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The impact of airflow on enamel surface roughness and color change

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ABSTRACT

Background: In dentistry, esthetic restorations are vital. Adequate polishing can minimize color changes of a tooth. The aim of this study was to evaluate the effect of the Prophy-Mate neo device, which uses airflow, on surface roughness and color changes in enamel.
Materials and Methods: In this *in-vitro* study included 30 teeth immersed in tea solution for 7 days. The specimens were divided into three groups based on the polishing procedure (airflow with calcium carbonate, airflow with sodium bicarbonate, and diamond paste). The whitening procedure was performed according to the instructions for each powder of airflow (Prophy-Mate neo, NSK, Japan) and paste. After polishing, the specimens were again immersed in a tea solution for another 7 days. Color assessment was carried out at baseline (T1) and after polishing (T2) using the CIELab* system. In addition, the morphology of the enamel surface for each specimen from each group was evaluated by profilometer at T1 and T2, and the paired *t*-test and Tukey's were used to compare results between groups.
Results: The variation in surface roughness (Ra) between calcium carbonate (0.381 μm) and sodium bicarbonate (0.447 μm) powders was not significant, but the performance of diamond paste was significantly better. The difference between the secondary staining after polishing was lower than the pigment absorption in the primary staining (before polishing) in the diamond paste group.
Conclusion: Overall, the study did not show any significant reduction in the amount of surface roughness and color changes in airflow compared to traditional polishing methods. The cost and services of the Prophy-Mate neo device make it challenging to introduce airflow as an alternative to conventional techniques (P<0.05).

Key Words: Airflow, enamel, polish, surface roughness

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INTRODUCTION

In recent decades, patients have been seeking a beautiful smile and the color of their teeth has become one of their major concerns.[1,2] The consequences of improper restoration can lead to multiple complications for patients, including the development of marginal decay and changes in color, ultimately leading to treatment failure and even tooth loss.[3-6]

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One of the most important factors that can compromise the beauty of teeth and restorations are pigmentation.[7,8] These pigments have both external and internal origins. Changes in external pigments occur due to the deposition of materials on the surface of teeth and are classified into metallic and nonmetallic categories.[9,10] Metallic pigments

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include the effects of iron, while nonmetallic pigments include the effects of chromogenic bacteria from tobacco, tea, coffee, soda, medication, mouthwash, as well as restorative materials, and are mostly related to the dietary pattern of individuals.[11-13] Various methods are available for removing pigments, but their effectiveness depends on the depth and intensity of the pigmentation.[14] The new methods used for polishing and removing pigments include air flow or air polishing devices, which spray cubic or spherical particles in micron dimensions.[15-17] According to the manufacturer's recommendations, if standards are followed, this approach is claimed to offer a smoother surface than older methods.[16] Other methods for removing pigments include using a combination of diamond paste (FGM, Brazil) and felt discs, whose particle size (extra-fine diamond particles) is 6 micrometers.[17,18] Surface roughness evaluation techniques include profilometry, atomic force microscopy, and scanning electron microscopy. In the present study, profilometry was used to measure surface roughness.[19] In studies related to dental discoloration, the three-dimensional (3D) color-matching system CIE (Commission on Illumination) Lab* is often used as an index.[20,21] Spectrophotometry is a method in chemistry for measuring and studying electromagnetic spectra. This technique determines the concentration of samples based on their level of light absorption. The system is defined by three components: L*, a*, and b* . The L* component expresses the brightness and darkness of a color, ranging from 0 (black) to 100 (white). Positive a* values represent red colors, while negative values represent green colors. Positive b* values indicate yellow colors, while negative values indicate blue colors. The color difference (ΔE) between two objects is calculated using the CIELab* system via the following formula:[22]

$$\Delta E = [(\Delta a^*)2 + (\Delta b^*)2 + (\Delta L^*)2]0.5$$

In the present study, the surface roughness of enamel, changes in surface light absorption, and the possible relationship between surface roughness and the amount of pigment absorption after polishing were investigated. Given the increasing demand for cosmetic dental treatments, it is necessary to introduce a method that can increase the durability and beauty of teeth while minimizing changes in their color.

