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Evaluation of Etching Patterns on Human Enamel Using Two Distinct Phosphoric Acid Etchant Viscidity- A Scanning Electron Microscope Study

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Abstract

This study aimed to evaluate and compare the etching patterns of human enamel produced by two viscosities of 37% phosphoric acid etchants—gel and solution—using scanning electron microscope(SEM). Forty extracted mandibular premolars were sectioned mesiodistally and divided into four groups which consists of 2 gel and 2 solution groups from two different commercial brands. The etching process involved acid application for 15 seconds, followed by rinsing, drying, and SEM analysis at 5000x magnification to assess etching pattern. The results revealed that the gel-based etchants produced Type II etching patterns, characterized by uneven distribution and selective removal of the enamel prism peripheries. This inconsistent pattern was attributed to the gel's higher viscosity. In contrast, solution-based etchants generated more consistent Type I patterns, with uniform removal of the enamel prism cores. The lower viscosity of the solutions allowed for better wetting and deeper penetration, providing a more favourable surface for resin bonding. Differences in pH between the etchants, although all containing 37% phosphoric acid, may also influence their etching efficacy. The study concluded that phosphoric acid solutions are more

effective than gels in producing uniform and consistent etching patterns, which are critical for strong micromechanical bonding in restorative dentistry.

Keywords: Etchant viscidity, Etching patterns, Human enamel, 37% Phosphoric acid

Summary: The study titled "Evaluation of Etching Patterns on Human Enamel Using Two Distinct Phosphoric Acid Etchant Viscosities: A Scanning Electron Microscope Study" investigates how different viscosities of phosphoric acid etchants affect the etching patterns on human enamel, a key factor in achieving successful dental bonding. The study compares two commonly available forms of 37% phosphoric acid etchants—gels and solutions—using SEM to evaluate the etching patterns on extracted human teeth.

Introduction: Acid etching is fundamental to modern dentistry, particularly for procedures like aesthetic restorations and orthodontic bonding. It involves applying an acidic substance to the enamel surface, roughening it microscopically, thereby improving resin bonding. Although gels offer more control during application due to their viscosity, there is debate over their effectiveness compared to traditional solutions.

Materials and Methods: Forty extracted mandibular first premolars were selected and sectioned mesiodistally. The samples were divided into four groups, each etched with one of two etchants (Prevest Denpro and Prime) in gel and solution forms. The etching process lasted 15 seconds, after which the samples were rinsed, vaccum dried, and prepared for SEM analysis. Samples were coated with gold-palladium to enhance image clarity, and SEM images were taken at 5000x magnification to assess the resulting etching patterns.

Results: The SEM analysis revealed distinct differences between the etching patterns produced by the gel and solution etchants. Samples treated with gel etchants exhibited a Type II etching pattern, characterized by selective removal of enamel prism peripheries, resulting in an irregular and less uniform surface. On the other hand, samples treated with solution etchants produced a more uniform Type I etching pattern, with deep, well-defined etching that is more conducive to resin bonding.

Discussion: The findings support the hypothesis that phosphoric acid solutions are more effective than gels in producing uniform and consistent etching patterns, which are critical for micromechanical bonding. The Type I etching pattern, observed more frequently with solution etchants, is considered ideal for dental bonding as it creates a uniform surface with deeper channels for resin penetration. The solution's lower viscosity allowed it to flow more freely over the enamel surface, ensuring better wetting and penetration into the enamel microstructure. Conversely, the irregular Type II pattern produced by gels may compromise bonding strength due to reduced surface area and inconsistent resin tag formation. The inconsistency in the etching pattern could be attributed to the gel's higher viscosity. The study also highlighted that differences in pH between the etchants might influence their efficacy. Pre-existing enamel imperfections or developmental defects may also affect etching patterns.

Conclusion: The study concludes that phosphoric acid etchant solutions are more effective than gels in producing desirable etching patterns for dental bonding. Using etchants according to manufacturer guidelines is crucial for achieving the best results.

Introduction

The ability of dental professionals to bond restorations to enamel has revolutionized various aspects of dentistry, including prosthetic, aesthetic restorations, orthodontic bonding techniques etc. Although attempts have been

made to develop simpler alternatives, none have surpassed the durability and reliability provided by traditional acid etching methods [1].

