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RESEARCH ARTICLE

Comparison of Coffee Stain Removal Effects of Commercial Whitening Toothpaste in Sound and Demineralized Teeth *In Vitro*

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Background: The size of the tooth whitening market and toothpaste market is increasing worldwide. The purpose of this *in vitro* study is to confirm and compare the coffee stain removal effects of commercial whitening toothpaste in sound and demineralized teeth, respectively.

Methods: A total of 112 flat permanent bovine teeth specimens were manufactured. Half of the surface of the specimen was coated with an acid-resistant varnish and deposited in an artificial demineralizing solution for 65 hours. The varnish applied to half of the specimen was removed and deposited in a coffee solution for 96 hours to induce coloring. Two control and five experimental group toothpastes for teeth whitening were selected and the main components were investigated. Toothbrushing was performed 50, 100, and 150 times for each toothpaste group. A total of four images were obtained: before the start and after 50, 100, and 150 times of brushing to obtain the lightness (L*) values of the sound and the demineralized tooth surfaces. The difference in the average value between toothpaste groups at each treatment period was analyzed by one-way ANOVA. The difference in the L* average value according to the number of the brushing was analyzed by repeated measure ANOVA.

Results: All toothpastes in the seven groups contained abrasive agents and had different ingredients for each product. Compared to before brushing, the L* value changed significantly in all toothpaste groups after brushing 50 times ($p<0.05$). This was common in both the sound and demineralized teeth surfaces. Demineralized teeth had significantly lower L* values at all brushing times than that in sound teeth ($p<0.05$).

Conclusion: The effect of whitening teeth was different for each toothpaste. Demineralized teeth were more likely to cause coloration than sound teeth, and the coloration was not removed well.

Key Words: Coffee, Demineralized tooth, Sound tooth, Tooth discoloration, Whitening toothpaste

Introduction

1. Background

Over the past decade, global coffee consumption has been steadily increasing[1]. The International Coffee Organization reported that global coffee consumption was less than coffee production in 2019~2020 but exceeded coffee production in 2021[1]. According to the International Coffee Organization, the average annual growth rate for coffee consumption in South Korea in 2021 was 1.7%, higher than the −0.8% in the United States[2]. Coffee is a mixture composed of various compounds such as polymeric carbohydrates, chlorogenic acid, caffeine, protein, sugar, trigonelline, and colored ingredients[3,4]. In particular, coffee is well known as a coloring substance because 20% to 35% of coffee's ingredients are dark colors such as brown and black[2,3]. Coffee can also cause coloring in teeth, characteristically with brown dark pigments. The degree of the stain depends on oral hygiene management or eating habits[5].

The most representative method of oral hygiene mana-

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gement is brushing using toothpaste and toothbrush. Toothpaste contains various compounds, and the function of toothpaste varies depending on the active ingredient. The size of the tooth whitening market and toothpaste market is increasing worldwide[6,7]. Whitening functional toothpaste is added with ingredients such as abrasives and chemical agents to enhance the whitening effect[8]. The ingredients and concentrations of commercially available whitening toothpaste vary greatly. Therefore, it is necessary to evaluate the efficacy of domestic whitening toothpaste products on the market as there is insufficient data.

The component of tooth enamel, hydroxyapatite ($Ca_{10}(PO_4)_6OH_2$), has the highest proportion of minerals in our body. Therefore, sound teeth have fewer micro-pores; however, early dental caries break the structure of hydroxyapatite and increase micro-pores[9]. Due to these structural differences, there may be differences in the degree of coffee coloration in sound and early dental caries and the whitening action of toothpaste.

2. Objectives

Dental hygienists need to recommend customized oral care products such as toothpastes[10]. However, there is a lack of research on this[11]. Therefore, the purpose of this study is to evaluate and compare the effect of commercial whitening toothpaste on coffee stain removal in sound and demineralized teeth, respectively. The null hypotheses of this study are: 1) There is no difference in whitening efficacy between the commercial toothpastes. 2) There is no difference in the degree of color removal between the surfaces of the sound and demineralized teeth.

Materials and Methods

The overall progress of this study is shown in Fig. 1.

