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The Effect of Diamond Bur Preparation, Air Abrasion and Phosphoric Acid Etching on Micro-Roughness of Tooth Enamel

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Abstract

Background: Conventional diamond bur preparation, air abrasion, and acid etching of hard dental tissues have become an integral part of modern restorative dentistry. However, their influence on the surface microstructure of anisotropic enamel is poorly elucidated. This study investigated the effect of acid etching on the micro-roughness of buccal and occlusal enamel surfaces after traditional treatment with a diamond bur and a subsequent air-abrasion with mixtures based on Al_2O_3 or erythritol powders (AFP).
Materials and Results: Eighteen unerupted wisdom teeth extracted for orthodontic reasons were included in the study. Only the coronal parts of the teeth were used. They were cleaned of pulp tissue fragments, sequentially treated in an ultrasonic bath with an 80% alcohol solution and distilled water, and then randomly divided into 2 groups of 9 samples each. In samples of Group 1, the ground surfaces were formed on the buccal sides, and in the samples of Group 2, they were made on the occlusal sides. The samples of each group were divided into subgroups of 3 depending on the type of tooth surface treatment: (1) grinding hard tissues with a diamond bur only; (2) grinding and an air abrasion using Al_2O_3 powder; (3) grinding and an air abrasion using erythritol-based powder (AFP). Areas for acid etching were allocated on the surface of each sample. The etching step was performed using a 37% phosphoric acid gel. Qualitative and quantitative alterations to the enamel surface were registered using SEM and applied software.
Traditional enamel processing with a diamond bur contributed to the formation of the highest roughness value profiles: 9.9±0.7 µm (buccal enamel side) and 9.6±0.8 µm (occlusal enamel side). Acid etching of enamel after diamond bur preparation resulted in a decrease in roughness values of buccal and occlusal enamel sides down to 5.4±0.4 µm and 5.5±0.4 µm, respectively (P=0.000). The use of AFP and Al_2O_3, followed by acid etching, reduced the roughness values to 5±0.4 µm and 5±0.3 µm (P=0.000), respectively, and to 4.4±0.7 µm and 5.4±0.3 µm (P=0.000), respectively.
Conclusion: Air abrasion, followed by acid etching of the enamel, contributed to a significant reduction in the micro-roughness of surfaces formed by the diamond bur. It was also noted that there was no significant difference in roughness values between buccal and occlusal enamel after diamond bur preparation, air abrasion with erythritol, and acid etching. The lowest surface roughness of enamel was observed on buccal sections of tooth slabs after consecutive air abrasion with Al_2O_3 and acid etching.(**International Journal of Biomedicine. 2025;15(3):559-563.**)

Keywords: tooth enamel • diamond bur • micro-roughness • air abrasion • acid etching

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Introduction

Due to the need to achieve a seamless appearance of direct tooth-colored restorations and reduce the risk of edge discoloration, which manifests as dark lines, the use of air-abrasive technologies aims to minimize the likelihood of associated cosmetic complications. Additionally, the macro- and micro-roughness of enamel, which can occur during various types of tooth treatment, has a significant impact on gap formation and the longevity of composite fillings.[1-3]

The mineral part of dental enamel, the hardest tissue in the body, is more than 95%. This creates favorable conditions for the formation of a stable, waterproof interface between the filling and the tooth. However, the brittleness of enamel rods and the high chance of microcrack propagation during grinding with rotary instruments are the main reasons for the occurrence of cohesive failures caused by shrinkage stress and the low strength of the hybrid layer to withstand it.[4-6]

Diamond burs and abrasive powders remain the primary tools and materials for tooth preparation and prophylaxis. However, each method has its own advantages and drawbacks. For example, rotary cutting instruments are very effective in the precise removal of caries-affected tooth tissues and finishing of cavity margins. However, the quality of grinding depends on the type of diamond cutter, spindle balance, operator's manual skills, orientation of enamel prisms, and much more. On the other hand, air abrasive methods are less precise than the traditional bur and abrasive powders.. However, they facilitate simultaneous cleaning and help to obtain a proper roughness of tooth adhesive surfaces without any risk of friction and temperature rise in hard tissues while they are being treated. Thus, both methods are in demand and complete each other.[7-9]

