

Comparative Evaluation of the Whitening Efficacy and Abrasiveness of Charcoal-Containing and Conventional Toothpastes: an in Vitro Study

Dr. Gursewak Singh

Abstract: Charcoal-containing toothpastes have become increasingly popular because of their claimed whitening effects and ability to remove extrinsic stains. This in vitro study aimed to evaluate and compare the whitening efficacy and abrasiveness of two commercially available charcoal toothpastes with a conventional non-whitening toothpaste. Thirty extracted human premolars were polished, sectioned, mounted, and immersed in a coffee solution at 37°C for six days to simulate staining. Baseline color and surface roughness measurements were obtained using a spectrophotometer and profilometer, respectively. The specimens were randomly allocated into three groups (n=10): Colgate Essentials Charcoal Teeth, Crest 3D White Charcoal Toothpaste, and Colgate Cavity Protection. Following 2,000 brushing cycles in a standardized brushing machine, post-brushing color and surface roughness measurements were recorded. Statistical analysis was performed using repeated-measures ANOVA and Bonferroni tests. All toothpastes produced significant increases in surface roughness and significant improvements in tooth color ($p < 0.05$). However, no statistically significant differences were observed among the three groups regarding abrasiveness or whitening efficacy ($p > 0.05$). The mean color change (ΔE) values for all groups were within clinically acceptable limits. Within the limitations of this study, charcoal-containing toothpastes demonstrated whitening and abrasive effects comparable to those of conventional toothpaste, with no evidence of superior whitening performance. Further clinical studies are recommended to assess their long-term effects under intraoral conditions.

Keywords: Cosmetic, charcoal, abrasion, whitening agent

1. Background

The study was intended to determine the extent of abrasiveness and degree of whiteness associated with the use of charcoal toothpaste in permanent teeth.

2. Introduction

Bleaching or whitening is one of the most significant cosmetic treatments for teeth and is quite popular in this time and age due to people being more aware of their appearance than before. White and well-aligned teeth can result in significant improvement in oneself image and confidence which is often lacking in people with discolored teeth leading to social embarrassment and other psychological issues. There can be several reasons for discoloration due to systemic issues, trauma, or drug use which is intrinsic. The color change due to external agents or extrinsic discoloration may be due to poor oral hygiene, consumption of foods and drinks that stain the teeth, or taking coffee, tea, etc.

The most used agent for whitening is Hydrogen Peroxide (H_2O_2) which comes in various concentrations depending on in-office or at-home use. The bleaching procedure which is carried out in the office contains a higher concentration of bleaching agent and is more effective than the at-home products available in the market. There are varieties of over-the-counter whitening products available including but not limited to bleaching strips, lights, pens, toothpaste, and gels. Among these, the most popular and convenient choice is whitening toothpastes due to their ease of usage and abrasive and other chemical agents and their ability to remove extrinsic agents.

One of the most important components of whitening toothpastes is abrasive agents which usually include (Harris,

Garcia-Godoy, & Nathe, 2014), silica, phosphates, carbonates, and bicarbonates. Other factors affecting the efficiency of these toothpaste are the technique of brushing, the hardness of the toothbrush and pressure applied during brushing, and the number of strokes used during brushing. The most significant chemical agents included in this toothpaste are H_2O_2 phosphate salts, sodium citrate, etc. The toothpastes containing active charcoal are marketed as charcoal toothpastes. The use of activated charcoal for oral health and hygiene dates to the Hippocratic time in ancient Greece. Charcoal is a commonly used coloring agent in various food items in Japan, Korea, and China and it improves overall health by its potential to eliminate toxins and heavy metals from the body. The charcoal is produced on partial oxidation of numerous materials and its high porosity allows charcoal to exchange ions in the mouth through the nanopores. These ions attach to the tooth surface removing the extrinsic stains and pigments. This action is due to active charcoal being an adsorbing agent and its tendency to adsorb chromophores, stains, and various pigments.

3. Materials and Methods

The study was held in vitro using 30 permanent premolars which were orthodontic extractions, and the patient and parent/guardian consent was taken prior to starting this study. The specimens were completely healthy, free of any discoloration, trauma, decay, restorations, periodontal diseases, or any other odontalgic pathologies, and intact at the time of extraction. The PA of all these teeth was also taken and was clear. All the teeth were polished with pumice using a low-speed handpiece for 30 seconds and were always stored in artificial saliva. Initially, teeth were placed in a wax mold to make sure there was no movement during the sectioning. A caliper was used to make precise measurements. The teeth were sliced using a diamond disc

under air and water spray in such a way that the buccal surface enamel stays intact. The dimensions of samples were 5 mm × 5 mm × 7 mm. This makes the height and width of each tooth sample 5 mm, and the thickness is 7 mm. At this stage, specimens were put in a regular saline bath for 20 sec. Once sectioned, the specimens were placed in plastic molds after mounting them in putty.

