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Abrasiveness and whitening effect of charcoal-containing whitening toothpastes in permanent teeth.

Masoud Fallahinejad Ghajari[1], Maryam Shamsaei[2], Kimia Basandeh[3], Maedeh Sadeghpour Galouyak[3]

[1]Department of Pediatric Dentistry, Dental Research Center, Research Institute of Dental Sciences, Dental School, Shahid Beheshti University of Medical Sciences, [2]Department of Pediatric Dentistry, Dental School, Shahid Beheshti University of Medical Sciences, [3]Dental Research Center, Dental School, Shahid Beheshti University of Medical Sciences, Tehran, Iran

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Address for correspondence:
Dr. Maedeh Sadeghpour Galouyak,
Dental Research Center, Dental School, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
E-mail: sadeghpour_maedeh@yahoo.com

ABSTRACT

Background: Charcoal toothpastes can whiten teeth through abrasion. The purpose of this study was to determine the level of whitening and abrasiveness of charcoal toothpastes in permanent teeth.
Materials and Methods: In this *in vitro* study, 30 premolars were polished, sectioned, mounted, and stored for 5 days in a coffee solution at 37°C. The color and surface profile of the teeth were measured by spectrophotometry and a profilometric device, respectively. The specimens were divided into 3 groups of 10 and were brushed 2000 times (equivalent to 3 times a day for 1.5 months) in a brushing machine using 20 g of each toothpaste (Bencer, Beverly, and Colgate) mixed with 40 ml of distilled water. The color and surface profile were remeasured. Bonferroni test and repeated measures analysis of variance (ANOVA) were used to examine the abrasion. One-way ANOVA was used to assess the whitening.
Results: The three toothpastes caused changes in the surface profile ($P = 0.0001$). ΔE was equal to 3.3 (within the acceptable range) in all groups (95% confidence interval). There was no significant difference in abrasion ($P > 0.05$) and color change ($P = 0.884$) among toothpastes.
Conclusion: The results of this study showed that all the three used toothpastes have the abrasive and whitening effect on the samples significantly. The differences between the toothpastes were not significant.

Key Words: Abrasion, activated charcoal, cosmetic, permanent dentition, whitening agent, whitening toothpaste

INTRODUCTION

Nowadays, dental bleaching is one of the important reasons for referring to dentists.[1] Parents, on the other hand, pay more attention to the color of their children's teeth, and children are more alert to their appearance than before and tend to look like people with white teeth. Dental discoloration reduces self-confidence and causes embarrassment and social problems and is psychologically harmful.[2,3]

Dental color changes can be due to intrinsic discoloration as a result of aging, systemic problems, and drug use. Extrinsic discoloration may be due to poor oral hygiene, consumption of tooth-staining

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foods and drinks, and smoking.[4] Common causes of dental discoloration in children are iron droplets, trauma, and fluorosis.[5]

Hydrogen peroxide (H2O2) is the most commonly used agent for whitening teeth, which is used in various concentrations according to various techniques at home and office.[6] Bleaching of teeth at office is done at a high concentration of H2O2 for a specified period of time.[7] In addition to conventional whitening treatments, over-the-counter products, including gels, toothpastes, bleaching strips, mouthwashes, and pens with different H2O2 levels, have been developed.[6,8] Whitening toothpastes are one of the common products for bleaching teeth, which contain abrasive and chemical agents and have the ability to remove external stains from the tooth. The abrasiveness of toothpastes depends on the hardness, size, and shape of abrasive particles. Furthermore, factors such as the brushing technique, brushing pressure, toothbrush hardness, and the number of brush strokes affect tooth abrasion. Abrasive agents include silica, phosphates, carbonates, and bicarbonates.[9] Chemical agents present in whitening toothpastes are H2O2, sodium citrate, phosphate salt, etc., which react with chromogenic molecules of superficial dental stains and eliminate them from the tooth surface.[10] Today, active charcoal is added to toothpastes which are marketed as charcoal toothpastes. The first (there is no mention of specific year in articles) report on the use of charcoal in oral and dental hygiene has been attributed to Hippocrates in ancient Greece. Charcoal is used as powder, soot, coal, and ash in different countries. Charcoal-based products are used in medical treatments, such as its use as an antidote for acute poisoning, drug overdose, skin infections, etc., Charcoal is used legally for the coloring of food in China, Japan, and Korea to improve health.[11]

Activated charcoal is produced as a natural method of the partial oxidation of various materials. High-porosity activated charcoal has the ability to exchange ion in the mouth through nanopores and can attach to tooth enamel and remove tooth-coloring agents (because of its capacity of adsorbing pigments, chromophores, and stains from the tooth surface). The application of this product has been suggested to eliminate some dental coloring agents. Charcoal can help tooth whitening through tooth abrasion. However, it has been reported that activated charcoal is more abrasive than other whitening toothpastes and is not suitable for intraoral use.[12]

The purpose of this study was to determine the degree of whitening and abrasiveness of charcoal toothpastes in permanent teeth.

