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Evaluating the Effects of Erythritol Air-Polishing Powder on Dental Hard Tissues

Eritritol Tozunun Diş Sert Dokuları Üzerindeki Etkisinin Değerlendirilmesi

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ABSTRACT: This study evaluated the changes in different dental tissue surfaces after applying erythritol air-polishing powder using scanning electron microscopy. Eight single-rooted human teeth extracted due to advanced periodontitis were included. The samples were randomly divided into one experimental group and one control group. The tested air-polishing powder was erythritol, with no powder application in the control group. Evaluations were conducted on scanning electron microscope images. Each sample was photographed at different magnifications from three areas on the tooth: the enamel, cementoenamel junction, and cementum. Hard and soft tissue debris, surface roughness, and polishing powder accumulation levels were evaluated using pre-defined indexes on each tissue surface. Significant differences were found between the experimental and control groups regarding powder accumulation on the cementoenamel junction and cementum surface. No significant difference between the experimental and control groups was found in surface roughness and hard/soft tissue debris level on the tooth surfaces. The results indicated that erythritol oral polishing powder used in periodontal prophylaxis has different effects on the tooth surface.

Keywords: Air polishing, erythritol, periodontal treatment

ÖZET: Bu çalışmanın amacı, toz püskürtme sistemlerinde kullanılan eritritol tozunun farklı diş dokuları üzerinde meydana getirdiği değişiklikleri taramalı elektron mikroskobu ile değerlendirmektir. Bu çalışmaya ileri periodontal doku kaybı nedeniyle çekilen 8 adet tek köklü insan dişi dahil edilmiştir. Örnekler rastgele bir deney grubu ve bir kontrol grubu olarak ikiye ayrılmıştır. Deney grubundaki örneklere eritritol tozu uygulanırken kontrol grubuna herhangi bir toz uygulaması yapılmamıştır. Değerlendirme taramalı elektron mikroskobundan elde edilen görüntüler üzerinde yapılmıştır. Her numunenin 3 farklı bölgesi (mine, mine-sement birleşimi ve sement) farklı büyütmelerde fotoğraflanmıştır. Sert ve yumuşak doku kalıntı düzeyi, yüzey pürüzlülüğü ve yüzeyde toz birikim düzeyi önceden tanımlanmış indeksler kullanılarak değerlendirilmiştir. Sement-mine birleşimi ve sement yüzeyindeki toz birikimi açısından deney grubu ile kontrol grubu arasında anlamlı farklılık bulunurken mine yüzeyinde anlamlı fark bulunamamıştır. Diş yüzeylerinde yüzey pürüzlülüğü ve sert ve yumuşak doku kalıntı düzeyi açısından deney grubu ile kontrol grubu arasında anlamlı bir fark bulunamamıştır. Sonuçlar eritritol tozunun diş yüzeyinde farklı etkilere sahip olduğunu göstermektedir.

Anahtar Kelimler: Eritritol, periodontal tedavi, toz püskürtme sistemi

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INTRODUCTION

Oral health maintenance is integral to overall well-being, and dental professionals continually seek innovative techniques and technologies to enhance oral hygiene. Among the myriad tools employed in modern dentistry, oral air-polishing systems have emerged as an effective method for removing dental plaque, stains, and biofilm from teeth and other hard surfaces in the oral cavity and interproximal areas. The first air-polishing device (APD) was marketed and introduced to dental professionals in 1970 (1–4). Research has shown that the advantages of this system over polishing with paste and brush are saving time, less dentist fatigue, and more efficiency in stain removal (5). Several air-polishing powders have been used in oral prophylaxis applications previously, including aluminum trihydroxide [Al(OH)3], calcium carbonate (CACO3), calcium sodium phosphosilicate (Ca.2Na.9O.2H3P.H4Si), and sodium bicarbonate (NAHCO3). These molecules cause severe abrasion on tooth surfaces (4,6,7).

As the demand for minimally invasive and patient-friendly dental interventions grows, the quest for superior oral air-polishing powders intensifies, driving researchers and practitioners to explore novel formulations and applications. In recent years, to overcome the disadvantages of sodium bicarbonate powder, other air-polishing materials such as glycine, trehalose, and erythritol have been used (8,9). One of the frequently used modern air-polishing powders is glycine. It is an amino acid with the chemical formula C2H5NO2. It has low abrasiveness and high biocompatibility, is soluble in water, and does not taste salty.