MATERIALS AND METHODS

In this *in-vitro* study thirty anterior teeth from the upper and lower jaws were collected. Because according to the protocol, each tooth is compared with itself, so there is no need to match their shape and color, but nevertheless, malformed teeth and those with color defects were excluded from the study. Soft tissue remaining on the teeth was removed using a curette. Then, they were disinfected for 1 h using a 5.25% sodium hypochlorite solution (Rakhsha, Iran). The teeth were stored in distilled water until the experiment began, with the water being changed daily. The roots of each tooth were sectioned with a cylindrical diamond bur (Flat end 014 Tiz Kavan, Iran) under air and water pressure from 1 mm apical to the cementoenamel junction determined by periodontal probe. For the purpose of standardizing the horizontal surface of the dental samples under profilometry, the teeth were mounted in yellow acrylic (AcroPars, Iran) with dimensions of 4612 mm. To standardize the measurement range of the profilometer pen on all samples at two different times, a thin diamond bur (Long Flat End Cylinder010, Tiz Kavan, Iran) was used to create a 4 mm line perpendicular to the measurement range. The depth of the lines was equal to half of the bur radius. To prepare for the study, yellow paint (Toboom, China) was applied to the samples. The paint was applied for 30 s at a speed of 600 rpm using a handpiece under water pressure. The first step involved measuring the surface roughness and color (T1) with Lab* colorimetry and Ra1 values recorded. Surface roughness was measured using a Dektak XT stylus profiler (Bruker, USA) at the Central Laboratory of the Growth Research Institute of Shahid Beheshti University. Then, artificial staining was performed on half of the samples using tea. The tea solution was prepared by boiling 9 g of Ahmad black tea leaves in 450 mL of distilled water for 5 min. Each sample was immersed in 10 mL of the tea solution at room temperature for 7 days, with fresh tea solution prepared each day. After 7 days, the samples were removed from the solution and washed with distilled water. Then, the samples underwent color removal using polishing methods (Air Flow and diamond paste) at T3 and T4. Choosing which of the three polishing groups each tooth was placed in was randomly selected by a random number table. The samples were then subjected to Air-Flow Prophy-Mate Neo (NSK, Japan) for 20 s at a distance of 3 mm and an angle of 10° (with the distance being determined using a graduated rod next to the nozzle), customized holding device was used for air polishing fixing tooth on a table of the holding device using a double adhesive metal tape and distance adjusted. The enamel samples in the control group underwent polishing by felt disc (Stoddard, UK) and diamond polishing paste (Diamond Excel, FGM, Brazil). The polishing paste was spread on the tooth surface and then the operator performed a cycle of 30 eight-shaped movements with each vehicle under a constant light manual pressure. During polishing, the specimens were cooled with a continuous air-jet blowing. The polished specimens were thoroughly washed and dried for subsequent surface roughness and color assessment. The samples were sent back to the laboratory for surface roughness and color measurement at T2. Assessors were not aware of which group each tooth belonged to.

RESULTS

According to the statistical formula and according to the opinion of the statistical consultant, the sample size is based on the following formula:

$$n = \frac{(z1 + z2)(2s^2)}{d2}$$

n = 30 was obtained. In this formula, z1 is equal to z_(1−α/2) and z2 is equal to z_(1−β), where α is the first type error and β is the second type error, which in medical science research is usually 0.05 and 1, respectively./0 is considered. In this case, z1 is equal to 1.96 and z2 is equal to 1.28. Furthermore, s2 is the variance of the dependent variable of the research in previous studies, which is equal to 0.46. d2 is the sampling error that can be considered between 0 and 1, which was considered equal to 0.1 by the opinion of the statistical consultant. By placing these values in the above formula, the sample volume was equal to 30, so 10 samples can be considered in each group.