Acid etching involves applying an acidic solution to the enamel surface, which microscopically roughens it to enhance the retention of resin-based materials. This process removes the smear layer and opens enamel tubules, which improves the bonding strength between the tooth and restoration material [2]. The technique was pioneered by Bunocore in 1955, who introduced the concept of enamel etching to improve adhesion. Initially, acid solutions were the primary method of etching; however, in recent years, etching gels have been introduced as an alternative that offers easier control and placement during procedures [3].

Gels, being thixotropic, allow for more precise application, reducing the risk of damage to adjacent tissues [4]. Despite these advantages, the efficacy of gels compared to solutions has been debated, with some studies suggesting the viscous nature of gels, may inhibit their ability to effectively wet the enamel surface [5]. Additionally, by-products from the etching process may accumulate at the enamel-gel interface, reducing the acid's efficacy. Continuous fresh acid application, as seen in etchant solutions, is often recommended to eliminate these by-products and maximize bonding potential [6].

The aim of this study is to evaluate and compare the etching patterns produced by two commonly available etchant forms—gel and solution, using scanning electron microscopy.

Materials and Methods

Forty extracted mandibular first premolars, selected for orthodontic purposes, were included in this study. These premolars were chosen due to their consistent enamel structure [5]. The root portions of each tooth were sectioned at the cementoenamel junction (CEJ). Following this, the samples were sectioned in a mesiodistal direction using a carborundum disc to create flat sections for evaluation.

Sectioned tooth samples were then randomly divided into Four groups: A1, A2, B1, B2 each containing ten samples:

A1	Prevest Denpro Etchant GEL
A2	Prevest Denpro Etchant SOLUTION
B1	Prime Etchant Gel
B2	Prime Etchant Solution

Group (A1, B1) samples were treated with 37% phosphoric acid gel.

Group (A2, B2) samples were treated with 37% phosphoric acid solution.

Before etching, the facial surfaces of all specimens were thoroughly cleaned using a slow-speed handpiece with a rubber cup and pumice slurry to remove debris, plaque, and any potential contaminants. Cleaning the enamel surface is a crucial step, as residual surface materials could interfere with the interaction between the enamel and the etchant, leading to inconsistent etching patterns. Ensuring a clean surface improves the ability of the etchant to penetrate the enamel, thus enhancing the precision of the subsequent SEM analysis.

pH of the phosphoric acid etchants was pre-assessed to check the differences in the pH values between the two commercially available etchant brands in both the gel and solution forms which interprets the etching efficiency.

Acid Etching is done for 15 seconds. After the etching process, all the groups were rinsed thoroughly with water for 20 seconds to remove any residual etchant. Following rinsing, the samples were air-dried for 10 seconds, ensuring that the enamel surfaces were completely dry before further steps were taken [4].

The samples were then, desiccated in a vacuum oven for 24 hours. This desiccation process was necessary to ensure the complete removal of moisture, which could interfere with the scanning electron microscopy imaging [6].

Photomicrographs of the etched enamel surfaces were taken at a magnification of 5000x using Scanning Electron Microscope.

Results

The results of the study, as observed through scanning electron microscopy (SEM), showed clear distinctions in the etching patterns produced by the two forms of etchants—37% phosphoric acid gel and 37% phosphoric acid solution.

The Scanning electron microscopy of the control group was enamel without any surface treatment are shown in Figure 1,3,5,7. Samples treated with Prevest Denpro Etchant gel (Group A1) exhibited a Type II etching pattern (Figure 2).

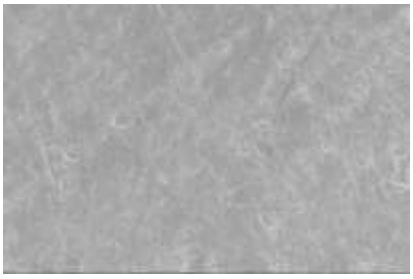

Figure 1: Pre-etched SEM Image (Prevest Denpro Etchant Gel(A1))

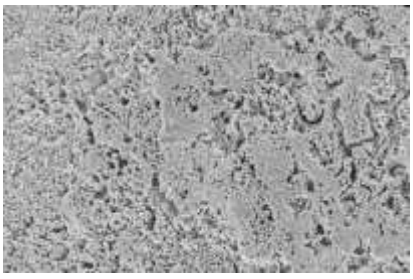

Figure 2: Post-Etched SEM Image (Prevest Denpro Etchant Gel(A1))

Samples treated with Prevest Denpro Etchant Solution (Group A2) exhibited **a** Type I etching pattern(Figure 4).