MATERIALS AND METHODS

In this *in vitro* study, 30 permanent premolars that were randomly drawn from teeth that were extracted for orthodontic purposes were used after receiving informed consent from the parents of the patients. Initially, the code of ethics was received from the Research Center of the School of Dentistry of Shahid Beheshti University of Medical Sciences (IR.SBMU.RIDS.REC.1396.337). The samples were intact and free of decay, restoration, and discoloration, and the intactness of the samples was checked under the light of a dental unit using a dental explorer. Samples were first polished with pumice paste using a low-speed handpiece for 30 s. Samples were stored in artificial saliva at all stages.

At first, the teeth were cut with a diamond disc under air and water spray such that the enamel on the buccal surface remained intact. The dimensions of the samples were 5 mm × 5 mm × 7 mm so that the height and width were 5 mm and the thickness of the sample was 7 mm. In order to avoid movement of the teeth during cutting, the samples were placed in a wax mold and measured with a caliper. At each stage, the specimens were first washed for 15 s with normal saline.

After cutting, the specimens were mounted in putty in a circular wooden mold measuring 25 mm × 9 mm. To measure color changes before and after brushing, the specimens were immersed in a coffee solution. First, 150 g of ILLY coffee (Italy) in 600 cc of water was prepared using the French Press device. The specimens were then incubated for 5 days at 37°C. In order to directly expose the samples to coffee, the teeth were removed from putty and kept in a microtube (2 cc; Iran).

After 5 days, the specimens were dried with air spray and were placed with putty in a spectrophotometric device. The color determination was carried out using the spectrophotometric device (MHTS.P.A., Via Milano Co., Verona, Italy) and with the Vita classic system from the most convex portion of the sample. Then, the tooth color and a*, b*, and L* parameters were recorded from Lab option.

A profilometric device (Surface Roughness Tester Time 1200, Salutron Co., Germany) was used to

determine the surface roughness. Samples were initially placed in a wax mold. The device's settings were as follows:

LTH = 0.25 × 1 mm, STO = ISO, RAN = AUTO, FIL = RC.

The needle and the sensor of the device were placed at the most convex part of the buccal surface of each sample and began to move, and a point was determined as the initial roughness (Ra) in microns. Two other points were recorded to increase the measurement accuracy, and the mean of the three points was recorded.

The numbers obtained from the initial roughness were arranged from small to large, and their initial color was also arranged. In each of the three groups, we tried to include the least, the average, and the highest roughness and color change in order to reduce the difference in the groups. Samples were coded from 1 to 10 in each group. Samples in Group A were brushed with Bencer toothpaste (manufactured by Dr. Jahangir Pharmaceutical and Hygienic Co., Iran), samples in Group B were brushed with Beverly toothpaste (Purity laboratories Ltd., Dublin, Ireland), and samples in Group C were brushed with Colgate toothpaste (Colgate-Palmolive Co., Poland) as the control group. Bencer and Beverly are charcoal-based toothpastes.

The specimens were brushed in a brushing machine (University of Tehran Research Center, Iran). Twenty grams of each toothpaste was measured by means of a 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 5 min. Finally, 10 ml of artificial saliva was added to the solution.

In the brushing step, the specimens were abraded using a three-body method with the presence of a toothpaste solution, dental enamel, and toothbrush with forward and backward movements of the device. Samples were brushed 2000 rounds equivalent to 3 times a day for 1.5 months or once a day for 4.5 months with 100 motions/min at 11.12 frequency for 20 min. The force was applied uniformly to all specimens. Six toothbrushes were placed in the device each time. The machine was turned on 5 times. Thirty G.U.M toothbrushes (classic G.U.M 411, full soft toothbrush, Butler Co., Chicago, USA) were used. At first, the specimens were fixed in their place, and then, the toothbrushes were tightened firmly on the specimens such that each specimen was placed in the middle of the toothbrush hair. Then, the toothpaste solution was poured into each container. After brushing, the specimens were washed with normal saline and then dried. The samples were placed in the same state in the roughness tester device, and three points were recorded, and the mean of these numbers was recorded as the secondary roughness. To measure the secondary color parameters, the samples were transferred to the spectrophotometric apparatus similar to the first state, and the parameters were recorded. The color changes calculations were performed using the following formula:

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

Kolmogorov–Smirnov and Shapiro–Wilk tests were used to determine the normal distribution of data. Repeated measures analysis of variance (ANOVA) was used to compare the groups with regard to the abrasion, and Bonferroni test was used for pairwise comparisons. The results of the whitening of the groups were compared by one-way ANOVA.

