Comparative Evaluation of Shear Bond Strength of Orthodontic Brackets using Laser Etching and Two Conventional Etching Techniques: An in vitro Study

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ABSTRACT

Introduction: The purpose of this study was to evaluate and compare the shear bond strength between the bracket and acid etched enamel, enamel treated with self-etch primer and laser irradiated enamel and to analyze the interface of the enamel bracket bond.

Materials and methods: Around 60 noncarious human premolars were divided randomly into three groups of 20 each and etched using 37% phosphoric acid, self-etch primer and Er:YAG laser. Stainless steel brackets were then bonded using Transbond XT following which all the samples were stored in distilled water at room temperature for 24 hours. Shear bond strength was tested using a chisel edge, mounted on the crosshead of Universal Testing Machine. After debonding, the teeth were examined under 10× magnification with a stereomicroscope and ARI score determined. Shear bond strengths of the three groups were then compared using ANOVA test (multiple comparisons, Tukey’s correction). Comparison of the ARI scores was done using Chi-square test.

Result: The acid etched group yielded the highest mean debonding force (13.34 Mpa) followed by self-etch group (12.15 Mpa) and laser etch group (12.10 Mpa). No significant difference was found between the three groups. On comparison of the ARI scores, it was found that the adhesive left on the enamel surface after debonding was significantly higher in the acid etched group than the self-etch group (p = 0.009). There was no significant difference in the ARI scores between the other two groups.

Conclusion: These results indicate that the shear bond strength of all the three groups was clinically acceptable with no significant difference between them but more adhesive was left on enamel treated with acid and laser as compared to self-etch primer treated enamel.

Keywords: Bond strength, Orthodontic brackets, Laser etching, Self etching primer, ARI score, Caries prevention.


INTRODUCTION

Fixed orthodontic treatment necessitates bonding of brackets to the enamel surface. Direct bonding of brackets to enamel can be considered an advancement in orthodontics as it makes the clinical practice easier and more acceptable among patients. Bonding can be accomplished with various enamel conditioning procedures which can be either chemical or mechanical. Since the report of Buonocore in 1955, the standard protocol to treat enamel for successful bonding has been etching with 37% phosphoric acid. The enamel tags created by dissolving hydroxyapatite crystals permit penetration of the fluid adhesive component and this provides a high level of micromechanical retention. Although a high level of bond strength is achieved with conventional acid etching, it is time consuming and also the loss of mineral crystals, essentially the acid protecting barrier, is inevitable because of which the etched enamel may be vulnerable to severe acid attacks in the oral environment.

With the introduction of self-etch primers, etching and priming are combined into a single step. One obvious advantage of using self-etch primer is lesser chairside time. Similarly, various commercially available laser systems create micro-irregularities on the enamel surface with no smear layer and hence also reduce procedural errors and saves chairside time.

The introduction of lasers has also revolutionized the bonding procedure. Laser etching has been reported to inhibit caries. It has been suggested that laser etching creates remineralization microspaces that trap free ions and thus produce a surface which is acid resistant and hence less susceptible to caries. Because of this property, laser etching holds a lot of promise as an alternative to acid etching procedure.
There has been a lot of study in the past two decades regarding the most acceptable bonding method. However, there has been no consensus regarding the bond strength achieved with various techniques and the result to date has been controversial. This study will evaluate the shear bond strength of brackets to enamel using acid, self-etch primer and laser.

**AIM**

To evaluate and compare the shear bond strength of bracket enamel bond following acid etching, use of self-etch primer and laser irradiation and to investigate the fracture mode of the bond.

**OBJECTIVES**

- To evaluate and compare the shear bond strength between the bracket and acid etched enamel, enamel treated with self-etch primer and laser irradiated enamel
- To analyze the fracture interface of the enamel bracket bond.

**MATERIALS AND METHODS**

Sixty noncarious human first premolars extracted for orthodontic treatment were used in the study (Fig. 1). Teeth were used within one month of extraction and those with any pathology were discarded. They were first disinfected in 10% formalin for 1 hour after which they were stored in distilled water until they were used. The water was changed weekly to prevent bacterial growth.

These 60 teeth were divided randomly into three groups of 20 each and were mounted in acrylic resin blocks so that at least 2 mm of buccal enamel was exposed. Color coding was done in a manner wherein 20 teeth were mounted in clear acrylic resin, 20 in blue and 20 in pink (Figs 2A to C). The buccal enamel surfaces were pumiced, washed and dried. According to the mode of enamel pretreatment, groups were formed:

1. **Group A**: Enamel etching with 37% phosphoric acid (clear acrylic).
2. **Group B**: Enamel treatment using self-etch primer (blue acrylic)
3. **Group C**: Enamel etching using Er:YAG laser (pink acrylic).