Erythritol, a sugar alcohol with the molecular formula C4H10O4, has attracted attention for its exceptional water solubility. Its low molecular weight and rapid dissolution in water contribute to its unique role in dental prophylactic procedures. Daily intake of erythritol is safe, and it has been reported that it is not metabolized after ingestion and is excreted unchanged in the urine (10,11). Erythritol can be used safely in the oral cavity and is well-tolerated due to its sweet taste (10,11). In recent years, significant attention has been shifted towards using erythritol powder air polishing due to its non-traumatic impact on soft and hard tissues (11–13). The utilization of micron-sized erythritol particles, particularly when combined with a novel plastic nozzle, has been found to enhance safety during subgingival debridement (14). Furthermore, the application of erythritol for air polishing within periodontal pockets has demonstrated microbiological outcomes similar to those attained through subgingival debridement (15–18). However, it should be noted that erythritol exhibits limitations in effectively removing large and firmly attached masses of calculus and other hard deposits (19).

Oral air-polishing applications have found areas of use across various dental disciplines, such as periodontal and peri-implant prophylaxis, orthodontic treatment receiving patients, and cosmetic dentistry.

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Few studies have evaluated the effects of different air-polishing powders on enamel and cementum. This study assessed the changes on different dental tissue surfaces after air-polishing with erythritol powder (EMS Airflow Plus, EMS Electro Medical Systems, Munchen, Germany) using scanning electron microscopy (SEM).

MATERIALS AND METHODS

The present study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Istanbul University Faculty of Dentistry Scientific Ethics Committee (protocol no: 2022/30 Date: 15.06.2022).

The eight single-rooted human teeth extracted due to advanced periodontal tissue loss were included in this study (grade III mobility, >70% alveolar bone loss). The extracted teeth were washed with distilled water and stored in a 10% formaldehyde solution. Teeth were randomly assigned to two groups, with four teeth in the experimental group and four in the control group. A coin toss was used to randomly assign the extracted teeth to the two groups. Before the air-polishing procedure, all the tooth samples were washed with a saline solution to remove soft tissue residues and plaque from tooth surfaces. The sample sizes obtained from the teeth were large enough for evaluation and fitting into the SEM tray, i.e., 8 mm. The 8-mm area was measured from the mesial and distal surfaces, including 4 mm of enamel and 4 mm of cementum surface, with a Williams periodontal probe (Hu-Friedy, USA). Markings were made with a hard pen, and two samples were obtained from each tooth. The application was made with the tip of the air-polishing device remaining 1 cm from the tooth surface. A 1-cm-thick wooden block with an opening was prepared to standardize this distance. The teeth were positioned behind the wooden block. Air-polishing powder was sprayed on each tooth, first on the mesial surface and then on the distal surface, at a 90º angle for 15 seconds. The Mylunos powder sprayer (Durr Dental, Bietigheim-Bissingen, Germany) was used for this study.

In the experimental group, Erythritol powder with a particle size of 14 µm was applied. In the control group, no powder was applied.

Then, all the teeth were cut horizontally with a diamond-coated bur under copious water cooling at the previously marked locations on the enamel and cementum and then cut longitudinally to obtain two samples from each tooth. A total of 16 samples were obtained. All the previously prepared samples from all the groups were evaluated using SEM images taken at different magnifications: ×500, ×1000, ×2000, and ×4000. The images were recorded and assessed by two researchers regarding surface roughness, accumulation of air-polishing powder on the tooth surface, and hard/soft tissue debris level on the tooth surface.

Before the study, two examiners were trained on 10 SEM root surface images for calibration. Tooth surface roughness index values demonstrated good reproducibility, which was assessed by interexaminer analysis (k = 0.892). In addition to the kappa agreement, the reproducibility assessment showed that, for 90% of

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thesites, the mean of repeated tooth surface roughness index value was within 1.

Scanning Electron Microscope Analysis

Following the air-polishing protocol, the samples were stored in saline solution in previously assigned containers and fixed in 99% isopropyl alcohol for two hours before being transported to the Nano & Opto Electronics Laboratory.

The samples were dried with nitrogen gas before being examined with a SEM. After the dried samples were vacuumed, they were placed on carbon plates for SEM analysis (20). Photomicrographs were taken of each sample at various magnifications, including the enamel surface, cementoenamel junction, and cementum surface. On the images obtained, tooth surface roughness, air-polishing powder accumulation, and hard/soft tissue debris levels were evaluated and scored using three different indices. All the evaluations were carried out by two researchers, and the mean scores were used for statistical analyses. These indexes were used based on the study designed by Camboni & Donnet in 2016 (21).

These indices are as follows:

1) Tooth surface roughness scoring range of 0–5, with 0 indicating no roughness on the surface and 5 indicating the highest roughness.

