significant difference in lightness value among the groups before the whitening of the specimens stained in black tea, black coffee, and instant noodles. There was a significant difference in the lightness value among the groups at the 1st week and onward ($p < 0.05$; Table 3～5). After 5 weeks of whitening procedures of specimens stained by different foods, those stained by black tea showed the highest lightness values for whitening gel (86.91±0.45), followed by Listerine Healthy White (79.66±2.29), whitening toothpaste (78.80±3.29), and artificial saliva (69.06±1.54). Both the experimental and control groups showed the most significant change in lightness at the 1st week of whitening (Table 3). For specimens stained by black coffee, the highest lightness values after 5 weeks of whitening were observed in the following order: whitening gel (88.00±2.04), whitening toothpaste (83.79±2.04), Listerine Healthy White (81.38±2.63), and artificial saliva (76.65±1.36). Whitening gel and whitening toothpaste showed the most significant change in lightness at the 4th week, whereas Listerine Healthy White showed the most significant change at the 5th week, and the control group at the 1st week (Table 4). For specimens stained by instant noodles, the highest lightness values after 5 weeks of whitening were in the following order: whitening gel (91.61±1.47), whitening toothpaste (89.30±1.53), Listerine Healthy White (87.28±1.75), and artificial saliva (82.81±1.47). Whitening gel showed the most significant change in lightness at the 1st week, whitening toothpaste at the 2nd week, Listerine Healthy White at the 5th week, and the control group at the 1st week (Table 5).

2. Changes in lightness (L*) before and after 5 weeks of whitening

For specimens stained by black tea, black coffee, and instant noodles, the lightness after 5 weeks of the whitening

Table 3. Lightness (L*) Change of Bovine Tooth after Staining with Black Tea Over Different Periods

Treatment period	Whitening gel	Whitening toothpaste	Listerine Healthy White	Artificial saliva	p-value
Baseline	65.19±1.78	63.91±6.42	66.75±4.73	65.21±4.23	0.560
1 week	72.58±2.60	68.83±4.64	72.16±2.31	68.37±2.50	0.011
2 weeks	78.37±2.57	72.19±5.49	73.48±1.75	68.72±1.93	<0.001
3 weeks	81.47±1.74	74.00±4.36	75.48±2.12	68.94±2.08	<0.001
4 weeks	84.95±1.21	76.59±2.85	77.59±3.43	68.99±1.55	<0.001
5 weeks	86.91±0.45	78.80±3.29	79.66±2.29	69.06±1.54	<0.001

Values are presented as mean±standard deviation.
p-values are determined by Kruskal-Wallis.

Table 4. Lightness (L*) Change of Bovine Tooth after Staining with Black Coffee Over Different Periods

Treatment period	Whitening gel	Whitening toothpaste	Listerine Healthy White	Artificial saliva	p-value
Baseline	75.01±2.51	74.13±1.48	73.47±2.57	73.53±1.25	0.226
1 week	77.72±2.17	75.61±1.45	75.04±2.53	75.81±1.44	0.041
2 weeks	80.76±2.29	77.84±1.57	75.43±1.92	76.27±1.40	<0.001
3 weeks	82.59±1.61	79.19±1.63	77.32±1.81	76.55±1.27	<0.001
4 weeks	85.78±1.81	81.68±1.68	79.12±2.43	76.63±1.42	<0.001
5 weeks	88.00±2.04	83.79±2.04	81.38±2.63	76.65±1.36	<0.001

Values are presented as mean±standard deviation.
p-values are determined by Kruskal-Wallis test.

Table 5. Lightness (L*) Change of Bovine Tooth after Staining with Instant Noodles Over Different Periods

Treatment period	Whitening gel	Whitening toothpaste	Listerine Healthy White	Artificial saliva	p-value
Baseline	80.77±1.72	79.45±2.30	79.57±1.46	80.20±1.50	0.261
1 week	83.49±1.76	81.22±3.04	81.55±1.05	82.22±1.29	0.043
2 weeks	85.32±1.31	84.57±2.63	82.79±1.96	82.59±1.05	0.003
3 weeks	87.74±1.06	85.84±2.03	83.63±1.86	82.69±1.22	<0.001
4 weeks	89.88±0.87	87.39±1.96	85.11±1.91	82.80±1.58	<0.001
5 weeks	91.61±1.47	89.30±1.53	87.28±1.75	82.81±1.47	<0.001

Values are presented as mean±standard deviation.
p-values are determined by Kruskal–Wallis test.