In order to analyze the data, first, the normality of the data was checked using Shapiro–Wilk. Because the significance level of this test for research variables is <0.05, so the data are not normal ($P < 0.05$). Therefore, the data were analyzed using nonparametric Mann–Whitney, Kruskal–Wallis, and Wilcoxon and Friedman tests. Analyzes using IBM SPSS® 27 software (IBM Corp., Armonk, NY., USA) were obtained.

In Table 1, the mean and standard deviation of the surface roughness index before the intervention (T1) and after the intervention (T2) on the tooth enamel surface using calcium carbonate and sodium bicarbonate powder and diamond paste are given. By using the Wilcoxon test, the mean surface roughness index before the intervention (T1) and after the intervention (T2) was compared in each of the calcium carbonate, sodium bicarbonate, and diamond paste groups, and there was a significant difference between this index in calcium carbonate and diamond paste groups. It was observed before and after the intervention ($P < 0.05$) [Table 1].

Furthermore, using the Kruskal–Wallis test, changes in the surface roughness index (T1, T2 difference) between all three enamel polishing methods (calcium carbonate, sodium bicarbonate, and diamond paste) were compared. The significance level of this test was calculated as 0.001 which is <0.05. There is a significant difference in average surface roughness (T1, T2 difference) between diamond paste compared to calcium carbonate and sodium bicarbonate.

In Table 2, the L* index in the samples that have been pigmented were compared between three enamel polishing methods (calcium carbonate, sodium bicarbonate, and diamond paste) at time T1 and T3 separately. Since the comparison between the groups has been done two by two, the Mann–Whitney test was used. Accordingly, in both T1 and T3 times, the difference between the methods is not significant ($P > 0.05$). Similarly, there was no

Table 1: Checking the roughness factor

Test results (P)	R1 (µm) (T2)	R0 (µm) (T1)	Time material
0.013	0.381±0.024	0.448±0.059	Calcium carbonate - Enamel
0.9	0.447±0.011	0.403±0.018	Sodium bicarbonate - Enamel
0.001	0.327±0.054	0.432±0.087	Diamond paste - Enamel

Table 2: Investigating the L* factor in samples that have undergone colorization

P		L*
T3	T1	
		Airflow (calcium carbonate)
0.555	0.422	Sodium bicarbonate
0.379	0.988	Diamond paste
		Airflow (sodium bicarbonate)
0.555	0.422	Calcium carbonate
0.281	0.144	Diamond paste
		Diamond paste
0.379	0.988	Calcium carbonate
0.281	0.144	Sodium bicarbonate

significant difference in the a* and b* indices between different methods [Table 2].

In Table 3, the ΔE index was compared between three enamel polishing methods (calcium carbonate, sodium bicarbonate, and diamond paste) at three times ΔE1, ΔE2, and ΔE3 separately. Since the comparison between the groups has been done two by two, the Mann–Whitney test was used. Based on this, there is no significant difference ($P > 0.05$) between enamel polishing methods (calcium carbonate, sodium bicarbonate, and diamond paste) during ΔE1, ΔE2, but during ΔE3 between the calcium carbonate and diamond paste groups and between the sodium bicarbonate and diamond paste have a significant difference ($P < 0.05$) [Table 3].