To improve the quality of adhesive surfaces, understanding the hierarchical microstructure of tooth enamel and its anisotropy can be of practical value. The variability in the mechanical strength of enamel in different regions is mainly explained by the perpendicular orientation of enamel rods on the occlusal side and their oblique running on the buccal and lingual aspects. Thus, in a case of the same algorithm of tooth preparation, the values of enamel surface roughness in different parts of a tooth crown may differ significantly.[10]

The presence of excessive roughness on the adhesive surfaces of teeth, characterized by pronounced peak heights, valley depths, and peak density of the profile, may be the cause of high shrinkage stress in the composite restorative material and contribute to the emergence of micro-gaps along the boundary of the filling-tooth interface. In this regard, one of the trusted methods for forming a uniform, three-dimensional surface roughness is etching with acid gels.[11,12]

A large amount of data has accumulated in the available databases, indicating the urgent need for acid etching of enamel, regardless of the adhesive system used. Additionally, a preliminary air abrasion of a tooth with Al_2O_3 particles has been considered state of the art for many years. However, the use of soft abrasive powders for treating tooth surfaces may alter the surface topography of enamel differently, and consequently, the efficacy of acid etching can be affected.[13]

Based on this, the study investigated the effect of acid etching on the average roughness of the buccal and occlusal enamel surfaces after traditional treatment with a diamond bur and following air-abrasion with mixtures based on Al_2O_3 or erythritol powders.

Materials and Methods

Eighteen unerupted wisdom teeth extracted for orthodontic reasons were included in the study. Only the coronal parts of the teeth were used. They were cleaned of pulp tissue fragments, sequentially treated in an ultrasonic bath with an 80% alcohol solution and distilled water, and then randomly divided into 2 groups of 9 samples each. In samples of Group 1, the ground surfaces were formed on the buccal sides, and in the samples of Group 2, they were made on the occlusal sides. The grinding of the surfaces in both groups was performed using diamond perforated discs under constant water cooling until flat areas of enamel were formed. Obtained tooth slabs were polished using sandpaper with a gradual increase in the grain size from 400 to 1200 units, and then were ground again at a speed of 40,000 rpm using diamond burs (FG 133139, NTI-Kahla GmbH) inserted in the angled handpiece (1:5 A 200 l, T2 Line, Dentsply Sirona). After that, the samples of each group were divided into subgroups of 3 depending on the type of tooth surface treatment.

In subgroup 1A (n=3) and 2A (n=3), the surface treatment consisted of grinding hard tissues with a diamond bur only; in subgroup 1B (n=3) and 2B (n=3), grinding was combined with an air abrasion using Al_2O_3 powder; in subgroup 1C (n=3) and 2C (n=3) erythritol-based powder was used for air-abrasion. Qualitative and quantitative characteristics of each enamel profile were assessed in 10 arbitrarily chosen sectors. The particle size of Al_2O_3 powder was 27 µm (KaVo, Biberach, Germany), and the size of erythritol grit was 14 µm (Air-Flow Plus (AFP), EMS, Nyon, Switzerland). The air-abrasion was performed with a constant flow of particles at a pressure of 0.25 MPa for an exposure time of 30 seconds. The nozzle was held at 3-5 mm and a 45° angulation of the tool to the surface. After that, the prepared surfaces were thoroughly washed with an air-water spray for 30 seconds and dried. To determine the roughness of the enamel before and after acid etching, the studied surfaces of each sample were additionally divided into 2 halves. The part of the surface subjected to acid etching (treated) was designated by the letter "T." The etching step was performed using a 37% phosphoric acid gel (FineEtch 37, Spident Co., Ltd, Korea) with a 30-second etching time, followed by consecutive rinsing with water for the same time.

