Original Article

Evaluation of the Potential Side Effects of Commercially Available Whitening Toothpaste

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Abstract

Background: The growing demand for an enhanced esthetic smile has led to the development of whitening toothpaste in the market. The whitening effects are usually achieved by the incorporation of bleaching and abrasive components. An ideal whitening toothpaste should remove stains effectively, with minimal effect on tooth structure. **Materials and Methods:** Twenty-four extracted human maxillary anteriors were randomly and equally divided into three groups, and each was subjected to tooth brushing using different toothpastes. Surface roughness was estimated using the surface roughness tester, and microhardness was estimated using the Vickers hardness tester at baseline and after 3 months. **Results:** In the activated charcoal group, there was an increase in the surface roughness from baseline to 3 months, which was found to be statistically significant. However, no statistically significant difference in surface roughness was found in the other groups. With respect to microhardness, the activated charcoal group showed a statistically significant difference from baseline to 3 months, unlike other groups, which did not show statistical significance. **Conclusion:** This study showed that whitening toothpaste containing charcoal significantly increased surface roughness and microhardness.

Keywords: Abrasives, Activated charcoal, Active oxygen, Fluoride, Microhardness, Surface roughness, Whitening toothpaste.

Introduction

A common cause for patients to be referred to dentists is tooth discolouration. Both internal and external factors can cause tooth discoloration.[1] The inner tooth surface is the source of intrinsic stain, which can be brought on by trauma, drugs, genetic abnormalities, and fluorosis. The surfaces of teeth are home to extrinsic stains, which can be brought on by smoking, drinking chromogenic beverages such as tea and coffee, and maintaining inadequate dental hygiene.[2] A range of techniques is used, ranging from extremely conservative procedures such as scaling as well as polishing, bleaching, micro- and macro-abrasions to more radical procedures such as ceramic laminates and crowns.[3] For certain people, using over-the-counter whitening treatments, such as toothpaste and powders, may be a better option.

Whitening toothpaste was released to the market to remove this type of discoloration. This composition is comparable to non-whitening dentifrices; on the other hand, whitening dentifrices may contain peroxides and have a higher abrasive content. The abrasives that are most frequently found in toothpaste are sodium bicarbonate, which eliminates extrinsic stains, hydrated silica, dicalcium phosphate dihydrate, calcium pyrophosphate, alumina, calcium carbonate, and perlite. The abrasive particles become lodged between the toothbrush bristles and the discolored tooth surface when brushing your teeth. The stain is removed from the tooth surface because the particle is tougher than the stain.[4]

Black, tasteless, and odorless, activated charcoal is a powder that is produced by extracting water and volatile ingredients from carbon-based compounds. It has also demonstrated strong anti-inflammatory and antibacterial qualities.[5] Ion exchange in the mouth is made possible by the charcoal's nanopores, which increase the surface area. The product's maker states that it can absorb and eliminate stains, chromophores, and pigments that cause teeth to change color, which is more likely to affect younger people.[6]

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Potassium peroxymonosulfate's (PMS) active oxygen formula is a green oxidant with greater oxidation potential than hydrogen peroxide. Given that singlet oxygen can be released gradually from the aqueous solution, the reaction is environmentally benign. Furthermore, due to a higher O-O bond energy, PMS has less reactivity at room temperature than hydrogen peroxide since its molecular weight is larger.[7]

While these dentifrices are effective in eliminating extrinsic stains, when used in conjunction with teeth-whitening procedures, their abrasion may result in gingival recession, dentin hypersensitivity, cervical abrasion, and excessive dental wear.[8] Every toothpaste has a relative dentin abrasivity value that affects the surface roughness of the restoration and the enamel.[9] The roughened surface raises the possibility of caries and affects periodontal tissue, and is more likely to hold on to stains, plaque, and food particles.[10]

Although these toothpastes lightened teeth to some extent, Jamwal *et al*. observed in their systematic review and meta-analysis that they also changed the mineral composition of teeth by making the surface rougher and decreasing the microhardness. A carefree attitude when using these toothpastes could have disastrous effects due to insufficient information about the harmful effects of these whitening chemicals on the tooth surface.[11] When used excessively, commercially available teeth whiteners have the potential to cause teeth to become more demineralized and deproteinized. For additional assistance, it is important to understand the consequences of using whitening toothpaste and any modifications.

