

Effect of Er: YAG Laser on Shear Bond Strength of Composite to Enamel and Dentin of Primary Teeth

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Abstract

Objectives: Bond strength of composite resin to enamel and dentin of primary teeth is lower than that to permanent teeth. New methods such as laser application have been recently introduced for tooth preparation. The purpose of this study was to evaluate the effect of tooth preparation with bur and Er: YAG laser on shear bond strength of composite to enamel and dentin of primary teeth.

Materials and Methods: Seventy-five primary molar teeth were collected and 150 specimens were obtained by mesiodistal sectioning of each tooth. In each of the enamel and dentin groups, the teeth were randomly assigned to three subgroups with the following preparations: bur preparation + etching (37% H₃PO₄), laser preparation + etching, and laser preparation without etching. Single Bond adhesive and Z250 composite were applied to all samples. After thermocycling, the shear bond strength testing was performed using an Instron testing machine. Data were analysed using SPSS-17 and two-way ANOVA.

Results: The bond strength of enamel specimens was significantly higher than that of dentin specimens, except for the laser-non-etched groups. The enamel and dentin laser-non-etched groups had no significant difference in bond strength. In both enamel and dentin groups, bur preparation + etching yielded the highest bond strength, followed by laser preparation + etching, and the laser preparation without etching yielded the lowest bond strength (P < 0.001).

Conclusion: In both enamel and dentin groups, laser preparation caused lower shear bond strength compared to bur preparation.

Keywords: Lasers, Solid-State; Shear Strength; Composite Resins; Tooth, Deciduous

Journal of Dentistry, Tehran University of Medical Sciences, Tehran, Iran (2015; Vol. 12, No. 3)

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Received: 5 August 2014
Accepted: 12 December 2014

INTRODUCTION

Despite the increasing use of composites due to more conservative cavity preparation and superior esthetics, their bond strength to dentin is still concerning and compromises their

longevity [1,2]. This is particularly problematic in deciduous teeth since the bond strength of composite to deciduous teeth is less than to permanent teeth due to their inherent morphological and physiological differences,

such as thinner enamel and dentin, smaller diameter of dentinal tubules, lower density and lower mineral content than permanent teeth [1,3,4].

In addition, the composite bond strength to dentin is less than to enamel mainly due to the heterogeneous nature of dentin composed of materials with high surface energy (hydroxyapatite) and low surface energy (collagen), and also the higher water content of dentin compared to enamel and the hydrophobic nature of this restorative material. Polymerization shrinkage causes cracks at the tooth-restoration interface increasing the risk of microleakage and secondary caries [1,5]. These issues have led to attempts to achieve a stronger bond.

Several factors can affect the bond strength of composite to teeth, and tooth preparation is one of them. Tooth preparation methods affect dentin morphology, its chemical composition and the smear layer produced [6].

Mentionable disadvantages of conventional bur cavity preparation include its invasiveness, damage to adjacent teeth and formation of smear layer comprising bond strength [7,8]. Laser irradiation is a recently introduced method of tooth preparation. Er: YAG laser at a wavelength of 2.94 microns was first approved by FDA in 1997 and was made available in the market. This laser has the ability to cut hard dental tissue and enables conservative cavity preparation without thermal damage to the pulp. It is also used for many soft tissue treatments [9]. This laser can be used to prevent caries and simulate the effects of etching. It is also used for soft tissue treatments, gingival excision over unerupted teeth for orthodontic treatment, excision of fibroma, frenectomy, treatment of aphthous ulcers, pulp capping, pulpotomy, gingivectomy and gingivoplasty [10,11].

Some benefits of laser in dentistry are as follows: reducing the need for local anesthetic injections and higher patient comfort, no more pressure, vibration and noise of the hand piece,

more conservative cavity preparation, antimicrobial effects and minimal pulpal temperature changes. The first three benefits are important for behavioral control of children in pediatric dentistry [12].

