



## Evaluation of Abrasion and Whitening Effect of Toothpastes Containing Charcoal on Primary Teeth

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### ABSTRACT

**Objectives:** Parents are aware of the importance of anterior tooth esthetics in their children. Children also pay attention to their appearance more than ever. Today, charcoal has been added to toothpastes. Charcoal can help whiten teeth through abrasion. This study aimed to investigate the degree of bleaching and abrasion of charcoal toothpaste on primary teeth.

**Materials and Method:** This in-vitro study was performed on 30 extracted primary teeth. Initially, the samples were polished, cut, and mounted in blocks of putty. The samples were placed in a coffee solution and then the tooth color was measured by a spectrophotometer and the initial surface profile was measured by a profilometer. The samples were brushed back and forth by the brushing machine with 20 gr Bancer, Beverly, and Colgate toothpastes (mixed with 40 ml of distilled water) for 2000 times (equivalent to 3 times a day for 1.5 months). A color determination was performed again and a second surface profile was measured. The data were analyzed by one-way ANOVA, ANCOVA and paired t-test.

**Results:** The results of this study showed that all three Beverly, Bencer and Colgate whitening toothpastes increased the surface profile and made significant statistical changes in the roughness of dental specimens ( $P=0.01$ ,  $P=0.005$ ,  $P=0.001$ ). The statistical study of the data did not show a significant difference between the groups in terms of abrasion and whitening properties ( $P=0.78$ ,  $P=0.99$ ).

**Conclusion:** Three whitening toothpastes whiten primary teeth and increase their surface roughness. These three toothpastes are not statistically different in terms of abrasion and whitening properties.

**Keywords:** Whitening, Abrasion, Toothpaste, Primary Teeth, Activated Charcoal.

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### INTRODUCTION

Parents are aware of the importance of anterior tooth esthetics in their children. Children also pay more attention to their appearance, because they live in a period of

great attention and evaluation by their peers. Unsightly teeth expose them to criticism and condemnation from their friends and those around them. This is to the extent that older children express their desire to have a

beautiful smile [1]. According to a 2007 study, tooth color is a major factor in its beauty. According to the study, 89.3% of people who were dissatisfied with the appearance of their teeth said that the reason was the color of their teeth. Besides, 88.2% of them expressed a tendency to whiten their teeth [2].

Human understanding of tooth color is a complex phenomenon and is influenced by light conditions, light properties of teeth (transparency, light scattering, glossy surface), and the experience of the observer [3].

Reasons for tooth discoloration are classified into two main groups: internal and external. Internal causes include factors such as genetics, age (yellowing of teeth), antibiotics, high levels of fluoride, and developmental disorders [4]. These disorders can occur before teeth eruption. After the teeth have erupted, some restorations can change the color of the teeth. The exterior discoloration is usually caused by environmental factors such as smoking, food pigments, antibiotics, and metals such as iron and copper [5]. The color compounds in these sources are absorbed by the dental pellicle or directly to the tooth surface and cause tooth discoloration [6].

There are several methods to remove tooth discoloration, such as professional teeth whitening, whitening toothpaste, internal bleaching of non-vital teeth, and external bleaching of vital teeth as well as enamel micro-abrasion [7]. Intense color changes can be covered by a crown or veneer, which is a more aggressive and expensive method [8].

Whitening toothpastes are more prominent among the options available to eliminate tooth discoloration [9]. These products act through the presence of abrasive, chemical, or optical agents [10, 11]. Abrasive agents include silica hydrate, calcium carbonate, dicalcium phosphate dihydrate, calcium pyrophosphate, alumina perlite, and sodium bicarbonate [12]. Chemical agents include hydrogen peroxide, calcium peroxide, sodium citrate, sodium tripolyphosphate, sodium hexametaphosphate, and optical agents include blue covarine [13].