Materials and Methods

Preparation of tooth samples

Twenty-four freshly removed maxillary anteriors were gathered. Using the hand scaler, the debris was eliminated. To eliminate teeth with caries, enamel cracks, erosion, deep grooves, fractures, or severe discoloration, the teeth were washed beneath flowing water from the tap, and viewed using a stereomicroscope at a magnification of ×10. Air/water jets and a dental curette were used to clean the teeth, which were maintained in a 0.1% thymol solution. In a mesiodistal orientation, the roots were removed from the coronary region 2 mm below the enamel–cement junction using a diamond disc and water cooling.

After that, each tooth was separately set into an acrylic resin cast, exposing the surfaces of the facial enamel. Water-cooling #600-grit carbide paper was used to flatten the teeth's facial surfaces (Figure 1).

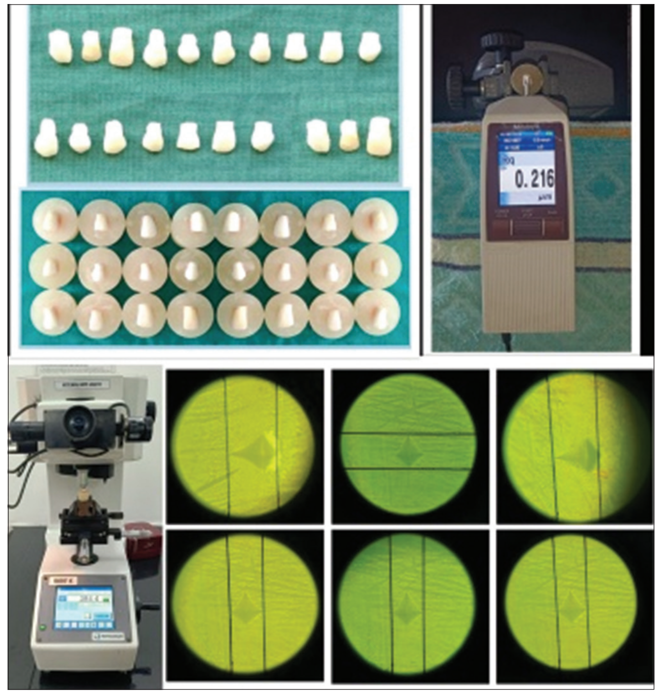

Figure 1: Mitutoyo surface roughness tester and Matsusawa microhardness tester

Brushing process

Based on the toothpastes used, the samples were split into three groups at random:

- Group 1: Colgate® Optic White toothpaste (Colgate Palmolive Company, USA) containing charcoal was utilized to brush the specimens
- Group 2: Colgate® Visible White 2, a whitening toothpaste that contains active oxygen, was utilized to brush the samples (Colgate Palmolive Company, USA)
- Group 3: Brushed every day using toothpaste that included fluoride (Closeup Triple Fresh, manufactured by Hindustan Unilever in Mumbai, India).

Toothpaste	Composition	Whitening technology
Colgate® optic white	Water, Hydrated Silica, Sorbitol, Glycerine, PEG-12, Pentasodium Triphosphate, Tetrapotassium Pyrophosphate, Sodium Lauryl Sulfate, Flavor, Cocamidopropyl Betaine, Xanthan Gum, Cellulose Gum, Charcoal Powder, Sodium Saccharin, Sodium Hydroxide, Blue 1, Red 40, and Titanium Dioxide	Activated charcoal
Colgate® Visible white 2	Poloxamer 105, Calcium Pyrophosphate, PEG-2M, EG/PPG-166/66 copolymer, Polyvinyl Pyrrolidone Silica, Tetrasodium Pyrophosphate Flavor, Sodium Lauryl Sulfate, Potassium Monoperoxysulfate, Disodium pyrophosphate, Sodium Monofluorophosphate, Sodium Saccharin, Cocamidopropyl Betaine, Sucralose, Butylated hydroxytoluene, Limonene, and Linalool	Active Oxygen
Closeup triple Fresh	Sorbitol, Water, Hydrated Silica, PEG-32, Flavor, Cellulose Gum, Sodium Lauryl Sulfate, Cocamidopropyl Betaine, Sodium Saccharin, Sodium Fluoride, Zinc Sulfate, Sodium Hydroxide, CI 77891, CI 16255, Eucalyptus Globulus (Eucalyptus Extract), Synthetic Hydroxide, I 16035, Melaleuca Alternifolia (Tea Tree Extract), and Eugenol	Control group