To measure the color changes before and after brushing with the sample toothpaste, the specimens were immersed in 200g of Tim Horton's coffee solution prepared in 700 cc of hot water using a French press. The immersion was incubated at 37°C for about 6 days prior to brushing them. After 6 days of direct contact by placing the specimens in a microtube (removed from mold) they were removed and air dried by syringe. Once dried the specimens along with the putty placed in the spectrophotometric device to measure the colour change from the coffee staining. The methods used for color determination were a spectrophotometric device (MHTS.P.A., Via Milano Co., Verona, Italy) and the Vita classic system. For measurement using Vita classic system the utmost convex portion of the specimens was taken into consideration as the point of measurement. After measuring the color, a*, b*, and L* parameters were also recorded.

To measure the surface roughness a profilometric device was used (Surface Roughness tester Time 1200, Salutron Co., Germany) with the device calibrations of LTH=0.25×1 mm, STO=ISO, RAN=AUTO FIL=RC. The measurement was commenced by placing the needle and sensor of the device at the most convex part on the facial surface and began to move sideways and one point was considered as the initial roughness (Ra) in microns. Three measurements were taken for each specimen by measuring on the facial/buccal surface and the mean of all 3 readings was taken into consideration to increase the accuracy of the measurement. Once the readings were obtained for roughness and color, they were arranged in ascending order for all the specimens. All three readings were included in each group which is low, high, and average in order to make sure the readings for roughness and color change are more accurate and precise. All the specimens in each of the groups that is A, B, and C were numbered from 1 to 10.

The group A specimens were brushed using Colgate essential charcoal white toothpaste (manufactured by Dr. Jahangir Pharmaceutical and Hygienic Co., Iran), specimens in group B were brushed using Crest 3D charcoal white toothpaste (Purity Laboratories Ltd., Dublin, Ireland), and

group C was brushed using Colgate toothpaste (Colgate-Palmolive Co., Poland) as the control group. Group A and Group B were the charcoal toothpaste used in this case Colgate was regular toothpaste used that is non-whitening. Twenty grams of toothpaste were measured by weighing on the digital scale after calibrating the scale with a precision of 0.0001 g and was poured into a beaker with 40 ml of distilled water and mixed for 3 minutes. 10 ml of artificial saliva was added to it later. The specimens were brushed about 2000 rounds equivalent to 3 times a day for 1.5 months or once a day for about 20 mins. The force was applied equally to all the samples.

Once the brushing was completed the specimens were bathed in normal saline and dried off. The roughness of the specimen was checked by using the same spots as prior to brushing them and taking 3 values and considering the mean value of them. To measure the color parameters the samples were transferred to spectrophotometric apparatus as placed in the earlier state in order to record the parameters. The calculations were done to perform color changes using the given formula:

$$\Delta E = \sqrt{((L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2)}$$

To make sure the distribution of data is normal Kolmogorov-Smirnov and Shapiro-Wilk tests were used.

Evaluated Samples:

- 1) Colgate Essentials Charcoal Teeth
- 2) Crest 3D White Charcoal Toothpaste
- 3) Colgate Cavity Protection

4. Results

To determine the distribution of data Shapiro-Wilk and Kolmogorov-Smirnov tests were used. P>0.05 and the normal distribution of data was confirmed.

The change in surface profile by 3 toothpastes was P=0.0001. ΔE=3.3, which was also within normal limits for all 3 groups with a confidence interval of 95%. The difference in abrasion was negligible, P>0.05, and the color change was P=0.884 among toothpaste.

The Abrasiveness of Toothpastes:

There was abrasion in all three specimen types which was measured using Bonferroni test showed roughness changes in each case.

Table 1: Statistical Indices of the Abrasion Results of Each Toothpaste Group

Group	Primary Roughness	Secondary Roughness	Standard Error	df	P	95% CI Upper	95% CI Lower
Colgate Essentials Charcoal Teeth	1	2	1.11	0.186	0.0001	0.728	1.493
Crest 3D White Charcoal Toothpaste	1	2	0.6	0.186	0.004	0.188	0.952
Colgate Cavity Protection (Control)	1	2	0.798	0.186	0.0001	0.415	1.18

There was significant abrasion in all the groups as Colgate Essentials Charcoal Teeth p=0.0001, Crest 3D White Charcoal Toothpaste p=0.004, Colgate p=0.0001. To elaborate further the average abrasion with these toothpastes was as follows:

- Colgate Essentials Charcoal Teeth = 2.123 μm
- Crest 3D White Charcoal Toothpaste = 1.581 μm

- Colgate Cavity Protection = 1.8686 μm

Repeated measures of ANOVA were taken which showed that interactions of primary and secondary surface profiles and the brand of toothpaste were important in terms of abrasion. This shows that the increasing and decreasing patterns were different for the surface profiles before and

after toothbrushing showing the abrasion levels related to toothpastes.