Of course, excessive abrasion of the teeth can

damage the enamel and in some cases dentin, increase tooth sensitivity, cause beauty problems, and ultimately damage the chewing system [14]. The cleaning power of toothpaste is evaluated based on the abrasives in them. The degree of abrasion of toothpaste depends on various factors such as the number of abrasive particles, the size of abrasive particles, the contents of the toothpaste, such as detergents, and the concentration of abrasives [14]. However, the best toothpaste is the one with the maximum amount of cleaning and the least amount of abrasives [15]. This abrasive power should be controlled and balanced in children's toothpaste to minimize damage to the growing surfaces of deciduous teeth along with its cleaning properties [16]. Still, the thickness of the enamel and dentin crown of deciduous teeth is less than permanent teeth [17]. One of the abrasives recently added to some toothpaste formulations is activated carbon powder. According to studies, charcoal not only absorbs contaminants but also reduces acidity and acetic acid as waste products [18]. Activated charcoal has a high porosity. This very fine (Nano-level) porosity increases its absorption ability, ions exchange in the mouth, sticking to the stains of discoloration on the surface of the teeth, and eventually removing the stains [19-23]. Now the question is the amount of abrasion and whitening of the materials in these toothpastes. The purpose of this study is to investigate the degree of abrasion and whitening of toothpaste containing charcoal in primary teeth.

## MATERIALS AND METHODS

In this in-vitro study, 30 extracted primary teeth for the therapeutic purpose were collected (informed oral consent of the patients' parents). Ethical code was taken from Research Institute of Dental Sciences, Shahid Beheshti University of Medical Sciences, Tehran, Iran. (IR.SBMU.RIDS.REC.1395.412).

The samples were healthy and free of decay, restoration, and discoloration, and the health of the samples was checked under dental unit light and with a probe. The samples were first polished with pumice paste using a low speed

handpiece for 30 seconds. Samples were stored in artificial saliva at all stages. Initially, the teeth were cut with a double-sided diamond disk along with the water and air bulb syringes, so that the enamel on the buccal surface remained intact. The dimensions of the sample were  $5 \times 5 \times 5$  mm so that the height and width were 5 mm and the thickness of the sample was 5 mm. The samples were placed in a wax cast and measured with a caliper. At each stage, the samples were first washed for 15 seconds with normal saline. After cutting, the samples were mounted in a circular wooden cast with dimensions of  $9 \times 25$  mm on putty. To measure the color changes before and after brushing, the samples were placed in a coffee solution. 150 grams of ILLY coffee (Italy) in 600 ml water was prepared by the French Press Machine. The samples were then kept in an incubator for 5 days at  $37^\circ\text{C}$ . In order for the samples to come into direct contact with the coffee, the teeth were removed from the putty and kept in the microtube (2 ml, made in Iran). After 5 days, the samples were air-dried by bulb syringe and placed in a spectrophotometer with the putty. A color determination was performed with a spectrophotometer (MHTS. P. A, Italy, Via Milano Co. Verona: VR) and with a vita classic system from the most convex part of the sample. Then the tooth color and the parameters  $a^*$ ,  $b^*$ , and  $L^*$  were recorded from the *Lab* option. The Surface Roughness Tester (Time 1200, Salutron Co. Germany) was used to determine the level of surface roughness (Fig 1). The samples were initially waxed.



**Fig. 1.** Determination of surface roughness of samples (Profilometri System)

The device settings were set as follows: LTH =  $0.25 \times 1$  mm, STO = ISO, RAN = AUTO, FIL = RC. The needle and sensor of the device were located in the most convex part of the buccal surface of the sample and began to move, and a point was identified as the initial roughness ( $R_a$ )

in microns. Another 2 points were recorded to increase the measurement accuracy and an average of 3 points was recorded. The numbers obtained from the initial roughness were arranged from small to large, and their initial color was arranged.

Attempts were made to place the lowest, medium, and highest levels of roughness and color in all three groups to reduce differences in groups. Samples were named in each group from 1 to 10. Group A was brushed with Bencer toothpaste (Dr. Jahangir Pharmaceutical & Hygienic Co., Iran), Group B with Beverly toothpaste (Purity laboratories Ltd., Dublin, Ireland), and Group C with Colgate toothpaste (Colgate-Palmolive Co., Poland) as a control group. The samples were brushed with a brushing machine (V8 Cross Brushing Machine, Ouj Andishak Isfahan, Iran) (Fig.2).