Some researchers have claimed that laser treatment can increase the bond strength of composite resin to teeth because of creating a porous and rough surface by removing the smear layer and changing the inorganic compounds in tooth structure [13]. However, there is still controversy about the efficacy of laser for an optimal bond between tooth and composite. Some studies have shown that erbium laser is similar or even superior to conventional hand piece and bur technique [3,14,15]. However, some others have reported opposite results, reporting inefficacy of laser preparation to increase the bond strength between tooth and composite and superiority of the conventional tooth preparation methods [13-20]. Considering the gap of information in this regard in primary teeth, the aim of this study was to assess the effect of Er: YAG laser preparation on shear bond strength of primary enamel and dentin to composite.

MATERIALS AND METHODS

In this in vitro study, 75 extracted primary first and second molars with intact buccal and lingual surfaces were used. The collected samples were stored in normal saline solution. The collected teeth were washed and immersed in 0.5% chloramine-T solution for one week. Each tooth was cut at 2 mm below the cemento-enamel junction and mesiodistally sectioned into buccal and lingual portions using a diamond disk (D & Z, Berlin, Germany). A total number of 150 samples were obtained. All samples were mounted in equal size molds filled with auto-polymerizing acrylic resin (Pattern resin, GC, Tokyo, Japan).

In each of the enamel and dentin groups, the teeth were randomly assigned to three subgroups. Enamel subgroups were coded as 1, 2 and 3 and dentin subgroups were coded as 4,

5 and 6 and received the following surface treatments:

The enamel groups:

Group 1: Bur preparation + 37% phosphoric acid etching

Group 2: Laser preparation + 37% phosphoric acid etching

Group 3: Laser preparation without etching

The dentin groups:

Group 4: Bur preparation + 37% phosphoric acid etching

Group 5: Laser preparation + 37% phosphoric acid etching

Group 6: Laser preparation without etching

The laser used in this study was Er: YAG laser (Fidelis Plus III, Fotona, Ljubljana, Slovenia) with a wavelength of 2.94 microns. In order to cut enamel and dentin, energy of 300 mJ and frequency of 10 Hz and 200 mJ and 10 Hz were used, respectively along with water cooling (7 mL/minute). In the non-contact mode, the head of the handpiece was placed in a handmade acrylic device (Putty, Speedex, ApadanaTak Co., Tehran, Iran) that maintained the tip of the handpiece at 17 mm distance from the surface with the beam perpendicular to the surface.

In the enamel samples, prophylaxis was done using pumice paste and 0.5 mm of enamel was removed using a fissure bur (group 1) and laser (groups 2 and 3).

For dentin preparation, after prophylaxis, the buccal and lingual enamel surfaces were removed by 008 fissure bur (Tyzkavan, Tehran, Iran) and high speed handpiece (NSK Ltd., Tokyo, Japan) under water coolant to expose the dentin surface. In group 4, 0.5 mm of dentin was removed with bur and in groups 5 and 6, 0.5 mm of dentin was removed by laser.

Composite was applied to the samples using Nelaton catheters with an internal diameter of 2mm and length of 2 mm.

Enamel groups (1 and 2) were then etched with 37% phosphoric acid (Fine Etch 37, Spident Co., Ltd., Incheon, South Korea) for 20 seconds and washed and dried for 10 seconds. Single Bond 2 (Adper, 3M ESPE, St. Paul, MN, USA)

was used for bonding of all dentin groups. After curing for 20 seconds, A3 shade of Z250 composite (3M ESPE, St. Paul, MN, USA) was applied via a plastic tube with an internal diameter of 2 mm and a height of 2 mm and light cured for 40 seconds by a light curing unit (Arialux, Apadana Tak, Tehran, Iran) with an intensity of 500 mW/cm². In groups 4 and 5 (samples of dentin), dentin was conditioned with phosphoric acid for 10 seconds. In groups 3 and 6, the samples were not etched, and the following stages were the same as in groups 1 and 2 (except the dentin was not completely dried as enamel and remained slightly wet).

In all the samples, the plastic tube was cut with a scalpel after curing. Samples were immersed in saline at 37° C for one day and were then thermocycled (Vafai, Tehran, Iran) (1000 cycles between 5 and 55° C with a dwell time of 30 seconds and a transfer time of 15 seconds).