Table 6. Lightness (L*) Change between Values before and after 5 Weeks of Whitening in Black Tea–Stained BovineTooth

Group	Number	L*		p-value
		Baseline	5 weeks	
Whitening gel	10	65.19±1.78	86.91±0.45	0.005
Whitening toothpaste	10	63.91±6.42	78.80±3.29	0.005
Listerine Healthy White	10	66.75±4.73	79.66±2.29	0.005
Artificial saliva	10	65.21±4.23	69.06±1.54	0.022

Values are presented as mean±standard deviation.
p-values are determined by Wilcoxon signed rank test.

procedure increased in all experimental and control groups. When comparing the lightness of specimens before and after 5 weeks of whitening, there were significant differences ($p < 0.05$; Table 6～8). The changes in lightness values for specimens stained by black tea after 5 weeks of whitening were in the following order: whitening gel (21.72), whitening toothpaste (14.89), Listerine Healthy White (12.91), and artificial saliva (3.85) (Table 6). For specimens stained by black coffee, the changes in lightness values after 5 weeks of whitening were observed in the following order: whitening gel (12.99), whitening toothpaste (9.66), Listerine Healthy White (7.91), and artificial saliva (3.12) (Table 7). For specimens stained by instant noodles, the changes in lightness values after 5 weeks of whitening were observed in the following order: whitening gel (10.84), whitening toothpaste (9.85), Listerine Healthy White (7.71), and artificial saliva (2.61) (Table 8).

Discussion

1. Interpretation

The advancement of societal and economic development has led to growth in human aesthetic desires. This has led to an increase in the use of self-whitening products that are easy to apply. As a result, products such as teeth whitening gels, whitening toothpaste, and mouthwash with whitening effects such as Listerine Healthy White have been introduced and are currently in use. These products are gaining popularity because they allow individuals to whiten their teeth economically without the need for dental visits. Research on the effectiveness of self-whitening products has been continuously reported[15,16]. However, experimental analysis of the tooth whitening effects of mouthwashes containing whitening agents is relatively limited. Therefore, in this study, we analyzed the tooth whitening effects of Listerine Healthy White and examined how it differs from existing self-whitening products.

Previous studies on color changes of teeth associated with food have reported that foods such as red pepper paste, coffee, tea, and instant noodles can cause tooth discoloration[17-20]. According to a study by Kim et al.[18], tannin compounds found in coffee and black tea can reduce bacterial plaque in the oral cavity; however, tannins' black pigments can bind to protein components, leading to tooth discoloration and reduced lightness. To achieve tooth whitening, teeth whitening products often contain peroxide

Table 7. Lightness (L*) Change between Values before and after 5 Weeks of Whitening in Black Coffee-Stained BovineTooth

Group	Number	L*		p-value
		Baseline	5 weeks	
Whitening gel	10	75.01±2.51	88.00±2.04	0.005
Whitening toothpaste	10	74.13±1.48	83.79±2.04	0.005
Listerine Healthy White	10	73.47±2.57	81.38±2.63	0.005
Artificial saliva	10	73.53±1.25	76.65±1.36	0.005

Values are presented as mean±standard deviation.
p-values are determined by Wilcoxon signed rank test.

Table 8. Lightness (L*) Change between Values before and after 5 Weeks of Whitening in Instant Noodles-Stained Bovine Tooth

Group	Number	L*		p-value
		Baseline	5 weeks	
Whitening gel	10	80.77±1.72	91.61±1.47	0.005
Whitening toothpaste	10	79.45±2.30	89.30±1.53	0.005
Listerine Healthy White	10	79.57±1.46	87.28±1.75	0.005
Artificial saliva	10	80.20±1.50	82.81±1.47	0.028

Values are presented as mean±standard deviation.
p-values are determined by Wilcoxon signed rank test.

compounds. The mechanism of whitening action involves peroxide compounds increasing ion movement within the teeth, leading to the oxidation of staining substances[5].

2. Key results and comparison with the results of previous studies

In this study, we measured the average lightness (L*) values of the bovine tooth specimens using a spectrophotometer and observe the changes in lightness over time with Listerine Healthy White and other self-whitening products. The results showed that all specimens stained by black tea, black coffee, and instant noodles showed an increase in lightness values after 5 weeks of whitening compared with before whitening. The whitening effects were the highest in the following order: whitening gel, whitening toothpaste, Listerine Healthy White, and artificial saliva. In this study, only the lightness (L*) values were presented to confirm the whitening effects. Previous research by Dietschi et al.[21] demonstrated that the lightness (L*) value, among the three color coordinates (L*, a*, b*), is the most important parameter in comparing products or experimental conditions. The saturation values (a*, b*) were found to be less useful for comparisons.