To obtain high-quality surface images, the samples were coated with a 10 nm layer of gold using a Quorum magnetron (Q150R ES) sputtering system. Scanning electron microscopy was performed using a SEM EVO MA 15 microscope (Carl Zeiss) and applied software.

Statistical analysis was performed using the statistical software package SPSS v. 21.0. For descriptive analysis, results are presented as mean±standard deviation. Multiple comparisons were performed with one-way ANOVA with Tukey's pairwise comparisons. Student's paired t-test was used to compare the differences between the paired samples. The probability value of $P<0.05$ was considered statistically significant.

Results

Analysis of results demonstrated (Table 1) that traditional enamel processing with a diamond bur was contributing to the formation of the highest roughness value profiles, characterized by the presence of zones of brittle fracture and smooth plastic surfaces, as well as chips of enamel rods on both the buccal and occlusal sides of teeth (Figure 1a, b). Subsequent acid etching was effective in removing sheared and torn material from the surface, leading to partial dissolution of the prism cores and peripheries (Figure 1 c, d). These alterations were accompanied by a significant decrease in average roughness values in 1AT and 2AT by 1.8 and 1.7 times, respectively (P=0.000 in both cases).

Table 1.

Ra values of buccal and occlusal enamel treated with different methods.

Roughness (Ra)	Subgroup 1A (n=30)	Subgroup 2A (n=30)	Subgroup 1B (n=30)	Subgroup 2B (n=30)	Subgroup 1C (n=30)	Subgroup 2C (n=30)	*P-value* between subgroups before acid etching
Ra (μm) Before acid etching	9.9±0.7	9.6±0.8	3.4±0.3	4.9±0.4	7.9±0.6	7.9±0.5	F=610.2513; P = 0.0000 P_{1A-2A}= 0.3367; P_{1A-1B}= 0.000; P_{1A-2B}= 0.000; P_{1A-1C}= 0.000; P_{1A-2C}= 0.000; P_{2A-1B}= 0.000; P_{2A-2B}= 0.000; P_{2A-1C}= 0.000; P_{2A-2C}= 0.000; P_{1B-2B}=0.000; P_{1B-1C}= 0.000; P_{1B-2C}= 0.000; P_{2B-1C}= 0.000; P_{2B-2C}= 0.000; P_{1C-2C}= 1.000
P-value	0.000	0.000	0.000	0.000	0.000	0.000	*P-value* between subgroups after acid etching
Ra (μm) After acid etching (T)	5.4±0.4	5.5±0.4	4.4±0.7	5.4±0.3	5.0±0.4	5.0±0.3	F=26.5565; P=0.000o $P_{1AT-2AT}$= 0.9497; $P_{1AT-1BT}$= 0.000; $P_{1AT-2BT}$= 1.000; $P_{1AT-1CT}$= 0.0067; $P_{1AT-2CT}$= 0.0067; $P_{2AT-1BT}$= 0.000; $P_{2AT-2BT}$= 0.9497 $P_{2AT-1CT}$= 0.002; $P_{2AT-2CT}$= 0.002; $P_{1BT-2BT}$= 0.000; $P_{1BT-1CT}$= 0.000; $P_{1BT-2CT}$= 0.000; $P_{2BT-1CT}$= 0.0067; $P_{2BT-2CT}$= 0.0067; $P_{1CT-2CT}$= 1.000