**Bonding Procedure using Conventional Acid Etching**

The labial surfaces of the group A samples were prepared by applying 37% phosphoric acid gel for 15 seconds following which the teeth were thoroughly washed with water and then...
air dried using moisture free air spray. The etched enamel showed a dull, frosty appearance. A thin coat of bonding agent (Transbond) was then applied onto the etched surface using the applicator tip following the manufacturer’s instructions. After this, the stainless steel brackets (Premolar brackets 0.022 inch slot from Gemini with mesh bracket base surface area as 9.806 square mm) were bonded. After the application of the bonding material (Transbond XT, 3M Unitek), the bracket was placed on the tooth surface, adjusted to its final position and then pressed firmly with a pressure of 300 gm with a dynamometer. The excess adhesive was removed from the periphery of the bracket base. Each side of the tooth (mesial, distal, occlusal and gingival) was light cured for 10 seconds, for a total of 40 seconds for each tooth.

**Bonding Procedure using Self-Etch Primer**

The labial surfaces of the group B samples were prepared using a self-etch primer (Adper Easy One, 3M ESPE) according to the manufacturer’s instructions. The agent was applied on the tooth using an applicator tip for 20 seconds, and then air thinned for 5 seconds until the film no longer moved, indicating complete vaporization of the solvent after which it was light cured for 10 seconds. After this, the stainless steel brackets were similarly bonded using Transbond XT.

**Bonding Procedure using Laser Irradiation**

Erbium: YAG laser with a wavelength of 2940 nm (Fotona Fidelis III plus) was used for irradiation using 2 Watt power with 100 mJ energy output and 20 Hz of frequency. The water and air settings were kept at 6 each as shown in Figure 3. The tip of the laser was directed perpendicular to the tooth surface to be etched at a distance of 1 mm and etched for 15 seconds as shown in Figure 4. The bonding agent (Transbond) was then similarly applied on the tooth followed by bracket bonding.

Following this, all the samples were stored in distilled water at room temperature for 24 hours.

**Shear Bond Strength Testing**

Shear bond strength test was accomplished by using a chisel edge, mounted on the crosshead of Universal Testing Machine. The loading head of the machine was subjected along the long axis of the tooth at the bracket tooth interface at a crosshead speed of 5 mm per minute as shown in Figure 5. The debonding force was recorded for each specimen in Newtons and then converted to Megapascals. This shear bond strength in Megapascals was calculated by dividing the force in Newtons by the bracket base area.

**Determination of the ARI Score**

After debonding, the teeth were examined under 10X magnification with a stereomicroscope to evaluate the amount of resin remaining on the tooth. The ARI or the Adhesive Remnant Index was used to describe the quantity of resin remaining on the tooth surfaces. The ARI score ranges from 0 to 3.9

- 0—no adhesive remaining on the tooth
- 1—less than half the bonding site covered with adhesive
- 2—more than half the bonding site covered with adhesive
- 3—the entire site covered with adhesive

**Statistical Analysis**

Descriptive statistics including mean, standard deviations, and minimum and maximum values were calculated for each group. Comparisons of shear bond strengths of different surface treatments were performed using ANOVA test (multiple comparisons, Tukey’s correction). Comparison of the ARI scores was done using Chi-square test.

**RESULTS**

**Shear Bond Strength**

Descriptive statistics and results of multiple comparisons are shown in Table 1 and Figure 6. The acid etched group (group A)
yielded the highest mean debonding force (13.34 Mpa) followed by self-etch group (12.15 Mpa) and then laser etch group (12.10 Mpa). When the acid etch and self-etch groups were compared, the p-value was 0.622 indicating that there was no significant difference in the bond strength between the groups. Similarly, it was found that there was no significant difference in the bond strength between the acid etch group and the laser etch group (p = 0.601) and between self-etch group and the laser etch group (p = 0.989).

**Residual Adhesive**

Table 2 and Figure 7 show the frequency of ARI scores for each etching group. On comparison, it was found that the adhesive left on the enamel surface after debonding was significantly higher in the acid etched group than the self-etch group (p = 0.009). There was no significant difference in the ARI scores between the other two groups with p = 0.154 for acid vs laser etch group and p = 0.082 for the self-etch vs laser etch group.