RESULTS

The normal distribution of data was verified by Shapiro–Wilk and Kolmogorov–Smirnov tests. $p > 0.05$ and the normal distribution of data were confirmed.

The abrasiveness of toothpastes

The comparison of the primary and secondary roughness values of Bencer, Beverly, and Colgate toothpastes using Bonferroni test showed roughness changes in each group, and all the specimens were abraded [Table 1]. There were significant differences in abrasion among the groups (Bencer, $p = 0.0001$, Beverly, $p = 0.005$, Colgate, $p = 0.0001$). in abrasion among the groups. Furthermore, the average abrasion with Bencer, Beverly, and Colgate toothpastes was 2.123, 1.581, and 1.8686 μm, respectively, and the highest abrasion was observed in the Bencer group.

The interaction of time and the type of toothpaste regarding abrasion

The results of repeated measures ANOVA showed that the interactions of the primary and secondary surface profiles and the type of toothpaste were significant with regard to the amount of abrasion ($p < 0.0001$). In other words, the descending and ascending patterns of the primary and secondary surface profiles at the

time before and after toothbrushing were not the same in each of the groups, which indicated the effects of toothpastes on the level of dental abrasion.

Pairwise comparisons of toothpastes with regard to abrasion

According to the results of Bonferroni test, there were no significant differences in the degree of abrasion in different groups of toothpastes, and the abrasion rates in the groups were almost the same [Table 2].

Comparison of color variations in each group

One-way ANOVA was used in this case. Considering the 95% confidence interval, the color variations were within the upper and lower bounds of the average whitening, and as a result, the whitening effect of each toothpaste was in an acceptable range [Table 3].

Comparison of color variations among toothpastes

The color changes were compared using repeated measures ANOVA, and according to the results of this test, there were no significant differences among the toothpastes with regard to color variation p =0.884.

DISCUSSION

Manufacturers of charcoal whitening toothpastes claim that these products improve the color of the tooth with minimum abrasion and can remove extrinsic stains. Almost all toothpastes contain more than one active ingredient, and in general, toothpastes are a mixture of abrasives, cleansers, and one or more other therapeutic agents. Knowing the content and function of each toothpaste is helpful in choosing the most effective type.[13]

According to research results, Bencer, Beverly, and Colgate toothpastes have the ability to wear enamel after three times of simulated toothbrushing per day for 1.5 months. Toothbrushing changes the primary and secondary surface profile of the tooth, which indicates the abrasive properties of whitening toothpastes. On the other hand, there was no significant difference among toothpaste groups regarding the amount of abrasion, so the three toothpastes had a relatively similar abrasive effect. Furthermore, the amounts of abrasion caused by charcoal toothpastes and the noncharcoal whitening toothpaste (Colgate) were the same. Bencer toothpaste caused a higher wear rate, which was not statistically significant.

Abrasive and whitening properties can be similar due to the size and shape of abrasive particles as well as common abrasive and whitening components in the three toothpastes. Almost all factories use reputable sources for abrasives in toothpastes, and there is a definite scope for the use of abrasives in these

Table 1: Statistical indices of the abrasion results of each toothpaste group

Group	Primary roughness	Secondary roughness	Standard error	df	*P*	95% confidence interval	
						Upper bound	Lower bound
Bencer	1	2	1.11	0.186	0.0001	0.728	1.493
Beverly	1	2	0.57	0.186	0.005	0.188	0.952
Colgate	1	2	0.798	0.186	0.0001	0.415	1.18

Table 2: Pairwise comparisons of toothpastes with regard to abrasion by Bonferroni test

Roughness testing time	Group 1	Group 2	Mean difference	Standard deviation	*P*
Bencer	Bencer	Beverly	0.542	0.255	0.129
	Beverly	Colgate	-0.288	0.255	0.808
	Colgate	Bencer	-0.255	0.255	0.981
Beverly	Bencer	Beverly	0.002	0.218	1.0
	Beverly	Colgate	-0.06	0.218	1.0
	Colgate	Bencer	0.058	0.218	1.0