DISCUSSION

In recent years, esthetic restorative treatments in dentistry have received considerable attention. While these treatments can provide patient satisfaction in the short term, the durability and quality of the treatments in the long term are important.[12] depigmentation treatments can be performed through two methods: (1) using coloring materials such as macroabrasion and microabrasion and (2) chemical methods such as bleaching.[23] Although these common methods can achieve the aesthetic goal by removing the pigments and part of the tooth surface, their long-term results are subject to controversy, and it is possible to provide a surface roughness that could provide a basis for microbial adhesion and subsequent problems.[24]

One of the mechanical methods for removing the discoloration that has been recently received attention is air polishing devices, which work by applying powders under pressure on the tooth surface.[9] In this study, the performance of one of these devices, Prophy-Mate Neo (NSK Japan), was examined for its effect on composite roughness and the amount of pigment absorption. The special powders used for this device include calcium carbonate and sodium bicarbonate particles. The spherical calcium carbonate particles decrease the damage to the tooth surface while the cubic sodium bicarbonate particles are placed on the surfaces under discussion.[25] Another polishing method, Diamond Excel paste (Dentsply), which can produce less surface roughness in enamel compared to other polishing pastes, was also reviewed and compared in this study. According to the study of Yurdaguven *et al*.,[12] diamond excel, which uses a felt disc, can achieve less surface roughness than other polishing pastes in enamel samples. Furthermore, in the study of Camboni and Donnet, there was no significant difference between the performance of airflow device and diamond paste in the field of enamel surface roughness.[11]

The surface roughness factor (Ra) was measured in each sample before and after polishing using a 3D profilometer. According to the results, there was no significant difference in changes in surface roughness between the two types of powders used in the enamel samples, which correlates with the study by Graumann *et al*. in 2013.[26] Furthermore, our findings can be considered consistent with Németh *et al*.'s study on surface roughness due to airflow. An increase in surface roughness was found compared to samples under other methods.[27] In the study of Janaphan, there were no significant differences in wear depth between sodium bicarbonate, glycine, and erythritol powders,[28] and the values of surface roughness created are close to the present study.

In a study whose structure was close to ours, Kousu and Karatas investigated surface roughness and color changes in composite samples subjected to airflow powders.[29] In this study, the color changes and surface roughness of the air polishing groups were significantly higher than the control group, unlike the present study where no clear difference was observed, which can be attributed to the difference in the base used. Kusu and Karatas used composite, while the present study was performed on enamel. While in the study of Valian *et al*., which used enamel base,[30] results similar to the current study were obtained regarding changes in surface roughness and color changes.

To examine general changes in color among the samples at different time points, the ΔE factor was

Table 3: Examination of ΔE factor in samples

P			ΔE
ΔE3	ΔE2	ΔE1	
			Calcium carbonate
0.211	0.393	0.234	Sodium bicarbonate
0.022	0.409	0.731	Diamond paste
			Sodium bicarbonate
0.211	0.393	0.234	Calcium carbonate
0.001	0.180	0.534	Diamond paste
			Diamond paste
0.022	0.409	0.731	Calcium carbonate
0.001	0.180	0.534	Sodium bicarbonate

investigated using the formula ΔE = [(Δa*)2 + (Δb*)2+ (ΔL*)2]0.5. As defined, ΔE values exceeding 3.5 were interpreted as significant changes in color. Between T2 and T3, where the airflow device was applied, color changes were observed in 93% of the colored enamel samples, indicating the successful performance of the air polishing device (in both calcium carbonate and sodium bicarbonate powders) in color picking, in line with the findings of Graumann *et al*.[26]

Pigmentation at ΔE3 in diamond polishing was significantly lower in enamel samples compared to using calcium carbonate (P = 0.022) and sodium bicarbonate powders (P = 0.001). Powder application (P = 0.255). Nevertheless, significant differences in secondary coloration and surface roughness were observed between diamond polishing and sodium bicarbonate powder application (P = 0.001).

CONCLUSION

Prophy-Mate neo (Airflow) does not significantly differ in surface roughness from other polishing methods in various tested samples. Although a reduction in pigmentation absorption was observed, the obtained level of surface roughness does not qualify this method to be considered a gold standard in this brand in the area of investigation. Considering the nonsignificant difference between the performance of the Prophy-Mate neo device and common polishing methods, as well as the associated costs and services, it cannot be recommended as an alternative method for current commonly used methods in the tested powders.

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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 non-financial in this article.

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