**DISCUSSION**

The direct bonding of orthodontic brackets has revolutionized and improved the clinical practice of orthodontics. However, there is a need to further improve the bonding procedure to save time and to minimize enamel loss without jeopardizing the ability to maintain clinically useful bond strength. Also, the orthodontic bond strength must satisfy two pronged requirements: It must be sufficient to retain the brackets but low enough to allow easy cleanup of adhesives when the brackets are removed. Traditionally, the use of acid etchants followed by a primer has been an essential part of the bonding procedure of composite adhesives to achieve good wetting and penetration of the sealant into the enamel surface. The early acidic primers were selectively compatible with certain adhesives and as a result either produced significantly lower...
bond strength or needed more working time.10 With the advancements in its formulations, the new self-etch primers provide clinically acceptable shear bond strengths.11

Another most important factor to be considered while choosing an appropriate method for enamel conditioning is its ability to inhibit caries. White spot lesions have been a regular finding in cases where conventional acid etching was used. Hence, laser induced caries resistance is gaining a lot of importance in orthodontics.8 The inhibition of mineral dissolution may be partially ascribed to the decomposed organic matrix. The decomposed organic matrix may block the ion diffusion channels and retard both the permeation of external acid solution and the dissolution of mineral.8

The first commercially available lasers, such as carbon dioxide and neodymium-doped:yttrium-aluminum-garnet, were suitable only for soft tissue treatments, especially in periodontics.12,13 The main disadvantage for application on dental hard tissues was the thermal side effects. It was also found that overall laser bonding took considerably longer, was less reliable in terms of bond strength, and produced more discomfort than conventional acid etching as reported by Dai P Roberts-Harry.14 There are some other contradicting findings about the use of lasers for enamel etching. Although some researchers15,16 agree that laser etching is not suitable for etching enamel, others17,19 reported that laser irradiation can be used to etch tooth enamel. In our opinion, the contrary findings were due to the different outputs and experimental designs of the studies.

With the use of hard tissue lasers like Erbium-doped:yttrium-aluminum-garnet systems, it is possible to ablate dental hard tissues like enamel and dentin without thermal side effects.8,19

The ability of Er:YAG laser to effectively ablate dental hard tissues is ascribed to its 2940 nm wavelength emission, which is coincident with the main absorption band of water and hydroxyapatite of enamel. The incident radiation is highly absorbed by water molecules in the dental hard structures, causing sudden heating and water evaporation. The resulting high-stream pressure leads to the occurrence of successive micro explosions with ejection of tissue particles, which are characteristic of the ablation process and determine the micro crater like appearance of lased surfaces. The ablation of tooth structure is achieved, via a thermomechanical interaction and, since the tissue is not completely vaporised, but only disintegrated into fragments, the majority of incident radiation is consumed in the ablation process, leaving very little residual energy for adverse thermal interactions with the pulp tissue and surrounding soft and/or hard structures.8,20

Moreover, Er:YAG laser etching is painless and does not involve either vibration or heat, and the easy handling of the apparatus makes this treatment highly attractive for routine clinical use.15 Also, this laser can be used in wet conditions and the water-cooled system does not cause any untoward thermal effects on the tooth pulp. Also, the clinician has more control of the area to be etched with the laser system. Although gel acids are more stable than liquid acids, there is always a shift of acid on the enamel surface.

The present study evaluated the use of Erbium-YAG laser etching as compared with the conventional 37% phosphoric acid etching procedure and a self-etch primer (Adper Easy One, 3M ESPE). The evaluation and comparison of the bond strengths revealed that though the bond strength achieved with laser etching (Mean-12.10) and the use of self-etching primers (Mean-12.15) were slightly lower than those achieved with acid etching (Mean-13.34), there was no significant difference among the three. This finding agreed with a recent study done by Ozer et al in 2008.13

The results show that all the three procedures produced clinically acceptable bond strengths. But this was an in vitro study and the results may vary when the procedures are actually done on the patients. Also, laser etching leaves the tooth with a rough surface, so the time saved with laser etching might be spent performing additional clinical work after debonding in restoring the tooth surface. Further investigation to define a standardized, optimal etching procedure with the Er:YAG laser system and to evaluate enamel structure after debonding is suggested.

CONCLUSIONS

- The shear bond strength of all the three groups was clinically acceptable.
- There was no significant difference in the bond strength obtained with 37% phosphoric acid etch group, self-etch primer group and the Er:YAG laser irradiated group.
- More adhesive was left on enamel treated with acid and laser etching as compared to self-etch primer treated enamel.

REFERENCES