2) Air-polishing powder accumulation on the surface with a score range of 0–5, with 0 indicating no powder accumulation on the surface and 5 indicating the highest powder accumulation.

3) Hard/soft tissue debris level on the tooth surface with a score range of 0–5, with 0 indicating no hard/soft tissue debris on the surface and 5 indicating the highest hard/soft tissue debris.

Statistical Analysis

Statistical testing was performed for all indexes using the SPSS statistical software program v.26. Descriptive statistics were computed, including minimum, maximum, mean, and standard deviations. Mean values and standard deviations were used for statistical analyses. The distribution of data was analyzed using the Kolmogorov-Smirnov test. Normally distributed data were evaluated with one-way ANOVA, and the rest were analyzed with the Kruskal-Wallis test. $P<0.05$ was set as statistical significance.

The required minimum sample size was determined at n=8 in statistical analyses based on the significant statistical difference. Along with the specified eight control samples, 16 samples were included in the study. Type I error was set at 5%, type II error was set at 20%, and the power of the study was set at 80%.

RESULTS

The results of the statistical analysis of surface roughness created by applying erythritol air-polishing powder are presented in Table 1 and Figure 1. There were no statistically significant differences between the two groups or on different tooth surfaces.

Table 2 and Figure 2 present the statistical analysis results of air-polishing powder accumulation on the tooth surfaces. According to the results, a significant

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difference was found in the statistical comparison of the experimental and control groups on the cementoenamel junction and cementum surface, with no significant difference on the enamel surface.

The statistical analysis results of hard/soft tissue debris levels on the tooth surfaces are presented in Table 3 and Figure 3. The results showed no significant difference between the experimental and control groups on different tooth surfaces.

Table 1. Statistical evaluation of tooth surface roughness between groups on different tooth surfaces

Group	Enamel	Cementum	Cementoenamel junction
Control & Erythritol	P = 0.1848	P > 0.9999	P = 0.9991

No statistically significant differences were observed between the experimental and control groups on different tooth surfaces (P<0.05).

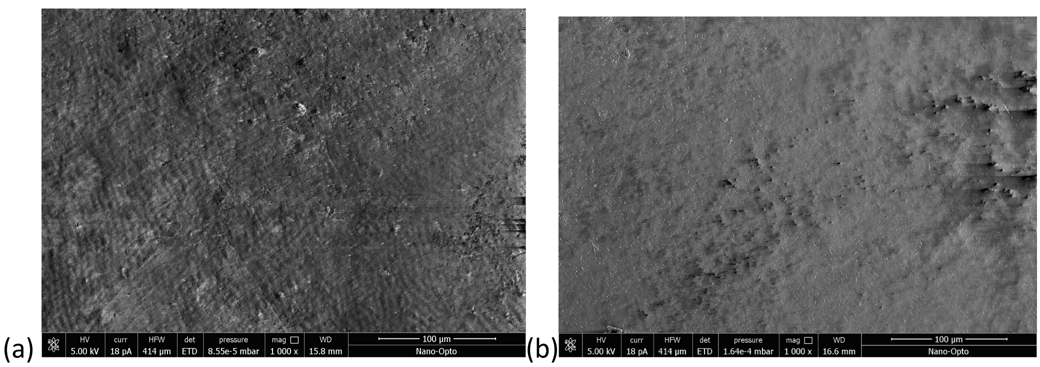

Figure 1. Scanning electron microscope images to examine the degree of roughness between the control and experimental tooth surfaces. (a) A scanning electron micrograph to examine the degree of root surface roughness in the control group. (b) A scanning electron micrograph to explore the degree of roughness created by erythritol powder on the root surface

Table 2. Statistical evaluation of air-polishing powder accumulation between the groups on different tooth surfaces

Group	Enamel	Cementum	Cementoenamel junction
Control & Erythritol	P = 0.0532	P = 0.0117*	P < 0.0001*

No statistically significant differences were observed between the experimental and control groups on the enamel surface. Statistically significant differences were observed between the experimental and control groups on the cementum and cementoenamel surfaces (P<0.05). Significant differences are shown with *.

