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Review Article

Enamel etching techniques in orthodontic bonding: A Comprehensive review

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Abstract

The attachment of brackets is a critical component of modern orthodontic procedures. Ensuring strong bonding of brackets requires appropriate preparation of the tooth enamel surface. Nonetheless, conventional techniques like pumice prophylaxis smoothing and enamel etching have been found to cause significant enamel damage.

In the following article, we will thoroughly explore the intricacies of etching in orthodontics, providing insights into the materials used and the nuanced procedures associated with this crucial step on various dental surfaces.

Keywords: Dental Etching, Orthodontic Bonding, Enamel Etching methods, Enamel Etching standards.

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1. Introduction

Traditional etching utilizing phosphoric acid is known for its ability to dissolve the outer enamel layer and create a surface conducive to bonding orthodontic brackets when appropriate acrylic or diacrylate resins are employed.[1-3]

In clinical settings, the customary preparatory measures prior to bonding brackets onto teeth usually entail prophylaxis to remove debris, smoothing the tooth surface, and enamel etching.[4] The main goal of etching is to initiate a controlled partial dissolution of enamel minerals, aiding in the mechanical retention between orthodontic resin tags and the porous tissue. This procedure creates substantial roughness on the tooth surface, which is crucial for the stability of braces attachment.[5]

Acid etching in orthodontics involves both additive and subtractive methods (**Figure 1**) to enhance bond strength and adhesion of brackets to the enamel surface. The subtractive method primarily uses phosphoric acid (typically 30-40%) to selectively remove the mineral content from the enamel, creating microporosities that facilitate mechanical retention. This technique increases surface roughness, improving bracket adhesion. On the other hand, the additive method involves the deposition of substances such as calcium phosphate or other bioactive materials after etching to enhance remineralization and reduce enamel demineralization. Both approaches play a crucial role in ensuring effective bonding while minimizing potential enamel damage during orthodontic treatments.

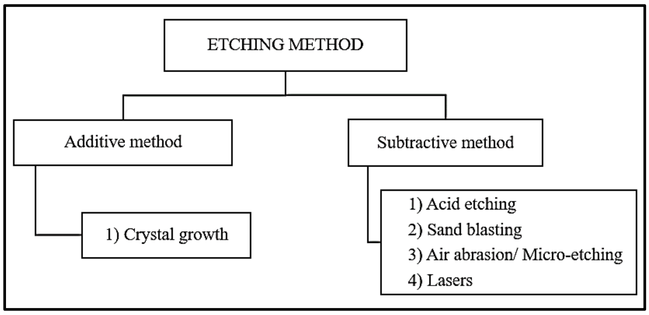

Figure 1: Various methods of etching.

2. Historical Background

Traditionally, orthodontic treatments with fixed attachments involved soldering brackets onto bands. As far back as 1907, Angle introduced gold clamp bands as part of his edgewise philosophy.[6] In the following years, there was a progression

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in orthodontic techniques, including the utilization of pitch-fit bands in full-mouth banding procedures, succeeded by the adoption of prefabricated stainless steel bands for orthodontic interventions.

Nonetheless, these methods presented challenges such as prolonged chair-time, the occurrence of diastemata due to band removal after treatment completion, aesthetically unpleasing outcomes, and irritation of the soft tissues.[7]

In a significant advancement in 1955, Buonocore introduced a groundbreaking technique where 85% phosphoric acid was utilized to etch enamel, laying the foundation for bonding acrylic structures through enamel etching.

3. Enamel Etching Technique

Newman and Retief played a pivotal role in refining the use of phosphoric acid for enamel etching during the 1960s, carefully adjusting its concentration and application time to optimize adhesion. Their pioneering work laid the foundation for subsequent research, with initial study results emerging in the 1970s and more comprehensive follow-up reports published in 1977.[8]

Today, phosphoric acid etching remains a cornerstone of modern orthodontic bonding techniques. A 37% orthophosphoric acid gel or solution is typically applied to the enamel surface for approximately 30 seconds. This controlled exposure facilitates the selective dissolution of minerals from the enamel, creating a microscopically roughened surface that enhances mechanical retention.[9-10]

The etched enamel exhibits distinct patterns of demineralization (**Table 1**). Depending on how the enamel prisms react to the acid, three primary etching patterns can be observed:

1. The enamel prism walls remain intact while the prism cores are selectively removed,
2. The prism walls are dissolved while the cores remain stable, or
3. Both structures are removed, resulting in a more pronounced etching effect.