1. Manufacture of enamel specimens

A sound permanent bovine tooth without crack or coloring was sectioned at 3 mm×5 mm. The sectioned bovine tooth was placed in a 20 mm×15 mm×15 mm mold and buried with composite resin (Curing acrylic denture repair material; Vertex, Soesterberg, Netherlands). When supplying water with P 200, 400, 600, 800, 1200, and 2400 sandpaper, the enamel was polished to expose it to a flat surface. The specimens in which dentin exposure was observed were discarded. Half of the surface of the specimen was covered with acid resistant nail varnish to preserve sound teeth. Subsequently, an artificial demineralizing solution with a pH of 4.8 was prepared, which contained 1% carbopol and was 50% saturated with calcium phosphate (calcium phosphate tribasic; Sigma-aldrich, Saint Louis, MO, USA). Five tooth samples were placed in a 30 mL artificial demineralized solution and stored in a shaking incubator (Wis-30R; DAIHA Scientific Co., Ltd., Wonju, Korea) at 37°C for 65 hours to cause demineralization. The specimen taken out of the artificial demineralizing solution was sufficiently washed with water and then dried. Nail varnish applied to half of the surface of specimen was

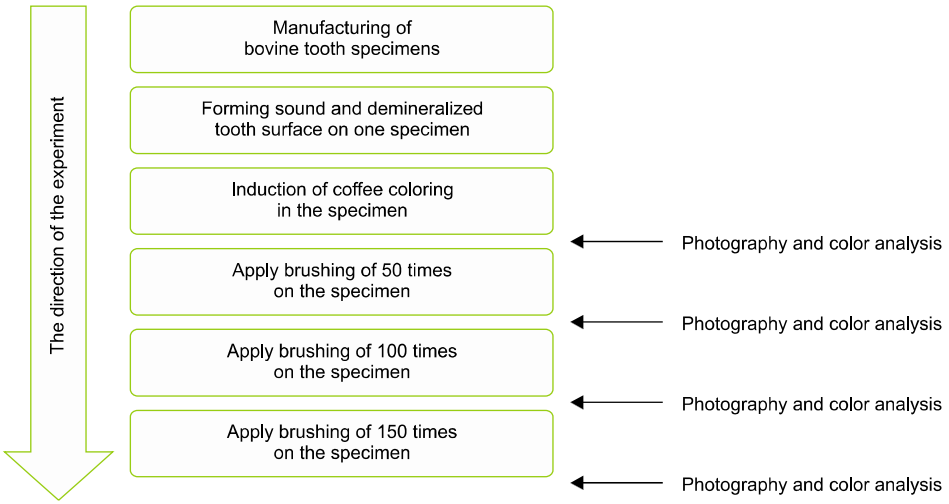

Fig. 1. Schematic diagram of the progress of this experiment.

removed. Finally, 112 specimens were produced in which half of the surface of the tooth specimen was formed with sound teeth and the remaining half with artificial demineralization. The number of tooth specimens assigned to each group was 16.

2. Tooth stain formation using coffee

To produce a colored solution, 10 g of coffee (Nescafe Supremo; Lotte-Nestlé Co., Ltd., Cheongju, Korea) was dissolved in 400 mL distilled water. The tooth specimen was immersed in the coffee solution, and coloring was performed in an incubator (Wig-155; DAIHA Scientific Co., Ltd.) at 37°C to reflect the human body temperature. Coffee coloring was performed for a total of 96 h until the coloring was confirmed with the naked eye.

3. Selection of toothpaste

The control groups included two products that did not indicate tooth whitening as the main action on the packaging container of toothpaste : Control group 1 (Cont1, Perioe new fresh alpha toothpaste; LG Household & Health Care, Seoul, Korea), Control group 2 (Cont2, Arm & Hammer dental care enamel care plus repair toothpaste; Clean & Cleaner, Paju, Korea). The selection criteria for five toothpaste products of the experimental group were toothpaste sold at more than two of Korea's three major supermarkets. Additionally, it was a product that promoted tooth whitening as the main action in the toothpaste packaging container: Experimental group 1 (E1, Bouquet garni nard whitening toothpaste; K.Boeun pharmaceutical, Pocheon, Korea), experimental group 2 (E2, 2080 Dr. clinic white clinic tooth paste; Aekyung Industrial Co., Ltd., Seoul, Korea), experimental group 3 (E3, Vussen 28 premium whitening toothpaste; Osstem Implant Co., Ltd., Seoul, Korea), experimental group 4 (E4, Aiobio white W toothpaste; Aiobio, Seoul, Korea), experimental group 5 (E5, Perioe white now 2X cooling mint; LG Household & Health Care, Seoul, Korea). The components of toothpaste presented by the manufacturer in the product packaging were investigated.