**Fig. 2.** Brushing Machine Unit after placing of samples

20 gr of each toothpaste was measured by a digital scales (Acculab AL-104, USA) after calibrating the scales with an accuracy of 0.0001 g and was poured into a glass beaker with 40 ml of distilled water and mixed for 5 minutes. In the end, 10 ml of artificial saliva was added to the solution.

During the brushing step, an abrasion on the specimens was performed by the three-body method, i.e. with the presence of toothpaste solution, tooth enamel, and toothbrush in the form of back and forth movements with the device. The samples were brushed 2,000 times, 3 times a day for 1.5 months or once a day for 4.5 months, with 100 movements per minute and 11.12 frequency (100 motions/minutes) for 20 minutes. The force was applied uniformly to all samples. Each time 6 toothbrushes were placed in the position, the device was turned on 5 times. 30 G.U.M toothbrushes (classic G.U.M 411, full soft toothbrush, USA, Chicago, Butler Co.) were prepared for the samples. First, the specimens were fixed in place, and then the toothbrushes were tightened correctly on the specimens so that each specimen was in the middle of the toothbrush's hair. Then the toothpaste solution was poured into each place. After brushing, the samples were washed with normal saline and then dried. The samples were placed in the roughness tester and 3 points were recorded, and the average of these numbers was recorded as secondary roughness. To measure the secondary color parameters, they were transferred to the spectrophotometer similar to the first case and the parameters were recorded. Calculations of color changes were performed with the following formula:

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

The data were analyzed by SPSS version 21.0 (IBM Corp., Armonk, N.Y., USA).

In order to check the normal distribution of data in the primary and secondary profile, surface profile differences, and color changes in all three groups were investigated, Kolmogorov-Smirnov and Shapiro-Wilk statistical tests was used.

To compare the mean tooth abrasion rates before brushing between groups, the one-way ANOVA test was performed. The difference between groups was not significant at  $\alpha=0.05$ . Therefore, the mean tooth abrasion rates were compared between groups after the brushing by one-way ANOVA. However, we repeated the analysis for comparing the after brushing values between studied groups by the means of ANCOVA and by adjusting the baseline values (before brushing) too. The mean amount of changes in abrasion rates in each group was also assessed separately by paired t-test. The average of  $\Delta E$  were compared between the studied groups by one-way ANOVA. The results of Kolmogorov-Smirnov and Shapiro-Wilk statistical tests showed that the distribution of data is almost normal ( $p>0.05$ ).

**Tooth Abrasion Rate**

A comparison of the primary and secondary roughness values of Bencer, Beverly, and Colgate toothpastes using the paired t-test showed that the roughness changes occurred in each group and all samples were abraded (Table 1).

**Table 1:** Statistical indicators of abrasion results of each group of toothpaste

	Toothpaste	n	Mean	SD	95% CI For The Mean		Min.	Max.	P-value
					Lower limit	Upper limit			
<b>Before Brushing</b>	Beverly	10	1.33	0.42	1.03	1.63	0.73	2.12	0.70
	Bencer	10	1.22	0.25	1.03	1.40	0.82	1.64	
	Colgate	10	1.33	0.34	1.09	1.58	0.69	1.97	
	Total	30	1.29	0.33	1.17	1.42	0.69	2.12	
<b>After Brushing</b>	Beverly	10	1.98	0.49	1.63	2.34	1.45	2.83	0.08
	Bencer	10	1.83	0.55	1.43	2.23	1.26	3.12	
	Colgate	10	1.90	0.38	1.63	2.18	1.26	2.52	
	Total	30	1.91	0.47	1.73	2.08	1.26	3.12	
<b>Changes</b>	Beverly	10	-0.65	0.65	-1.12	-0.18	-2.1	0.1	0.01
	Bencer	10	-0.61	0.53	-0.99	-0.23	-1.9	0	0.005
	Colgate	10	-0.57	0.35	-0.82	-0.31	-1.1	-0.1	0.001
	Total	30	-0.61	0.51	-0.80	-0.42	-2.1	0.1	