Table 3: Statistical indices of color changes by the studied toothpastes

Group	Number of samples	Mean	Standard deviation	Minimum	Maximum	95% confidence interval	
						Upper bound	Lower bound
Bencer	10	3.566	0.62	1.25	6.34	2.16	4.97
Beverly	10	3.378	0.66	1.12	8.4	1.88	4.88
Colgate	10	3.145	0.5	0.46	5.1	2.01	4.28

materials.[14] To assess abrasion, a roughness testing method was used that was highly accurate and did not cause surface damage during measurement.[15]

In a review by Macdonald *et al*., it was found that a toothpaste with a high relative dentin abrasivity (RDA) causes more abrasion.[16] Furthermore, measuring RDA and roughness testing are more precise methods for testing the toothpaste's abrasiveness.[17] Due to the high cost and limited access to the RDA technique, this method was not used in this study.

An RDA below 100 indicates an abrasion in the normal range.[16] Beverly's manufacturing company has announced an RDA of 85 for this toothpaste. Furthermore, Colgate Total toothpaste has an RDA of 70, and toothpastes containing charcoal have an RDA of 76.

According to the results of this study, the whitening range of the three toothpastes, with 3 times brushing a day during 1.5 months, was in an acceptable range (3.145, 3.56, and 3.37 μm for Colgate, Bencer, and Beverly, respectively).[18] There was no significant difference among toothpaste groups regarding the whitening degree. In other words, all toothpastes can equally satisfy the patients.

Limited research has been done on charcoal toothpastes, and therefore, there is not a completely relevant study to compare the results of this study.

In a study by Pertiwi *et al*., it was found that enamel roughness in the group that was brushed with water was significantly different at the beginning and after 1 month, but after 3 months, no significant difference was observed. Furthermore, in groups that were brushed with strongly formulated toothpaste and charcoal toothpaste, the roughness of the surface was significantly different at all times.[13] There was a significant difference in wear between water and whitening toothpastes, but there was no significant difference in the amount of abrasion between the two toothpastes. The results of this research are consistent with the present study. In the cited study, it was found that the size of abrasive charcoal particles is effective in the amount of wear.

McCarty *et al*. showed that activated charcoal toothpaste is significantly more abrasive than other toothpastes (McCarty *et al*., contrary to us, showed that activated charcoal toothpaste is significantly more abrasive than other whitening toothpaste. This difference in result can be attributed to the material used in the samples [acrylic] and the hand brushing versus machine brushing). In this study, the specimens were acrylic and were brushed with hands. Furthermore, a solution of toothpaste was made of a charcoal capsule in water.[12] A different implementation protocol can be the reason for differences between the results of the two studies. In our study, the samples were teeth and were brushed by a brushing machine.

Moghareabed *et al*. showed that the average wear was not the same in the studied groups; Pooneh toothpaste caused the least wear, whereas crest toothpaste caused the highest wear, and the rest of the toothpastes were not significantly different in this regard. On the other hand, there was a significant difference in the mean roughness values before and after brushing, but the effect of the type of the toothpaste on the level of abrasion was not significant.[14] The results of the cited research are consistent with our study.

A study by Franzò *et al*. showed that the amount of enamel wear among toothpastes was not significantly different, but the difference in dentin wear was significant.[19] Differences in the wear of enamel and dentin can be attributed to their molecular structure. The results of the recent research are consistent with the results of our study.

In a clinical trial, de Moraes Rego Roselino *et al*. showed that whitening toothpastes did not significantly change dental color and did not increase the roughness of the enamel surface during toothbrushing.[20] In the present *in vitro* study, it was not possible to determine the effects of intraoral conditions such as saliva and hand force of the participants. On the other hand, in the mentioned study, the impression-taking and casting method was used to determine wear.

Soares *et al*. showed that after brushing, changes in surface roughness and color variations were significant for all toothpastes, but no significant difference was observed among the toothpastes.[10] The results of the present study are consistent with the cited research.

In a study by Pintado-Palomino *et al*., there was no significant difference among the three groups of toothpastes in terms of color variation. In the cited study, color variations were obvious, and all toothpastes caused a significant clinical color change.[21] The results of this research are consistent with the results of the present study (color changes were measurable, but there was no significant

difference among the three groups of whitening toothpastes in terms of color variation).

CONCLUSION

In conclusion, Bencer, Beverly, and Colgate whitening toothpastes caused changes in the surface profile and significant changes in the color of the teeth before and after toothbrushing, indicating their abrasiveness and whitening ability. The difference in abrasion and dental color change among the toothpastes was not significant, and Bencer toothpaste was more abrasive than other toothpastes, but the difference was not statistically significant.