To avoid possible discrepancies between researchers, one researcher used a soft power toothbrush (Oracura, SB100 sonic light battery-operated electric toothbrush) and a horizontal tooth brushing approach on the specimens. To replicate a 12-week treatment duration of two daily brushings (brushing twice a day for 1 min), 108 brushing cycles were carried out.

The specimens' Ra was measured using the Mitutoyo Surface Roughness Tester SJ-210-Series 178-Portable (Figure 1) at baseline and after a 12-week brushing session. To ensure that the specimen's position was consistent throughout each measurement, it was set up on a certain jig. Recordings were then made once the needle of the instrument was positioned on the specimen's surface. Every item's surface center was used to obtain readings in various directions. For every specimen, five Ra measurements were obtained and averaged. The equipment was calibrated using three separate measurements.

Microhardness (Vickers hardness number [VHN]) measurement

A Vickers microhardness tester (Matsuzawa Co., Ltd., Akita Pref, Japan) was used to measure the specimens' VHN both at baseline and following a 12-week brushing period. Matsuzawa microhardness testing applied a force of 980 g for 15 s. The VHN was calculated using five indentations that were 100 µm from the center of each specimen. The arithmetic mean value was calculated for each specimen. The equipment was modified after each measurement (Figure 1).

Results

The mean values for surface roughness for the three groups at baseline and 3 months later are displayed in Table 1. However, in Group 2, the surface roughness dropped from 0.25 ± 0.10 at baseline to 0.14 ± 0.58 at 3 months, and in Group 3, the surface roughness decreased from 0.28 ± 0.92 at baseline to 0.17 ± 0.58 at 3 months. Group 1's changes were determined to be statistically significant, where surface roughness was 0.23 ± 0.74 at baseline and grew to 0.47 ± 0.63 at 3 months (Figure 2).

A statistically significant increase in microhardness was seen in Group 1, with values rising from 349.4 ± 45 at baseline to 476.6 ± 88 at 3 months. The microhardness value in Group 2 increased from 312.3 ± 71 at baseline to 347.3 ± 59; however, this disparity was not statistically significant. The microhardness value in group 3 increased from 335.2 ± 50.6 at baseline to 358.0 ± 35.3; however, Table 2 indicates that this increase was not statistically significant (Figure 2).

The mean surface roughness ratings for the three groups at baseline and 3 months later are displayed in Table 1. At baseline, Group 1's surface roughness was 0.23 ± 0.74, Group 2's was 0.25 ± 0.10, and Group 3's was 0.28 ± 0.92. These values were not statistically significant. After 3 months, surface roughness was 0.475 ± 0.63 in Group 1, 0.14 ± 0.58 in Group 2, and 0.17 ± 0.58 in Group 3. These differences were statistically significant (Figure 2).

At baseline and 3 months, the mean microhardness scores for each group are displayed in Table 2. Group 1's microhardness was 349.4 ± 45 at baseline, whereas Group 2's was 312.3 ± 71, and Group 3's was 335.2 ± 50.6. These values were not statistically significant. After 3 months, the micro hardness in Groups 1 and 3 was 476.6 ± 88, 347.3 ± 59, and 358.0 ± 35.3, respectively. These differences were statistically significant (Figure 2).

The Tukey test was used to determine whether groups showed a variation in surface roughness levels that was statistically significant, and after 3 months, Group 2 and Group 3's surface roughness values were statistically significant when compared to Group 1's in an intergroup comparison. The Tukey test was used to determine if the groups displayed a significant difference in the microhardness values. Microhardness values were statistically significantly lower in Groups 2 and 3 than in Group 1; however, after 3 months, Groups 2 and 3 did not vary statistically significantly.

Discussion

The current study investigated the surface roughness and microhardness of whitening toothpastes containing activated charcoal and active oxygen in comparison to ordinary fluoridated toothpaste.