**Table 2:** Statistical indicators of color change ( $\Delta E$ ) in each group of toothpastes

Group	n	Mean	SD	Min.	Max.	95% CI For The Mean		p-value ANOVA
						Lower limit	Upper limit	
Colgate	10	5.23	2.62	1.91	10.51	3.36	7.10	0.99
Bencer	10	5.17	2.15	2.85	10.32	3.63	6.70	
Beverly	10	5.09	1.73	2.70	7.70	3.85	6.32	
<b>Total</b>	30	5.16	2.12	1.91	10.51	4.37	4.37	

Due to the  $p$ -value lower than 0.05, significant differences in abrasion occurred in all groups. Also, the average abrasion in Bencer, Beverly, and Colgate toothpastes was 2.12, 1.58, and 1.87  $\mu\text{m}$ , respectively, and the highest abrasion values were observed in the Bencer group.

#### Comparison of Toothpastes abrasion

Before and after the brushing no significant difference was detected between groups according to the abrasion rates with one-way ANOVA ( $p=0.70$  and  $p=0.78$ ).

We also try to compare the after brushing abrasion values of three groups by adjusting the baseline abrasion values (before brushing) by the means of ANCOVA, and again no significant difference was detected between groups ( $p=0.85$ ).

#### Comparison of Color Change in Each Group of Toothpastes

Description of color change ( $\Delta E$ ) is presented in three groups of toothpastes in Table 2. Considering the 95% confidence interval for the  $\Delta E$  index in all three groups, which is greater than 3.3, it can be concluded that we have changed color with high confidence in all three groups. The comparison of color changes between groups was performed with the One Way ANOVA test. It can be concluded that there is no significant difference between toothpastes in terms of color change ( $P = 0.99$ ).

## DISCUSSION

The results of this study showed that the whitening rate of the toothpastes examined was statistically the same. Although the mean color changes in the Beverly toothpaste samples were larger than the other two groups, the statistical analysis of the data did not make a significant difference between the three groups.

The  $\Delta E$  for unprofessional person to be able to detect discoloration without using special tools is 3.3 (24). The results of this study report 5.23  $\Delta E$  for Beverly toothpaste, 5.17  $\Delta E$  for Bencer toothpaste, and 5.09  $\Delta E$  for Colgate toothpaste. Therefore, using each of these toothpastes for a certain period (three times a day for a month and a half or equivalent), the consumer will notice changes in the color of his teeth. In other words, all three of these toothpastes can satisfy the consumer in terms of whitening ability.

Different techniques are used to check the abrasive properties of toothpastes. RDA (Relative Dentine Abrasivity), lost weight, and volume measurement is some of the quantitative techniques that measure the volume of abrasives removed from the tooth surface [25]. In this study, the profilometry technique was used to evaluate the abrasion of toothpaste. In fact, according to studies in this field, the gold standard is the measurement of dental abrasion of the profilometry method and measures surface roughness without damaging the surface of the samples [26]. RDA (Relative Dentine Abrasion) is a standard for measuring the abrasive effect of toothpaste on teeth. So far, several in-vitro studies have shown a direct link between RDA and tooth abrasion [27]. Toothpastes with an RDA below 250 are considered safe and secure. However, in most studies, an RDA below 100 has been considered as the normal range [28]. Among the toothpastes studied in this study, Bencer toothpaste did not provide the RDA of the product. The RDA of Colgate and Beverly toothpastes is 70 and 85, respectively.

According to the results of this study, it can be claimed that the toothpaste involved in this study causes teeth whitening through the abrasion mechanism. All three toothpastes erode the surface of the teeth in a period of one

and a half months, brushing three times a day or the equivalent. As a result, all three toothpastes use the abrasion mechanism to apply the whitening effect.