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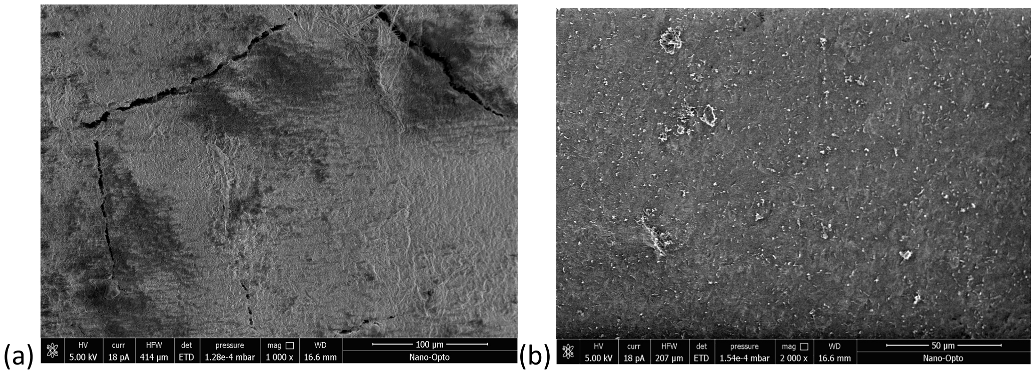

Figure 2. Scanning electron microscope images to compare the degree of powder accumulation between the control and experimental tooth surfaces. (a) A scanning electron micrograph to examine the degree of powder accumulation on the root surface in the control group. (b) A scanning electron micrograph to investigate the degree of powder accumulation created by erythritol powder on the root surface.

Table 3. Statistical evaluation of hard/soft tissue debris levels between groups on different tooth surfaces

Group	Enamel	Cementum	Enamel- Cementum junction
Control & Erythritol	P = 0.4258	P = 0.5356	P > 0.9999

No statistically significant differences were observed between the experimental and control groups on different tooth surfaces (P<0.05).

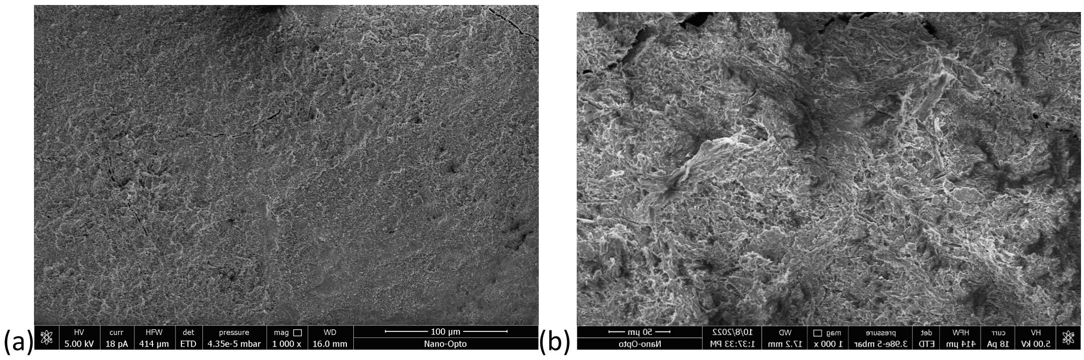

Figure 3. Scanning electron microscope images to examine the degree of hard/soft tissue debris levels between the control and experimental tooth surfaces. (a) A scanning electron micrograph to explore the degree of hard/soft tissue debris on the root surface in the control group. (b) A scanning electron micrograph to examine the degree of hard/soft tissue debris created by erythritol powder on the root surface.

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DISCUSSION

Considering previous studies, a comparison was made between sodium bicarbonate powder and polishing pastes or sodium bicarbonate powder and glycine powder, which were first used in powder spray systems (22,23). The number of studies evaluating trehalose, glycine, and erythritol powders is limited and almost non-existent. Similarly, no study was found in which all three anatomical regions of the tooth, i.e., enamel, cementoenamel junction, and cementum, were included in the study simultaneously. Due to these shortcomings, the present study was designed and conducted by applying erythritol powder separately to three different anatomical regions of the teeth and evaluating the results.

Factors affecting the results of powder spray systems include the application time, the distance between the spray nozzle and the tooth surface, the technique used to apply the powder to the surface, the brand of powder sprayer, the water-to-powder ratio during the application, the airflow and the pressure during the application, the angle between the application head and the tooth surface during application, the chemical structure of the applied powders and the water solubility rate of the applied powders, the particle size determined by variables other than the chemical structure of the powders, the particle size, and the water solubility rate, are kept constant (4, 24–26).

Regarding Table 1 and Figure 1, no significant difference in tooth surface roughness was observed in the present study, possibly due to the sweeping technique used and the duration of application. Statistical studies have illustrated that powder spray systems produce a rougher surface but mimic the naturally rough surface of tooth enamel (21). Camboni (21) reported that the powders used in powder spray systems do not cause defects and scratches on the tooth surface, do not deform the natural morphology of the enamel structure, and can, therefore, be used repeatedly without clinical concerns, consistent with the present study concerning the roughness of the surface. Since the natural roughness of the surface was mimicked after the powder spraying process, no significant difference was found between the control and experimental groups. Furthermore, since the process in the present study was performed using the sweeping technique, the defect rate and roughness were minimized, which is consistent with previous studies. For instance, one study found that a defect occurs with single-point focusing (23). However, with a sweep motion, defect formation is absent or minimal. In addition, the effects of differences in particle size of similar powders are minimized (27).