Figure 3: Pre-etched SEM Image (Prevest Denpro Etchant Solution (A2)).

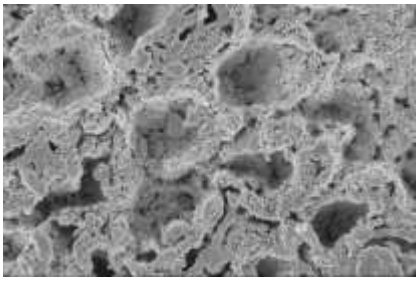

Figure 4: Post-etched SEM Image (Prevest Denpro Etchant Solution (A2)).

Samples treated with Prime Etchant gel (Group B1) exhibited a Type II etching pattern (Figure 6).

Figure 5: Pre-etched SEM Image (Prime Etchant Gel(B1))

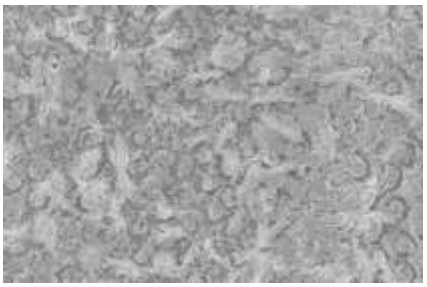

Figure 6: Post-etched SEM Image (Prime Etchant Gel(B1))

Samples treated with Prime Etchant Solution (Group B2) exhibited a Type I etching pattern (Figure 8).

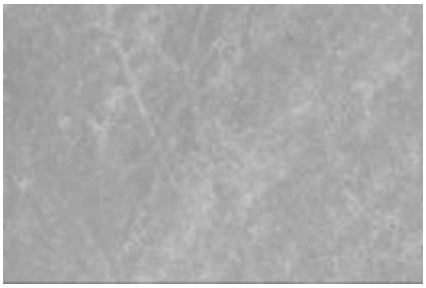

Figure 7: Pre-etched SEM Image (Prime Etchant Solution (B2)).

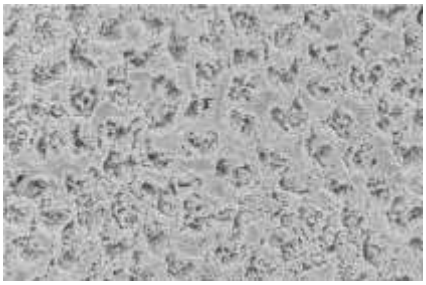

Figure 8: Post-etched SEM Image (Prime Etchant Solution (B2)).

This Etching pattern observed in Gel samples (A1, B1) was characterized by an uneven distribution of the etched areas, with selective removal of the peripheral regions of the enamel prisms, leaving relatively intact cores. This irregular etching pattern was less uniform, with variations in depth and coverage across the enamel surface. This less consistent pattern suggests that the gel did not penetrate the enamel surface as effectively as expected, potentially due to its higher viscosity.

The SEM photomicrographs of etching patterns of Solution samples (A2, B2) observed a more consistent and uniform removal of enamel prism cores. The prism boundaries remained intact, resulting in a well-defined, evenly distributed etching pattern.

Discussion

The process of enamel etching is fundamental to achieving strong adhesion in restorative dentistry. When enamel is treated with an acid, approximately 10 micrometres of the enamel surface is removed. This results in the creation of micro-porosities, that act as channels into which resin bonding agents can flow. These channels substantially increase the surface area for bonding, enhancing the mechanical bond between the enamel and the resin.