4. Toothbrushing by toothpaste group

For toothbrushing, 0.5 g of toothpaste was applied to a toothbrush (Hiclean 12FS; HANMIECLEAN, Daejeon, Korea). The width and length of the toothbrush bristles were 10 mm×23 mm, and it had four rows of bristles. When brushing, 50 μl of distilled water was applied to the tooth specimen. The specimen was placed and fixed on the electronic scale (ABJ220-4M; Kern & Sohn GmbH, Frommern, Germany) to brush so that the load was 200±20 g. A series of pull-and-push movements was considered a single brushing. Toothbrushing was performed 50 times, additional 50 times (100 times in total), and additional 50 times (150 times in total).

5. Image analysis

The tooth surface was photographed four times for each toothpaste group: 1) before applying toothbrushing to the specimen (after staining using coffee, baseline), 2) after brushing the specimen 50 times, 3) after brushing the specimen a total of 100 times, 4) after brushing the specimen a total of 150 times. A photograph of the specimen was obtained under the following conditions: ISO 1600, shutter speed 1/160 s, and aperture value 8.0 in the quantitative light-induced fluorescence-digital (2+ Biluminator™; Inspektor Research Systems BV, Amsterdam, the Netherlands) in white light mode, at which time light was blocked from the outside.

The red, green and blue (RGB) value of the captured image was obtained using the image analysis program (Image-pro premier 9.1; Media Cybernetics, Inc., Rockville, MD, USA). The RGB value was converted into a GIEL*a*b* value[12]. Statistical analysis was conducted using the lightness (L*) values to see how bright the surface of the specimen became with the application of toothpaste. The L* value of 0 indicates black, and a value of 100 indicates white.

6. Statistical analysis

For each group of toothpaste, the average L* value at the baseline and after brushing 50, 100, and 150 times was calculated. The difference in the average value between groups at each treatment period was analyzed by one-way ANOVA. The Tukey test was used for post-hoc analysis. The difference between the L* average value according to the number of brushing was analyzed by repeated measure ANOVA. The multiple comparisons were performed with Bonferroni correction. All analyses were analyzed by IBM SPSS statistics ver.