The most commonly observed patterns, Type 1 and Type 2, have been extensively studied for their effectiveness in promoting strong adhesive bonds.[10-11]

Following the etching process, the surface is thoroughly rinsed with water to remove residual acid and debris, then air-dried to reveal the characteristic frosty appearance of demineralized enamel. These etched regions, now lacking minerals, display uneven depths and an increased surface area for bonding. Orthodontic brackets and other fixed attachments are then securely bonded to the treated enamel by allowing adhesive materials to penetrate the newly created micro-retentive sites.[12]

4. Types of Acids Used in Enamel Etching

Acids used in the enamel etching procedure play a crucial role in preparing the tooth surface for bonding. The most commonly used acid is phosphoric acid, typically in concentrations ranging from 30% to 40%. Other acids, like maleic acid and polyacrylic acid, have also been explored (**Figure 2**), but phosphoric acid remains the gold standard due to its effectiveness and reliability in clinical applications."

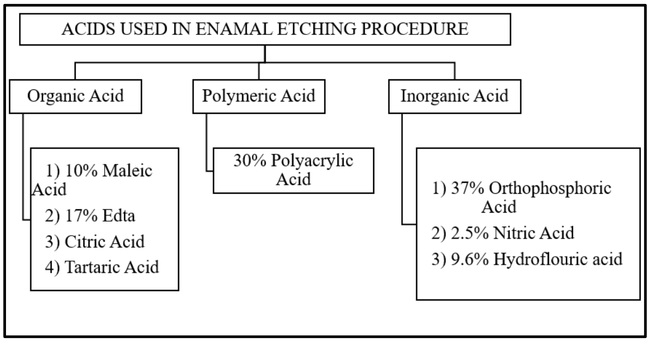

Figure 2: Acids used in enamal etching procedure

A variety of acids are used in enamel etching, each with different concentrations, etching times, and bond strengths, playing a crucial role in enhancing the adhesion of bonding materials. The choice of acid and its application parameters can significantly impact the overall success of bonding procedures in orthodontic treatments (**Table 2**).

Table 1: Types of acid etching (Silverstone et al)

Type	Preferential dissolution of enamel	Appearance of enamel surface
Type I	Prism cores	Honeycomb like
Type II	Prism peripheries	Cobblestone like
Type III	Both cores and peripheries	Mixture of Type I & II
Type IV	Not defined	Pitted surface
Type V	Not defined	Flat, smooth surface

Table 2: Enamel etching agents

S. No.	Enamel Etching agents	Time	Primer	Bond strength to enamel
1.	10 % Phosphoric acid	15-60 sec	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive	20-25 Mpa
2.	37% Phosphoric acid	15 sec	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive	28 Mpa
3.	10% Melic acid	15 sec	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive	15 Mpa
4.	EDTA 17% (pH: 7.0)	20 sec	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive	18-25Mpa
5.	EDTA (17g), NaOH(9.25 ml)	30 sec	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive	18-25Mpa
6.	EDTA (17g), distilled water (100ml)	60 sec	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive	18-25Mpa
7.	Air abrasion using 50µm Al_2O_3	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive		50 % of acid etched enamel
8.	Nd:YAG laser	-	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive	
9.	Er:YAG laser	-	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive	
10.	CO_2 laser	-	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive	
11.	ErCs:YAG laser	-	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive	

Table 3: Comparison of bond strength of acid etch & crystal growth

	Tensile bond strength*(MPa)			
	Acid etch		Crystal growth	
Storage day	7	30	7	30
Water	-	1.3 ± 0.19	0.96 ± 0.08	1.11 ± 0.16
Lactic acid	-	1.12 ± 0.22	0.99 ± 0.09	1.01 ± 0.13

Table 4: Etching of different tooth surfaces

Type of tooth surface	Etching method	Time	Primer
Amalgam	Air abrasion using 50µm Al_2O_3	-	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive
Composite	9.6% HF followed by Silane coupling agent application	60 seconds	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive
Ceramic	9.6% HFA Air abrasion using 30µm Al_2O_3	60 seconds	Silane coupling agent followed by 3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive primer
Gold	Air abrasion using 30µm Al_2O_3 particles	60 seconds	Silane coupling agent followed by 3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive primer
Feldspathic porcelain	9.6% HFA	120 seconds	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive
Alumina porcelain	Air abrasion using 30µm silane coated Al_2O_3 particles	-	3M Unitek transbond XT/ Ormco Enlight/ All Bond universal adhesive