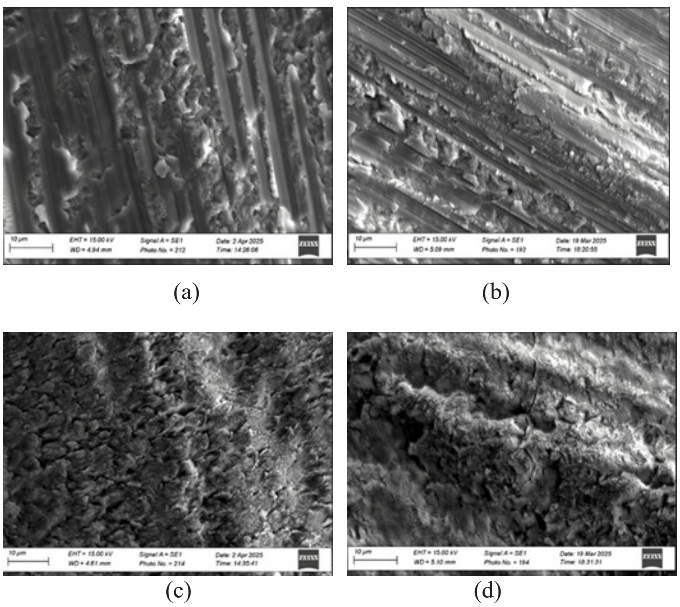


Figure 1. *(a) -1A; (b) - 2A; (c) - 1AT; (d) - 2AT.*

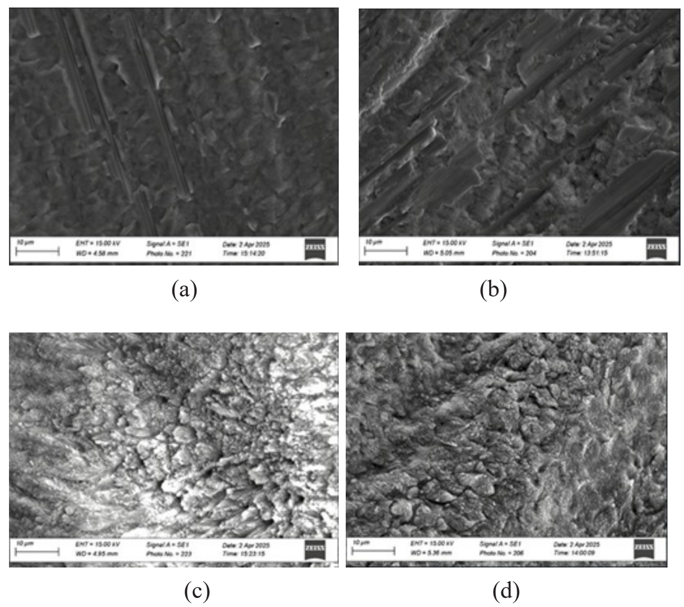


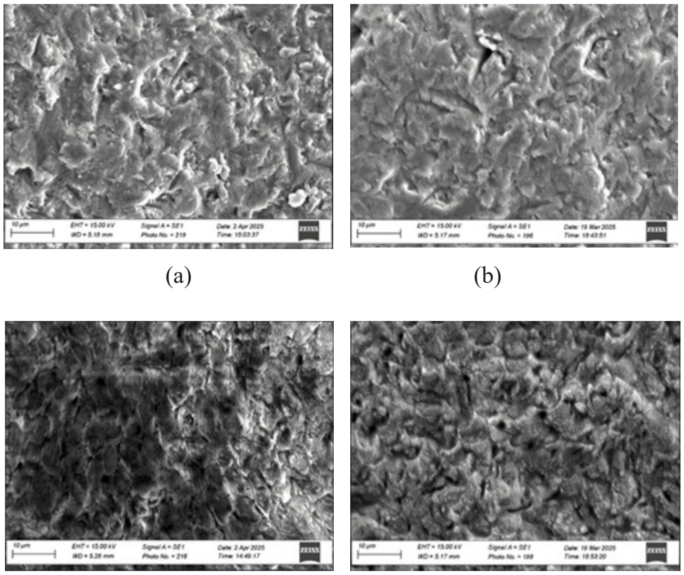
Figure 2*. (a) -1C; (b) - 2C; (c) - 1CT; (d) - 2CT.*

Air-abrasion of enamel samples with AFP powder was effective in removing chips from the surfaces, but did not contribute to the elimination of traces of brittle and smooth plastic fracture caused by preparation with a diamond bur (Figure 2 a, b). This type of treatment resulted in less reduction of linear micro-roughness of buccal and occlusal enamel surfaces by 1.3 and 1.2 times, respectively.