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Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or nonfinancial in this article.

REFERENCES

1. Mortazavi H, Baharvand M, Khodadoustan A. Colors in tooth discoloration: A new classification and literature review. Int J Clin Dent 2014;7:17-28.
2. Ganesh R, Aruna S, Joyson M, Deepa M**.** Comparison of the bleaching efficacy of three different agents used for intracoronal bleaching of discolored primary teeth: An *in vitro* study. J Indian Soc Pedod Prev Dent 2013;31:17-21.
3. Anantharaj A, Patil P, Ramakrishna S, Jagadeesh R. Walking bleach in primary teeth. SRM J Res Dent Sci 2015;6:187-90.
4. Gursoy UK, Eren DI, Bektas OO, Hurmuzlu F, Bostanci V, Ozdemir H. Effect of external tooth bleaching on dental plaque accumulation and tooth discoloration. Med Oral Patol Oral Cir Bucal 2008;13:E266-9.
5. Pani SC, Alenazi FM, Alotain AM, Alanazi HD, Alasmari AS. Extrinsic tooth staining potential of high dose and sustained release iron syrups on primary teeth. BMC Oral Health 2015;15:90.
6. Jurema AL, Claudino ES, Torres CR, Bresciani E, Caneppele TM. Effect of over-the-counter whitening products associated or not with 10% carbamide peroxide on color change and microhardness: *In vitro* study. J Contemp Dent Pract 2018;19:359-66.
7. Pretty I. Tooth whitening: Indications and outcomes of nightguard vital bleaching. Br Dent J 2007;203:164-5.
8. Ermis RB, Uzer Celik E, Yildiz G, Yazkan B. Effect of tooth discolouration severity on the efficacy and colour stability of two different trayless at-home bleaching systems. J Dent Res Dent Clin Dent Prospects 2018;12:120-7.
9. Harris NO, Garcia-Godoy F, Nathe CN. Primary Preventive Dentistry. 8th ed.. Boston: Pearson Education; 2014.
10. Soares CN, Amaral FL, Mesquita MF, Franca FM, Basting RT, Turssi CP. Toothpastes containing abrasive and chemical whitening agents: Efficacy in reducing extrinsic dental staining. Gen Dent 2015;63:e24-8.
11. Brooks JK, Bashirelahi N, Reynolds MA. Charcoal and charcoal-based dentifrices: A literature review. J Am Dent Assoc 2017;148:661-70.
12. McCarty B, Letteri N, Singletary J, Primus C. Activated Charcoal as a Whitening Dentifrice. Academy of General Dentistry June18-21; San Francisco, USA 2015. Available from: http://www.epostersonline.com/agd2015/node/72.
13. Pertiwi U, Eriwati Y, Irawan B. Surface changes of enamel after brushing with charcoal toothpaste. J Phys Conf Ser 2017;884:012002.
14. MoghareAbed A, Izadi M, Kave M, Tavakoli M, Yaghini J. Comparative study investigating abrasive effects of 12 commercially available toothpastes on enamel, in Iran. J Mash Dent Sch 2012;36:239-48.
15. Grenby TH. Methods of assessing erosion and erosive potential. Eur J Oral Sci 1996;104:207-14.
16. Macdonald E, North A, Maggio B, Sufi F, Mason S, Moore C, *et al*. Clinical study investigating abrasive effects of three toothpastes and water in an *in situ* model. J Dent 2010;38:509-16.
17. Attin T. Methods for assessment of dental erosion. Monogr Oral Sci 2006;20:152-72.
18. Fazi G, Vichi A, Ferrari M. Influence of four different cements on the color of zirconia structures of varying ceramic thickness. Int Dent SA 2006;9:54-61.
19. Franzò D, Philpotts CJ, Cox TF, Joiner A. The effect of toothpaste concentration on enamel and dentine wear *in vitro*. J Dent 2010;38:974-99.
20. de Moraes Rego Roselino L, Tirapelli C, de Carvalho Panzeri Pires-de-Souza F. Randomized clinical study of alterations in the color and surface roughness of dental enamel brushed with whitening toothpaste. J Esthet Restor Dent 2018;30:383-9.
21. Pintado-Palomino K, Vasconcelos CV, Silva RJ, Fressatti AL, Motta BJ, Pires-DE-Souza FC, *et al*. Effect of whitening dentifrices: A double-blind randomized controlled trial. Braz Oral Res 2016;30:1-8.