Table 1. Ingredients and Contents of Toothpaste Suggested by the Manufacturer

Group	Product name	Company, Country	Ingredients listed in the product by the manufacturer
Control group			
Cont1	Perioe new fresh alpha toothpaste	LG Household & Health Care, Korea	Main ingredients: sodium monofluorophosphate, calcium carbonate Other additives: glycerin, sodium lauryl sulfate, sorbitan monooleate, non-crystalline sorbitol solution 70%, saccharin sodium hydrate, sodium acid pyrophosphate, zinc acetate, xylitol, purified water, sodium carboxymethyl cellulose, hydrated silica (TIXOSIL 43K), flavoring
Cont2	Arm & Hammer dental care enamel care plus repair toothpaste	Clean & Cleaner, Korea	Main ingredients: sodium fluoride, sodium bicarbonate, dental type silica Other additives: glycerin, polyethylene glycol 400, silicon dioxide, calcium sulfate, sodium lauryl sulfate, flavoring, potassium phosphate (dibasic), PEG/PPG (150:35) copolymer, sodium carbonate, saccharin sodium, cellulose gum, tar pigment (fast green FCF)
Experimental group			
E1	Bouquet garni nard whitening toothpaste	K.Boeun pharmaceutical, Korea	Main ingredients: hydrogen peroxide 35%, colloidal silicon dioxide,tocopheryl acetate Other additives: concentrated glycerin, polyethylene glycol 1500, sodium cocoyl glutamate, sodium carboxymethyl cellulose, polysorbate 20, enzymatically modified stevia, disodium dihydrogen pyrophosphate, peppermint oil, eucalyptus oil, spearmint oil, tea tree oil, L-menthol, EDTA sodium, xylitol, hydroxyapatite, ascorbic acid, sodium chloride, grapefruit seed extract, licorice extract, rosmarinus officinalis extract, chamomilla recutita extract,sage extract, curcuma longa root extract, eucalyptus globulus extract,calendula officinalis flower extract,propolis extract, scutellaria baicalensis root extract, purified water, flavoring
E2	2080 Dr. clinic white clinic toothpaste	Aekyung Industrial Co., Ltd., Korea	Main ingredients: hydrogen peroxide 35%, colloidal silicon dioxide Other additives: sodium L-tartrate dihydrate, glycerin, sodium lauryl sulfate, saccharin sodium hydrate, sodium acid pyrophosphate, disodium edetate, phosphoric acid, xanthan gum, purified water, sodium carboxymethyl cellulose, polyvinyl pyrrolidone, polyethylene glycol 1500, flavoring, hydroxyethyl cellulose
E3	Vussen 28 premium whitening toothpaste	Osstem Implant Co., Ltd., Korea	Main ingredients: hydrogen peroxide 35%, colloidal silicon dioxide Other additives: glycerin, sodium lauryl sulfate, sodium metaphosphate, saccharin sodium, citric acid, L-menthol, purified water, poloxamer 407, polyethylene glycol 1500, flavoring, hydroxyethyl cellulose
E4	Aiobio white W toothpaste	Aiobio, Korea	Main ingredients: calcium phosphate tribasic, calcium carbonate, sodium pyrophosphate Other additives: gilkyung concentrated extract, green tea extract, sodium lauryl sulfate, rosemary extract, L-menthol, D-sorbitol solution, ginseng extract, grapefruit seed extract, xylitol, xanthan gum, purified water, sodium carboxymethyl cellulose, taraxacum platycarpum extract, polyethylene glycol 1500, propolis extract, silicon dioxide, optamint156665, yellow and white concentrated extract, enzymatically modified stevia
E5	Perioe white now 2X cooling mint	LG Household & Health Care, Korea	Main ingredients: dental type silica, sodium monofluorophosphate, sodium pyrophosphate, tocopheryl acetate Other additives: sodium lauryl sulfate, sorbitan monooleate, non-crystalline sorbitol solution 70%, saccharin sodium hydrate, citric acid, xanthan gum, purified water, sodium carboxymethyl cellulose, polyethylene glycol 300 (PEG 300), flavoring

27.0 (IBM Corp., Armonk, NY, USA) at α=0.05.

Results

1. Major whitening ingredients by toothpaste group

Cont1 and Cont2 were not products that marked the tooth whitening function as the main action in toothpaste packaging containers, but the main raw materials contained calcium carbonate and dental type silicide, which are believed to have a whitening effect, respectively. E1～E3 commonly contained 35% hydrogen peroxide as the main component. The main components of E4 included calcium carbonate and sodium pyrophosphate. One of the main components of E5 was dental type silica (Table 1).

2. Analysis of the whitening effect of each toothpaste group on sound tooth surface

There was no significant difference in the L* average value between toothpaste groups before (baseline) and after brushing 50 times. However, after brushing 100 and 150 times, significant differences were found in the L* values, respectively ($p<0.05$). The E3 and E5 groups had significantly higher L* values than the Cont2 group when brushing 100 times ($p<0.05$). After brushing 150, L* was found to be significantly higher in the E1, E2, E3, and E5 groups than Cont2 ($p<0.05$, Table 2).

After brushing 50 times, the L* value was significantly increased in all toothpaste groups compared to the baseline. Each L* value after brushing 100 and 150 times was also found to have a significant difference from that at baseline ($p<0.05$, Table 2).

3. Analysis of the whitening effect of each toothpaste group on demineralized tooth surface

There was no significant difference in the L* average value between toothpaste groups before (baseline) and after brushing 50 times. However, the E3 and E5 groups had significantly higher L* values than the Cont2 group when brushing 100 times ($p<0.05$). When tooth brushing was performed 150 times, the L* was significantly higher in the Cont1, E1, E2, E3, and E5 groups than in Cont2 ($p<0.05$, Table 3).