The results of this study showed that the average abrasion rate of Beverly toothpaste is higher than Bencer. The abrasion rate of these toothpastes did not show a statistically significant difference compared to each other. According to a study conducted in 2016, tooth abrasion is directly related to the chemical composition, size, and shape of the abrasive components of toothpaste [29]. The toothpastes involved in this study have the same whitening and abrasive components. This could be a reason to explain the same statistical results for tooth abrasion [30-32].

A 2015 study by Soares et al. reported that the amount of activated charcoal abrasion was higher than whitening toothpaste. The reasons for the difference in the results of that study with the present study can be the use of acrylic samples instead of teeth, the use of activated charcoal on the surface of the teeth instead of the use of toothpaste containing activated charcoal, and the method of brushing the samples (Manual brushing) [6].

The study results of Pertiwi et al. (2017), in terms of abrasion properties, are consistent with the present study. The difference in the study method was in the groups studied. The negative control group (water), at first and after a month, had a significant difference in surface roughness, but after 3 months, the difference was not significant. Enamel abrasion of the specimens in the toothpaste group (charcoal toothpaste and *Strong* formulated toothpaste) as in the present study, in both toothpastes increased the surface profile of the specimens after one month as well as after three months. There was no statistically significant difference between them in terms of abrasion properties [33]. Another study conducted in 2013 by da Cas NV et al. on 25 samples of micro-hybrid resin composites provided similar results for the abrasion of bleaching toothpaste with the present study. In this study, two groups of the negative control (water) and positive control (normal toothpaste) were considered in

addition to toothpastes groups. The number of cycles of the Brushing device in this study was 20,000, which is different compared to our study (2000). The results of this study showed that all groups except the negative control group increase the surface roughness of the samples and the use of toothpaste, regardless of its contents, can increase the surface roughness of the samples [34].

The results of a 2011 study by Abed et al. are consistent with the results of our study. In this study, the average abrasion before and after brushing showed significant statistical changes, and all toothpastes caused abrasion of the tooth surface. According to this study, which was performed on anti-allergic, whitening, and normal toothpastes, there was no significant difference between the enamel abrasions of common toothpastes used in Iran [35].

According to the results of Moares' clinical study in 2018, toothpastes have changed the color of teeth to an acceptable level. The results of statistical analysis of data did not show a statistically significant difference in terms of abrasion properties before and after the use of these toothpastes that are inconsistent with the results of the present study. Conducting this study as a clinical one and the effect of oral agents, including the presence of saliva, has led to differences in the results of these two studies. In addition, in the mentioned study, the casting method was used to investigate abrasion, which due to the possibility of distortion, was not considered as a precise method [36].

A 2017 study by Mosquim et al. found that all five samples of whitening toothpastes caused enamel abrasion. Dental specimens were exposed to four 90-second cycles of 0.1% citric acid with pH 2.5 for 7 days to simulate similar acidic conditions of the mouth. Different laboratory conditions in the above study as well as differences in the dental samples studied in this study could be the reasons for the differences in the results of that study with the present study [37].

The results of a 2018 study by Silva et al. were consistent with the present study and showed that all three toothpastes used caused

significant statistical changes in the properties of abrasion and bleaching. In this study, color indices L, a, and b were examined separately before and after the brushing process. All three toothpastes reduced the L index and increased the index [15].

The results of the study by Karen PINTADO-PALOMIN et al. were similar to the findings of the present study, and significant statistical results were visible in color changes. However, no significant statistical difference was observed between the three groups of toothpastes studied. Therefore, it can be concluded that all three toothpastes cause noticeable clinical color changes in the teeth [30]. The limitation of this study was collecting of sound primary tooth samples, control and regulating of brushing machine and difficulty of working with profilometer apparatus.

## CONCLUSION

Bencer and Beverly charcoal toothpaste and Colgate whitening toothpaste increase the surface profile and whiten the tooth enamel. These three toothpastes have the property of abrasion and whitening of teeth. According to statistical tests, none of the toothpastes is superior to the other in terms of whitening and abrasion.

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## CONFLICT OF INTEREST STATEMENT

None declared.

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