The Etching patterns created by acid etching can vary significantly and have been classified into different types. Silverstone et al. (1975) developed a classification system for these etching patterns:

- Type I: The enamel prism cores are preferentially removed, resulting in a deep, well-defined pattern with intact peripheries. This type is considered the most desirable for creating optimal micromechanical bonding.
- Type II: The peripheral regions of the enamel prisms are dissolved, while the cores remain relatively intact. This pattern tends to be less uniform and may provide less effective bonding than Type I.
- Type III: A combination of both Type I and Type II, showing alternating removal of cores and peripheries, resulting in a mixed or irregular etching pattern) [6].
- Additionally, Ripa et al. (1966)[7] and Wei (1975)[8] introduced Type IV and Type V patterns. Type IV refers to prismless enamel that displays no clear rod or prism structures, while Type V represents a smooth, flat etching pattern with minimal porosity, which provides poor bonding conditions.

In this study, the etching patterns produced by the four different etching agents— Two phosphoric acid gel etchants and two phosphoric acid etchant solution were evaluated using scanning electron microscope (SEM). The results revealed distinct differences between the two groups in terms of etching depth, uniformity, and overall effectiveness.

A. Group A1 and B1(Phosphoric Acid Etchant Gel): The enamel surfaces treated with 37% phosphoric acid

gel exhibited a Type II etching pattern. This pattern was less uniform, with selective removal of the peripheral regions of the enamel prisms, leaving the prism cores relatively unaffected and intact. The SEM photomicrographs revealed an irregular distribution of etched areas, with varying depths across the enamel surface. The inconsistency in the etching pattern could be attributed to the gel's higher viscosity, which may limit its ability to adequately wet the enamel surface and penetrate its microstructure. This limitation reduces the etching depth and coverage, leading to less favourable conditions for resin bonding[3]. Additionally, the formation of by-products at the enamel-gel interface may further inhibit the effectiveness of the etching process, as these residues are not easily removed unless fresh acid is continuously applied [5]. Longer rinsing times are also necessary to remove the viscous gel residues, which can affect the quality of the etched enamel.

B. Group A2 and B2 (Phosphoric Acid Solution): The samples treated with the 37% phosphoric acid solution showed a Type I etching pattern. This pattern was more uniform and consistent, with the enamel prism cores preferentially dissolved and the peripheral boundaries left intact. The SEM images demonstrated deeper and more even etching across the enamel surface, resulting in a more defined and regular micro-topography. The solution's lower viscosity allowed it to flow more freely over the enamel surface, ensuring better wetting and penetration into the enamel microstructure. This resulted in the formation of deeper channels, which are ideal for the infiltration of resin bonding agents [6]. Continuous application of the solution during the etching process helped to eliminate reaction by-products, further enhancing the quality of the etched surface. This pattern is associated with improved micromechanical bonding, as it allows for better resin penetration and the formation of stronger resin tags, which are crucial for long-lasting adhesion[9].

The findings of this study are consistent with previous research, which has demonstrated that solution etchants, due to their lower viscosity, tend to produce more effective and uniform etching patterns compared to gels[5-6]. The more consistent Type I pattern observed in Group A2, B2 indicates that solution-based etchants are better suited for preparing the enamel surface for bonding, as they create deeper micro-channels and more uniform surface roughness, both of which are essential for achieving strong micromechanical interlocking between the resin and the tooth[10].

In contrast, the less consistent Type II pattern seen in the gel-treated group (Group A1, B1) may compromise the bond strength and durability of resin restorations. The irregularity in the depth and distribution of the etched areas reduces the surface area available for bonding and limits the formation of uniform resin tags. This could potentially lead to weaker adhesion and increased susceptibility to bond failure over time.

On evaluating the pH values, it was observed that Prevest Denpro etchant Gel – 1.57; Prevest Denpro Etchant Solution – 1.94; Prime Etchant Gel – 0.45; Prime Etchant Solution – 0.38. Though all the etchants are 37% phosphoric acid, other elements of composition can alter the pH. Additives in the etchants solution or gels consists of Preservatives, colouring agents, viscosity maintainers, which can make the difference in pH. The highly acidic nature of etchants can enhance the dissolution of enamel's organic components, causing damage to the prism matrix, which may interfere with

resin bonding. [11].From this study it is concluded that Etchants are to be used according to the Manufacturer's instructions, failing to which can lead to alteration of etching patterns.

Conclusion

The results of this study support the use of phosphoric acid solution over gel for producing more effective and consistent etching patterns on enamel surfaces. The superior performance of the solution-based etchant in creating a uniform Type I etching pattern suggests that it is more effective for achieving strong and durable bonds in restorative dental procedures.

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