A previous study expected that the defects would shrink if the distance between the head of the applicator and the root surface increased, with no change in the size of the defects. In other words, the distance between the nozzle and the root surface is inversely proportional to the depth of the defects (3). In the present study, the distance between the application nozzle and the tooth surface was set at 1 cm. This distance

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is longer than for intraoral application, resulting in minimal defects and roughness.

With reference to Table 2 and Figure 2, we can evaluate the results in terms of powder accumulation on the surface separately for three different surfaces. There was no significant difference between the control and erythritol groups when assessing the surface of the enamel. In contrast, a significant difference was found in the cementum and cementoenamel junction. The rougher surface of the cementum can possibly explain this. Enamel consists almost exclusively of inorganic materials, which are mainly carbonated hydroxyapatite crystals (28). In contrast, dentin contains approximately 50 vol% carbonated hydroxyapatite minerals and 30 vol% collagen, which leads to a lower hardness of the substrate, and changes in the surface morphology occur more quickly (28). Cementum structure is softer than dentin; therefore, removing the applied powders from the cementum surface is more difficult, and there is a greater powder accumulation. In a previous study, erythritol powder with a particle size of 11–14 µm was used in the supragingival area. However, due to its low abrasive effect, its use was recommended in the subgingival area where the dentin is exposed (7).

Other studies have reported that powder spray systems are a safe biofilm removal method in periodontitis and peri-implantitis patients and are also comfortable for the clinician and patient. The results of our study on the cementum surface support the results of this study. Powder deposits on the surface of these experimental groups may lead to tubule clogging, resulting in reduced sensitivity, and their use in the subgingival area is safe.

According to Table 3 and Figure 3, examining the hard/soft tissue debris on the surface revealed no significant difference between experimental and control groups on different tooth surfaces. According to our results, in clinical studies, we can use the powders more safely if we apply them with a sweeping motion and from a greater distance rather than focusing on a single point, and the possibility of defects is minimal or non-existent. However, it should not be overlooked that it is difficult to keep the application angle and the distance of the head from the tooth surface constant in the clinical setting.

On the other hand, it was observed that powder accumulates on the tooth surface due to the application of powders. The sensitivity after the procedure is minimal as this blocks the dentinal tubules, forming a protective layer on the tooth surface. At the same time, this powder accumulation mimics the natural prismatic and irregular surface of the enamel but can also increase the risk of bacteria and biofilms attaching to these irregular areas (21).

Other factors, such as the type of blasting material and the quality of the tooth material, could affect the results (9, 18–21). A critical issue is the quality of the specimen. The extracted teeth can be stored in different solutions, such as formaldehyde or chloramine, for disinfection. These solutions might weaken the tooth substance (29–31). For this study, the teeth were stored in formaldehyde solution, which might have affected the surface of the teeth.

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Another important aspect is the effect of air polishing on clean dentin. Usually, every debridement method should be applied only if there is a bacterial biofilm or stain to be removed. It should be remembered that as long as the biofilm is not removed, the procedure cannot damage the tooth surface. Therefore, the manufacturer advises staining the biofilm to perform air-polishing only where necessary. Yet, staining of the biofilm would only be helpful supragingivally but not subgingivally. Moreover, clinically, the adhering biofilm might not always be homogeneous; therefore, the biofilm may remain completely in some places and leak elsewhere.

In clinical settings, it might not be possible to prevent air polishing from affecting already clean surface areas (31). We simulated this situation in our in vitro study by intentionally air-polishing clean tooth surfaces.

In future studies, changes in powder spraying speed, pressure, and water ratio can be made to examine the relationship between surface roughness, powder accumulation, and application pressure and water ratio. A decision can also be made about which device setting will be more appropriate for clinical studies.

CONCLUSION

The present in vitro study showed that performing air-polishing with erythritol did not cause substance loss or roughness in any part of the tooth surfaces and did not cause any hard or soft tissue loss. Additionally, performing air-polishing with erythritol caused powder accumulation on the rougher surfaces of the cementum and cementoenamel junction. However, considering the limitation of our study regarding the distance between the application nozzle and the tooth surface, which may not be maintained in clinical practice, closer application distances are necessary. Consequently, further research is needed with combinations of different angles and durations at closer distances.

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