5. Crystal Growth Solution for Enamel Adhesion Enhancement / Crystal Bonding for Improved Adhesive Retention

5.1 Procedure

Treating enamel with a polyacrylic acid solution containing sulfate ions prompts the growth of calcium sulfate dihydrate crystals on the enamel surface. These crystals, in turn, enhance adhesive retention.[13] The advantages of crystal bonding technique are as follows:

1. The fluoride-rich outer enamel layer experiences minimal impact.
2. No significant damage occurs to the enamel surface.
3. Residual resin tags on the enamel are scarce, if present at all.
4. Sufficient bond strength for clinical use is attained.
5. Removal and cleanup are simplified, reducing iatrogenic damage.
6. The crystal interface presents an opportunity for potential future integration of fluoride or other antiplaque agents, enhancing anticariogenic properties.

In prior in vitro research, several orthodontic bonding agents have shown similar tensile bond strength at the crystal interface compared to the acid etch method using the same bonding resin. Moreover, the observed tensile bond strength remained stable even after immersion in water for six months at 37°C.[14] **(Table 3).**

The data obtained following immersion in water were contrasted with those obtained from immersion in 0.1N lactic acid. These comparative analyses validate the formation of a durable bond, similar to that achieved through phosphoric acid etching.[14]

The shear strength of the bonds formed ranges between 65% to 80% of that achieved by acid etching with the same resin. Nonetheless, the strength attained through this approach appears sufficient for clinical use and offers a simpler debonding process.[15]

The strength of orthodontic bonding needs to strike a balance: it should be strong enough to keep the bracket in place, yet gentle enough to facilitate the removal of adhesive once the treatment is finished.[16]

Ortho phosphoric acid etching time <10 sec or >60 sec does not produce enough bond strength. Retief & Dreyer, 1970- used 50% Phosphoric acid, Concentration <27%, produce dicalcium phosphate dihydrate which decreases bond strength because of difficulty in removal by washing.[17]

Chow & Brown, 1973 Phosphoric acid concentration >27% -Formation of mono calcium phosphate monohydrate which is soluble, Easy removal by washing.[18]

6. Discussion

This article explores the various methods used for etching enamel and other tooth surfaces, highlighting both additive and subtractive techniques and their significance in dental treatments. Each method is thoroughly examined in terms of its effectiveness, application, and overall impact on tooth structure, providing a comprehensive understanding of its role in adhesive dentistry.

Furthermore, the article reviews the different types of acids utilized in the enamel etching process, discussing their respective concentrations, optimal etching times, and the specific effects they produce on the enamel surface. A detailed comparison of the bond strength achieved with each acid is presented, offering valuable insights into their effectiveness in enhancing adhesive retention for restorative and orthodontic procedures.

In addition to enamel etching, specialized techniques for different tooth surfaces are analyzed (**Table 4**), considering the unique structural and compositional properties of enamel, dentin, and other dental tissues. This ensures a tailored approach to achieving optimal bonding outcomes across various clinical scenarios.

Moreover, the role of primers used in conjunction with etching methods is examined, emphasizing their contribution to improving adhesion, enhancing mechanical retention, and ensuring the long-term stability of orthodontic and restorative bonding. By integrating these insights, this article provides a well-rounded perspective on the science and application of enamel etching in modern dentistry.

7. Conclusion

Enamel etching has revolutionized orthodontic bonding, providing a strong foundation for the secure attachment of brackets and fixed appliances. The introduction of phosphoric acid etching marked a significant milestone, transitioning from labor-intensive banding methods to modern, efficient, and aesthetic bonding techniques. Despite its benefits, careful consideration must be given to minimize enamel damage during the etching process.

The understanding of etching patterns, as outlined by Silverstone et al., underscores the importance of selecting the appropriate etching method based on clinical requirements and enamel conditions. Advances in acid formulations, application techniques, and adhesive materials have further refined the procedure, enhancing bond strength and minimizing enamel loss.

Future innovations in enamel etching and bonding materials hold the potential to optimize outcomes, reducing iatrogenic damage while maintaining the stability and longevity of orthodontic attachments. As research continues, the emphasis should remain on balancing efficiency with enamel preservation to ensure patient safety and treatment success.

8. Source of Funding

None.

9. Conflict of Interest

None.

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