After brushing 50 times, the L* value was significantly increased in all toothpaste groups compared to the baseline. Each L* value after brushing 100 and 150 times was also found to have a significant difference from that at baseline ($p<0.05$, Table 3).

4. Comparison of L* values of sound and demineralized tooth surfaces

Significant differences were confirmed when comparing

Table 2. The Lightness (L*) Value of Sound Teeth Surface by Toothpaste Group and Number of Brushing

Group	N	Baseline (0 times of toothbrushing)	After brushing 50 times	After brushing 100 times	After brushing 150 times	F (p-value)
Control group						
Cont1	16	65.10±2.56	68.70±1.64*	70.19±1.60^{ab}*	70.76±1.03^{ab}*	31.137 ($p<0.001$)
Cont2	16	65.37±2.80	68.45±1.80*	68.61±1.57^{a}*	68.77±1.62^{a}*	10.454 ($p<0.001$)
Experimental group						
E1	16	65.61±2.96	68.66±3.30*	70.09±2.45^{ab}*	71.15±2.27^{b}*	12.018 ($p<0.001$)
E2	16	65.46±2.67	69.51±2.09*	70.57±2.08^{ab}*	71.20±2.04^{b}*	21.366 ($p<0.001$)
E3	16	65.41±2.91	69.74±1.96*	71.00±1.85^{b}*	71.34±2.10^{b}*	24.228 ($p<0.001$)
E4	16	65.38±1.91	69.28±1.52*	70.22±1.50^{ab}*	70.21±1.60^{ab}*	31.508 ($p<0.001$)
E5	16	65.22±2.71	69.30±2.35*	70.89±2.40^{b}*	71.05±2.25^{b}*	19.894 ($p<0.001$)
F (p-value)		0.061 (0.999)	0.810 (0.564)	2.672 (0.019)	3.658 (0.002)	

^{a,b}Different letters indicate that there is a statistically significant difference in L* values between each toothpaste group by the Tukey posttest ($p<0.05$).
*It indicates that a significant mean difference compared to the baseline was confirmed by Bonferroni correction multiple comparisons ($p<0.05$).

Table 3. The Lightness (L*) Value of Demineralized Teeth Surface by Toothpaste Group and Number of Brushing

Group	Number	Baseline (0 times of toothbrushing)	After brushing 50 times	After brushing 100 times	After brushing 150 times	F (p-value)
Control group						
Cont1	16	62.67±2.69	66.24±1.79*	68.46±1.69^{ab}*	69.25±0.87^{a}*	39.512 ($p<0.001$)
Cont2	16	63.31±2.42	66.30±2.01*	66.64±1.39^{a}*	66.91±1.37^{b}*	13.068 ($p<0.001$)
Experimental group						
E1	16	63.29±2.55	65.66±3.18*	67.72±2.35^{ab}*	69.03±2.55^{a}*	14.055 ($p<0.001$)
E2	16	63.25±2.53	66.19±2.28*	68.22±2.14^{ab}*	69.04±2.08^{a}*	20.778 ($p<0.001$)
E3	16	63.44±2.69	67.51±2.08*	69.17±2.12^{b}*	69.67±2.16^{a}*	25.105 ($p<0.001$)
E4	16	63.31±2.44	66.83±1.83*	68.33±1.87^{ab}*	68.55±1.90^{ab}*	22.899 ($p<0.001$)
E5	16	63.29±2.41	67.46±1.70*	69.43±2.08^{b}*	69.93±1.86^{a}*	35.521 ($p<0.001$)
F (p-value)		0.156 (0.988)	1.632 (0.145)	3.569 (0.003)	4.353 (0.001)	

^{a,b}Different lowercase letters in the alphabet indicate that there is a statistically significant difference in L* values between each toothpaste group by the Tukey posttest ($p<0.05$).
*It indicates that a significant mean difference compared to the baseline was confirmed by Bonferroni correction multiple comparisons ($p<0.05$).