Concerns about the negative effects of whitening toothpaste on dental hard tissue are addressed in the literature, and the study actively addresses these issues in line with findings published by Jamwal *et al*., Feitosa *et al*., Ozkan *et al*., and other studies discussions of morphological changes and increased surface roughness, adding to the overall context of potential risks related to the careless use of certain whitening toothpaste.[11-13]

Table 1: Comparison of means between the time intervals for surface roughness (analysis of variance)

Time	Group	Mean	STD	95% confidence levels		F-value	*P*-value
				Lower bound	Upper bound		
Before	Group 1	0.2390	0.74	0.17	0.3013	0.455	0.641
	Group 2	0.2554	0.10	0.16	0.344		
	Group 3	0.2825	0.92	0.20	0.360		
After	Group 1	0.475	0.63	0.42	0.52	73.51	0.000*
	Group 2	0.1425	0.58	0.09	0.91		
	Group 3	0.1788	0.58	0.13	0.22		

* $p < 0.001$ (highly statistically significant)

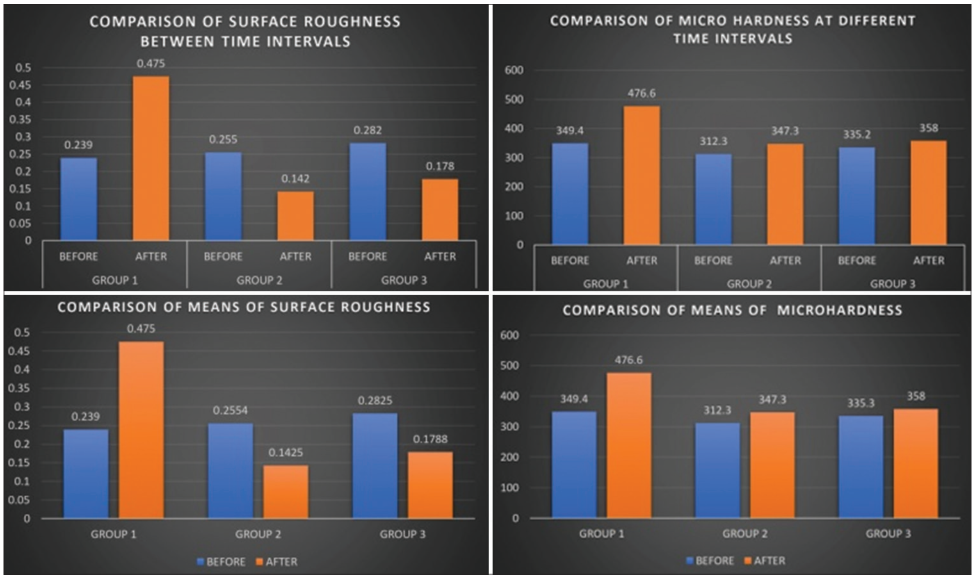

Figure 2: Mean surface roughness and mean microhardness for the three groups at baseline and 3 months

Table 2: Comparison of means between the time intervals for micro hardness (analysis of variance)

Time	Group	Mean	STD	95% confidence levels		F-value	*P*-value
				Lower bound	Upper bound		
Before	Group 1	349.4	45.2	311.61	387.3	0.868	0.434
	Group 2	312.3	71.4	252.5	372.0		
	Group 3	335.3	50.6	292.9	377.6		
After	Group 1	476.6	88.05	403.06	550.2	9.872	0.001*
	Group 2	347.3	59.36	297.7	396.9		
	Group 3	358.0	35.3	328.5	387.5		

* $p < 0.001$ (highly statistically significant)

The whitening agents utilized in toothpaste can be abrasive agents such as alumina, calcium carbonate, hydrated silica, calcium pyrophosphate, dicalcium phosphate dehydrate, perlite, and sodium bicarbonate. They could also be chemical agents such as calcium peroxide, sodium citrate, sodium tripolyphosphate, hydrogen peroxide, sodium pyrophosphate, papain, or sodium hexametaphosphate. They could be an optical agent, such as blue covarine.[3]