Pairwise comparisons of toothpastes with regard to abrasion:

The Bonferroni test showed that the difference in degrees of abrasion in all 3-toothpaste group specimens was negligible.

Table 2: Pairwise Comparisons of Toothpaste Roughness Changes (Bonferroni Test)

Time / Comparison Base	Group 1	Group 2	Mean Diff.	Std. Dev.	P
Roughness testing time	Colgate Essentials	Crest 3D White	0.542	0.255	0.129
Roughness testing time	Crest 3D White	Colgate	-0.288	0.255	0.808
Roughness testing time	Colgate	Colgate Essentials	-0.255	0.255	0.981
Post-Brushing Interaction	Crest 3D White	Colgate Essentials	0.002	0.218	1
Post-Brushing Interaction	Crest 3D White	Colgate	-0.06	0.218	1
Post-Brushing Interaction	Colgate	Colgate Essentials	0.058	0.218	1

Comparison of color variations in each group:

A 95% confidence interval was considered using one-way ANOVA for these readings. The color variations of all the

specimens were within an acceptable range within upper and lower bounds.

Table 3: Statistical Indices of Color Changes by the Studied Toothpastes

Group	Samples (n)	Mean (ΔE)	Std. Dev.	Min	Max	95% CI Upper	95% CI Lower
Colgate Essentials Charcoal Teeth	10	3.566	0.62	1.25	6.34	2.16	4.97
Crest 3D White Charcoal Toothpaste	10	3.378	0.66	1.12	8.4	1.88	4.88
Colgate Cavity Protection	10	3.145	0.5	0.46	5.1	2.01	4.18

5. Discussions

These charcoal toothpaste are claimed to improve the color of teeth with the least abrasion by removing any kind of extrinsic stains. Generally, toothpaste consists of abrasives, cleansers, and a few more active ingredients. It is crucial to be well-informed about the active ingredients in toothpaste to be able to choose the correct one.

According to research results, all the sample toothpastes used have the ability to wear the surface of enamel after brushing 3 times a day using the same amount of force for 1.5 months. All the given toothpastes were able to change the primary and secondary surface profile but there was no significant difference in the abrasion that is the changes related to each toothpaste were the same. To elaborate, there was no significant difference in abrasion caused due to charcoal and non-charcoal toothpaste. The abrasiveness and whitening of the sample toothpastes used are quite similar which can be attributed to the similar components used.

Toothpaste with higher relative dentin abrasivity (RDA) tend to cause more abrasiveness according to a review by Macdonald et al. Although RDA is the most accurate measure for surface roughness and abrasiveness, it was not used in testing of surface roughness due to its limited access. Due to a lack of research on charcoal toothpastes, there is no relevant study to compare this study with.

Another study done by Dimitrios Dionysopoulos et al. also verified that the whitening toothpaste and mouthwash improved the shade of teeth. This study was also done in vitro and showed that the surface of teeth became smoother but there were large craters as compared to the control toothpaste being used. The McCarty et al. did a study and showed that charcoal toothpastes have higher abrasion than other toothpastes. This study was done using acrylic teeth so that can be one of the reasons for the difference in results. To add to this the toothpaste was made by mixing charcoal capsules in water. Moreover, the difference in

implementation protocol can be a reason for the difference between the results of these two studies.

Another study was done by Franzo et al. to observe the difference between enamel and dentin wear which showed that there was not much difference in the enamel wear, but the dentin wear was significantly different depending on the brand. This difference is primarily due to the different molecular structures of enamel and dentin.

Another significant in vivo study was done by de Moraes Rego Roselino et al. which showed that regardless of brand these whitening toothpaste did not have a significant change in color and did not increase the roughness of the tooth surface by a significant amount. This was a clinical trial done intraorally whereas this study was performed in vitro so the intraoral conditions can have a significant impact such as human saliva, hand force of the patients, and other habits or nutritional differences. There may be difference in the measurement of abrasion since the methods used were impression-taking and casting.

The current study resonates with this study done by Soares et al. which showed that the changes in colour and roughness were significant for all toothpastes, but no significant difference was observed among any of the toothpastes. The results of this study were most relevant to the current research.

In a study done by Mariele Vertuan et al. it was evident that activated charcoal-containing toothpastes should be used with care as these can have significant abrasion in patients with erosive tooth wear. This study was also done in vitro, and the toothpastes used were combined with pyrophosphate.

6. Conclusion

To conclude, all 3 toothpastes had a significant impact on the surface and color of the specimens used indicating they

all have similar levels of whitening effect and abrasiveness. There was no significant difference between different toothpaste brands, but all the toothpaste had a crucial abrasive and whitening effect on teeth.

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