Consecutive phosphoric acid etching was leading to the typical surface dissolution of intrarod and interrod spaces of enamel (Figure 2 c, d) and further decline in roughness values down to the level of 5μm (*P*=0.000).

Air-abrasion of buccal and occlusal enamel ground sections with Al_2O_3 powder after traditional surface treatment with a diamond bur resulted in a significant decrease in micro-roughness by 2.9 and 1.9 times, respectively (*P*=0.000 in both cases). Visual analysis of micrographs revealed the complete elimination of traces of plastic and brittle fracture caused by a diamond bur. However, there was a lot of chipped material, which was mainly noted on the buccal surfaces, and a significant number of microcracks and pits were observed on the occlusal surface of the enamel (Figure 3 a, b).

Subsequent acid etching contributed to both the cleaning of chips from enamel surfaces (Figure 3 c, d) and an increase in roughness values of buccal and occlusal surfaces by 1.3 and 1.1 times, respectively (*P*=o.ooo). Thus, significant differences were found in roughness (Ra) values between subgroups 1B and 2B, as well as 1BT and 2BT, of 1.4 and 1.2 times, respectively (*P*=0.000 in both cases).



(a) (b) (c) (d)

Figure 3. *(a) -1B; (b) - 2B; (c) - 1BT; (d) - 2BT.*

Discussion

Among the primary priorities in treating caries pathology and tooth restoration, minimal invasiveness and high aesthetics are of particular concern. The discovery made by Buonocore, along with the differentiated approach to selecting abrasive powders for the prophylaxis and treatment of teeth, became the key to the stability of interfaces and the long-lasting aesthetic performance of direct composite restorations.[14]

However, the specificity of enamel structure is determined by anisotropy, and different surface treatment modalities in combination with acid etching can contribute to the occurrence of various alterations in tooth surfaces.

It has been adopted to categorize the etched patterns of tooth enamel into 5 types: (1) honeycomb-like pattern with a predominant dissolution of prism cores; (2) cobblestone-like pattern with a preferential dissolution of interprism spaces; (3) a combination of the first and second options; (4) pitted surface; and (5) smoothed surface patterns.[15]

Visual analysis of SEM images revealed that acid etching of buccal enamel surfaces after traditional diamond bur preparation or its combination with air abrasion using an erythritol-based powder was the reason for the mixed-type changes of honeycomb- and cobblestone-like patterns. The same treatment algorithms for the occlusal part of tooth enamel led to surface alterations with a predominant cobblestone appearance. Buccal and occlusal enamel surfaces treated with Al_2O_3 powder and etched with an acid were characterized as pitted, with the most pronounced changes on the occlusal sides of teeth.

Conclusion

The results of our study established that air abrasion, followed by acid etching of the enamel, contributed to a significant reduction in the micro-roughness of surfaces formed by the diamond bur. It was also noted that there was no significant difference in roughness values between buccal and occlusal enamel after diamond bur preparation, air abrasion with erythritol, and acid etching. A significant difference was found in average roughness between buccal and occlusal samples after air abrasion with Al_2O_3 powder, followed by acid etching. The lowest surface roughness of enamel was observed on buccal sections of tooth slabs after consecutive air-abrasion with Al_2O_3 and acid etching. In addition, in these samples, a sharp decrease in the enamel surface roughness after sandblasting with aluminum oxide particles was replaced by a slight increase due to the action of phosphoric acid. Such changes in microroughness differed from those of other groups and can be explained by the formation of microcracks and pits on the enamel surface caused by the narrow stream of Al_2O_3 particles.

Competing Interests

The authors declare that they have no competing interests.

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