Studies by Kim et al.[7] and Ahn et al.[22] found that tooth whitening with teeth whitening gels and toothpaste was effective. In this study, we also observed an increase in the lightness of specimens following the use of tooth whitening gel and toothpaste. In the study by Lee et al.[23], it was found that tooth whitening gel significantly increased the initial lightness of specimens, with relatively minimal subsequent color changes. In the case of whitening toothpaste, color changes occurred gradually over an 8-week application period. In our study, we observed similar results, with tooth whitening gel initially significantly increasing lightness, followed by a gradual reduction in the degree of change. For whitening toothpaste, we observed a gradual increase in lightness, consistent with the results of previous studies. In a study by Kim et al.[6], whitening toothpaste was applied three times a day for 3 minutes to the enamel surface with a thickness of 1 mm. It showed no significant difference in color changes up to 2 weeks; however, significant differences were observed from the 3rd week onward. In this study, whitening toothpaste was applied using the same method and duration. However, we observed a gradual change in lightness from the 1st week. We believe that the difference in results was due to variations in the compositions and concentrations of the whitening agent used in the experiments, although the

treatment method was the same.

When comparing the effects of whitening gel and whitening toothpaste, previous studies have has shown varying results regarding the concentration and duration of treatment. Chung et al.[24] found that higher concentrations of whitening treatments tend to be more effective. In contrast, Leonard et al.[25] suggested that lower concentrations, when applied for an extended period, can achieve results similar to higher concentrations. Additionally, studies by Kim and Lim[26], using Carbamide peroxide as the main component of whitening agents, reported that specimens treated with a low concentration (10%) for an extended period (8 hours) showed brighter results than specimens treated with a high concentration (22%) for a short period (1 hour). This phenomenon is attributed to the slow breakdown of Carbamide peroxide into hydrogen peroxide, which results in whitening effects[25]. In this study, when we applied a 3% low-concentration Carbamide peroxide-based whitening gel for 30 minutes to specimens stained by various tooth-coloring-inducing foods, it resulted in higher lightness values compared with applying an whitening toothpaste containing a 35% high-concentration hydrogen peroxide solution for 3 minutes.

Listerine Healthy White were observed to increase the lightness over time. A study by Karadas and Hatipoglu[27] revealed that when various mouthwashes with whitening functions were applied to bovine specimens for 56 days, lightness increased over time, indicating that time is a significant factor in tooth whitening. On the other hand, specimens soaked in artificial saliva showed an increase in lightness at the 1st week, followed by minimal changes. Meireles et al.[28] reported that specimens soaked in distilled water as a control group showed an increase in lightness owing to the removal of surface pigments. Kishta-Derani et al.[29] suggested that wrapping specimens in gauze and storing them in artificial saliva may lead to some dilution effects. Therefore, in this study, it is believed that dilution caused by artificial saliva increased the lightness value. Mouthwashes with a pH of 4.0 or lower are known to pose a risk for tooth erosion[30]. According to a study by Ganss et al.[31], a higher content of sodium fluoride in mouthwash is associated with less enamel erosion. Similarly, a study by Min[32] found that mouthwash containing sodium fluoride as the main ingredient does not cause enamel erosion owing to its pH content being 6.0 or higher. Listerine Healthy White, which was used in this study, also contains sodium fluoride, suggesting a minimal impact on enamel in addition to its tooth whitening effect. Jang et al.[33] reported that whitened teeth may be more prone to staining by foods that cause discoloration when organic substances are removed from teeth. Kim et al.[18] proposed limiting the consumption of coffee, a type of food that can cause tooth staining, during tooth whitening. Therefore, further research is needed to evaluate the extent of re-staining due to different food and changes in mineral content in teeth after using Listerine Healthy White.

3. Suggestion

Based on the results of this study, when Listerine Healthy White was applied to specimens stained by black tea, black coffee, and instant noodles for 5 weeks, the lightness values increased. This suggests that consumers looking for a convenient way to achieve teeth whitening at home should consider continuous use of Listerine Healthy White. Additionally, consumers should follow the recommended usage instructions provided by the manufacturer to minimize potential side effects.

4. Limitations

However, it is important to note that this study used bovine permanent teeth, not human teeth, and did not consider the oral environment. Future research should address these limitations by conducting studies under conditions that more closely resemble the oral environment.

Notes

Conflict of interest

Prof. Soon-Jeong Jeong has been journal editor-in-chief of the *Journal of Dental Hygiene Science* since January 2023. She was not involved in the review process of this study. Otherwise, there is no potential conflict of interest relevant to this article was reported.

Ethical approval

This article does not require for IRB screening because

human origin is not used.

Author contributions

Conceptualization: Moon-Jin Jeong and Do-Seon Lim. Date acquisition, Formal analysis: Jung-Hui Son, Soon-Jeong Jeong, Ye-Jin Kim, Hee-Jung Lim, and Im-Hee Jung. Funding: Moon-Jin Jeong. Supervision: Do-Seon Lim. Writing-original draft: Do-Seon Lim. Writing-review & editing: Moon-Jin Jeong and Do-Seon Lim.

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Data availability

Please contact the corresponding author for data availability.

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