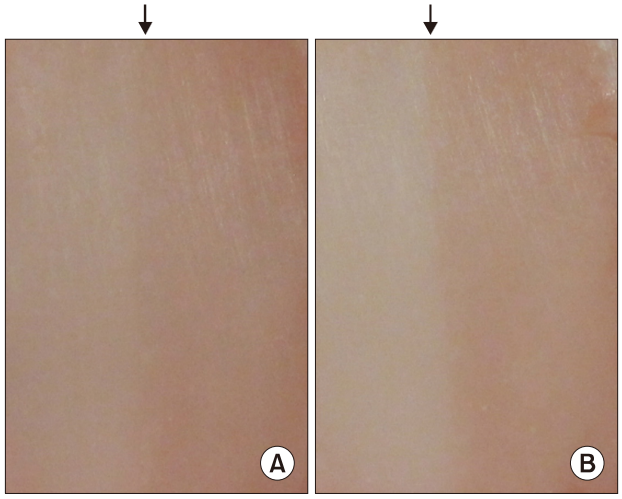

Fig. 2. Photographs of representative tooth samples. (A) Picture of the baseline before brushing; (B) picture after 150 brushing. The area left to the arrow shows sound tooth surface and right to it shows demineralized tooth surface. The presented photos are an example of one specimen from experimental group 1.

the L* values of the surfaces of sound and demineralized teeth by toothpaste group and number of brushing. In other words, the L* mean values of all demineralized surfaces were significantly lower than that of sound tooth surfaces ($p<0.05$, Fig. 2, Table 4).

Discussion

1. Interpretation and comparison to previous studies

Tooth whitening toothpaste has the purpose of removing or preventing external coloring. Usually, an insoluble abrasion agent component is added for this purpose, and the abrasion agent serves to prevent coloring by mechanically removing the accumulation of colored pellets on the surface of the teeth[13-17]. Hydrated silica, calcium carbonate, dicalcium phosphate dihydrate, calcium pyrophosphate, alumina, perlite, and sodium bicarbonate are used as abrasives for teeth whitening[8]. One of the main ingredients of E1, E2, and E3 products was colloidal silicon dioxide. The hydrated silica, a representative abrasive ingredient, is a high-performance abrasive and is a derivative of silicon dioxide[18,19]. Therefore, colloidal silicon dioxide contained in E1, E2, and E3 products is one of the abrasives. As a result, all toothpaste used in this study contained abrasives.

Chemical agents typically used for teeth whitening include hydrogen peroxide, calcium peroxide, sodium citrate, sodium pyrophosphate, sodium tripolyphosphate, sodium hexametaphosphate, and papain. Among the toothpaste products used in this study, E1, E2, and E3 contained 35% of hydrogen peroxide, and E4 and E5 contained sodium pyrophosphate as the main ingredient.

Table 4. Comparison of the Lightness (L*) Values of Sound and Demineralized Teeth Surfaces by Toothpaste Group and Number of Brushing

Group	t (p-value)[a]			
	Baseline (0 times of toothbrushing)	After brushing 50 times	After brushing 100 times	After brushing 150 times
Control group				
Cont1	3.716 (0.002)	11.156 (<0.001)	7.348 (<0.001)	5.728 (<0.001)
Cont2	5.755 (<0.001)	5.178 (<0.001)	8.566 (<0.001)	7.546 (<0.001)
Experimental group				
E1	7.155 (<0.001)	8.650 (<0.001)	8.538 (<0.001)	8.887 (<0.001)
E2	4.210 (0.001)	9.372 (<0.001)	7.837 (<0.001)	7.773 (<0.001)
E3	6.856 (<0.001)	7.154 (<0.001)	7.304 (<0.001)	7.392 (<0.001)
E4	8.195 (<0.001)	8.701 (<0.001)	7.636 (<0.001)	7.406 (<0.001)
E5	8.836 (<0.001)	6.153 (<0.001)	6.969 (<0.001)	4.221 (0.001)

[a]t (p-value) is obtained by analyzing the difference between L* values between sound and demineralized teeth with paired t-test.

In this study, brushing was performed a total of 150 times on the surfaces of sound and demineralized teeth per toothpaste. The L* value of the E1, E2, E3, and E5 groups was significantly higher than that of the Cont2 group when brushing was performed 150 times on the surface of the sound tooth ($p < 0.05$). Since the main components of the E1, E2, and E3 groups were the same 35% hydrogen peroxide and colloid dioxide, it was judged that the whitening effect was similar. However, E5 toothpaste products containing dental type silica and sodium pyrophosphate were also able to confirm whitening effects similar to those of E1, E2, and E3. Cont2 toothpaste contained the same ingredient, dental type silica as E5, and additionally sodium bicarbonate; however, it had the lowest teeth whitening effect on both sound and demineralized tooth surfaces. The effect of tooth whitening may vary not only depending on the type of abrasive, but also on the particle surface and size of the abrasive and the presence and concentration of chemical components for whitening[18]. Therefore, it was thought that different effects appeared even if it contained the same ingredients.