When viewed from a clinical perspective, surface roughness is quite significant. Surface roughness can lead to increased biofilm production and buildup, which can cause irreparable damage to the hard tissues of teeth and restoration surfaces. This is because surface roughness has a significant influence on bacterial adherence.[14] In addition to causing dentin hypersensitivity, gingival recession, and the buildup of oral pigments, surface roughness can also affect how restoration margins and enamel seem from an optical standpoint.[15]

The abrasive components of toothpastes and the hair hardness of toothbrushes have been identified as the two elements that affect enamel or dentin. One operator brushed all specimens to ensure consistent brushing and to decrease the abrasiveness of the toothbrush in this investigation. "Soft" hair hardness was favored. Power and manual toothbrushes' capacity to maintain the final color of whitened teeth was evaluated in clinical research. When it came to maintaining the whiteness after 6 months, the powered toothbrush group outperformed the manual toothbrush group.[10]

The structure, content, and particle sizes of charcoal can make it abrasive. Charcoal can bind to all dental surfaces and deposits, including pigments, stains, and chromophores that have a significant potential to modify the color of teeth. That is to say, it may make the enamel's surface rougher.[16]

Following a 14-day period, Franco *et al*. found no discernible variation in surface roughness between bovine enamel surfaces manually brushed with ordinary toothpaste or tooth powder with activated charcoal.[17] After brushing with conventional toothpaste and powdered activated charcoal, Palandi *et al*. saw modest changes on the enamel surfaces.[18] After using whitening toothpaste containing charcoal for 1 or 3 months, Pertiwi *et al*. also observed an increased surface roughness.[9] The surface roughness of enamel was higher in the activated charcoal-containing whitening toothpaste groups, according to a recent experimental *in vitro* investigation by Zamudio-Santiago *et al*.[19]

Hydrated silica was also included in toothpaste with titanium dioxide and activated charcoal. To remove stains, toothpaste manufacturers add hydrated silica, a medium-hard abrasive, to the product. However, the amount, size, shape, and percentage of silica that is added determine how abrasive the toothpaste is; this information is not revealed by the manufacturer. Silva *et al*. reported surface changes on enamel, with the enamel prisms being more evident after brushing with different whitening toothpastes.[15] The surface roughness of teeth cleaned for 2 min, twice a day, for a week, increased statistically significantly while using Ipana White Power Carbonate toothpaste, according to Maden *et al*.[20] Jamwal *et al*., in their meta-analysis unveiled found that teeth brushed with whitening toothpastes had higher surface hardness, which also corresponds to the current study.

When the microhardness within the toothpaste groups was examined, it was discovered that Groups 2 and 3 exhibited no significant changes. The mechanical characteristics of enamel are heavily influenced by the degree of mineralization and the arrangement of enamel prisms with respect to fracture orientation.[21] Fluoride-containing toothpastes have been thoroughly demonstrated in the literature for promoting the remineralization of human enamel following acid damage and are widely accepted by the public.[22] Tomaz *et al*. found that toothpastes containing 1,450 ppm fluoride were able to restore the hardness of the enamel surface,[23] whereas Oliveira *et al*. discovered that fluoride-only toothpaste greatly enhanced the microhardness of demineralized samples after a week of therapy.[24]

After using charcoal whitening toothpaste for 3 months, Vural *et al*. saw no change in the microhardness of the enamel, conversely to the current study, which found a significant increase in microhardness among teeth brushed with Colgate Optic white, which contained active charcoal as a whitening agent.[25]

In a recent study, using toothpaste with 500, 1,000, and 1,500 ppm fluoride resulted in better mineral recovery than the control group that did not include any fluoride.[26] The outcomes of this investigation are consistent with the current literature and support the "fluoride toothpaste has a dose-response relationship" protocol, as the highest fluoride-containing toothpaste resulted in a considerable increase in surface microhardness.[10]

Conclusion

Within its constraints, this research discovered the following:

1. Toothpaste with activated charcoal significantly increased the surface roughness of teeth *in vitro*
2. Toothpaste with activated charcoal significantly increased the microhardness of the teeth *in vitro*.

Although there is a wealth of research supporting the effectiveness of whitening toothpaste in enhancing tooth color, it was important to consider the other viewpoint, where the literature was limited. This study set out to determine how various whitening chemicals affected the microhardness and surface roughness of teeth.

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