There was no significant difference between the Cont1 group and E1, E2, E3, and E5 on the surface of the demineralized tooth after brushing 150 times. This is thought to be due to the fact that the Cont1 group toothpaste also contained calcium carbonate, an abrasive used as a whitening toothpaste component, as the main ingredient. In addition, since demineralized tooth was not hard compared to sound tooth, wear could easily occur in demineralized teeth, so it was estimated that the tooth whitening effect occurred effectively as the tooth tissue on the surface of the demineralized teeth where coffee coloring occurred[4]. These findings correspond to previous studies that reported a significant correlation between dentifrice abrasivity and stain removal efficacy[20]. However, other previous studies have shown that abrasiveness and cleaning efficiency are not related[21,22]. This was thought to be because the whitening effect of toothpaste can vary due to a combination of various ingredients such as abrasive type, particle surface and size, and chemical composition and concentration of toothpaste components[18]. Therefore, a comprehensive evaluation is needed.

As a result of confirming the L* value of baseline by conducting coffee coloring on the surfaces of sound and demineralized teeth, the demineralized teeth showed a significantly low L* value. This means that the demineralized teeth were colored darker than sound teeth. In addition, this effect showed a lower L* value on the surface of the demineralized tooth compared to the surface of the sound tooth in all toothpaste groups that were brushed 50, 100, and 150 times. This could suggest that when discoloration occurs on the demineralized teeth, it is darker than the coloring on the sound teeth, and more brushing is required for whitening using whitening toothpaste. The reason for this phenomenon is thought to be that demineralized teeth have a lower mineral density than sound teeth, so colorants can penetrate better and stick better between low-density minerals[9]. Previous studies have also

reported that coloring matter can more easily penetrate from lower mineral density teeth than higher mineral density enamel, causing more tooth discoloration[23].

2. Suggestion

Clinically interpreted, the efficacy of whitening may vary depending on the whitening ingredient of toothpaste, so dental hygienists need to provide information effectively to consumers. In addition, demineralized teeth are more easily colored than sound teeth. After brushing the same number of times, the demineralized teeth were still darker than sound teeth. Therefore, care for demineralized teeth should be more than sound teeth in terms of coloring.

3. Limitations

The manufacturer disclosed the components of each product to some extent, but did not disclose the exact capacity or concentration, making it difficult to accurately discuss the tooth whitening effect on each component. This study identified the whitening effect of toothpaste on the sole colorant of coffee. In the future, it is necessary to conduct research using complex coloring materials. In addition, since this study was an in vitro study, the results cannot be directly applied to the oral cavity. In the future, actual oral evaluation is required. The whitening effect was analyzed by color analysis through image analysis of the surface of the tooth, but the evaluation of the abrasion of the tooth was not conducted.

4. Conclusion

In this study, the components of toothpaste in seven groups were investigated, and there was a difference in the ingredients for each product. A sound and a demineralized tooth surface were manufactured on a tooth enamel specimen to induce coffee coloring. After brushing the tooth specimen 50, 100, and 150 times, the color change of the tooth surface was confirmed. When the teeth were brushed more than 50 times, the functionality of tooth whitening was confirmed in all toothpaste used in this study. When brushed more than 100 times, a difference in the degree of tooth whitening was confirmed for each toothpaste group. Demineralized teeth were more easily colored than sound teeth. After brushing the same number of times, the demineralized teeth were still darker than sound teeth.

Notes

Conflict of interest

Ji-Hyun Min has been journal manager of the *Journal of Dental Hygiene Science* since January 2023. Ji-Hyun Min was not involved in the review process of this editorial. Otherwise, no potential conflict of interest relevant to this article was reported.

Ethical approval

Not Applicable.

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Data availability

Data supporting the results of this study are available from the corresponding author or the Korean Society of Dental Hygiene Science upon reasonable request.

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