To determine the shear bond strength of composite bonded to enamel and dentin surfaces, an Instron testing machine (Dartec Ltd., Sturbridge, England) with a crosshead speed of 0.5 mm/min was used parallel with the tooth surface at the tooth-composite interface. The shear bond strength (MPa) was measured as the force applied to the composite at the moment of failure divided by the specimen's surface area. Data were analysed by two-way and one-way ANOVA. Multiple comparisons were made by Tukey's HSD test. SPSS 17 for windows (Chicago, IL, USA) was used for data analysis.

RESULTS

In this study, 150 sections were made from 75 primary molars and randomly assigned into three enamel groups and three dentin groups, as described later.

Before shear bond strength testing, two teeth were lost in group 3, and four teeth in group 6; thus, we performed the shear bond strength test on 144 teeth. The Shapiro-Wilk test was used to assess the normal distribution of variables.

P-value > 0.05 in all groups revealed that the variables had normal distribution.

The results were analyzed using two-way ANOVA. Significant results suggested possible presence of an interaction effect (P=0.001). Thus, one-way ANOVA was used for the next comparisons (Table 1). The results showed that the three enamel groups had significantly different shear bond strength values (P< 0.001).

The highest shear bond strength value was observed in group 1 and the lowest in group 3. Similar to enamel groups, among dentin groups, group 4 had the highest shear bond strength while group 6 showed the lowest shear bond strength value.

Significant differences were noted in shear bond strength among groups (P<0.05), except for groups 3 and 6. As we expected, the shear bond strength in the enamel groups was higher than in dentin groups but no significant difference was noted in this regard in groups 3 and 6 (P>0.05).

DISCUSSION

According to previous studies, the primary teeth have smaller tubular diameters, less peritubular dentin and thicker hybrid layer than permanent teeth [1,3,4,20]. Thus, enamel etching can provide a more porous surface compared to dentin etching.

Composite-tooth bond must be capable of withstanding functional forces; thus, the bond strength must be somehow enhanced. Dentin-composite bond in primary teeth is not highly reliable because primary dentin is naturally different from permanent dentin and yields lower bond strength compared to permanent teeth. In our study, the bond strength was greater in all enamel groups compared to dentin groups; which is probably due to greater mineralization of enamel than dentin. The Er: YAG laser was chosen for this study since it has minimal thermal effect on tooth during preparation in comparison to other lasers [16]. Also, its wavelength corresponds to the absorption peak of the hydroxyapatite crystals, collagen and water, which is important especially for dentin preparation [6]. As described earlier, no statistically significant difference was seen between laser without etching subgroups of dentin and enamel and the bond strength was low in both subgroups, which indicates that laser alone without acid etching does not provide optimal bond strength. Thus, if laser is to be used for tooth preparation, it must be necessarily accompanied by acid etching. Comparison of enamel subgroups with corresponding dentin subgroups revealed statistically significant differences except for laser without etching subgroups [subgroups 3 and 6].

Table 1. Shear bond strength values in different groups (post analysis with one-way ANOVA)

Group	Number of samples	Mean shear bond strength (MPa)	Standard deviation (SD)	Min	Max	P-value
Enamel:						
Bur + etching	25	18.17	2.91	14.46	25.12	<0.001
Laser + etching	25	14.13	1.70	1.08	17.22	
Laser without etching	23	4.89	1.10	3.08	7.12	
Dentin:						
Bur + etching	25	14.53	2.22	10.70	19.03	<0.001
Laser + etching	25	10.69	2.08	6.71	15.22	
Laser without etching	21	3.53	0.89	2.04	5.36	

Maximum bond strength values belonged to bur and etching preparation in dentin and enamel groups followed by laser and etching; laser without etching caused the lowest bond strength. Lower bond strength values in the laser groups are probably due to the pulsing nature of laser, irregular pattern of etching (creating a surface without efficient undercuts in spite of increased surface roughness, which makes the surface resistant to etching), obstruction of dentinal tubules due to laser irradiation and subsequently lower resin diffusion into them [16,21,22]. It is believed that laser irradiation makes the surface resistant to acid because it increases the calcium-phosphorous ratio and decreases carbonate-phosphorous ratio resulting in a more resistant structure to acid and decay [23].

Ceballo et al, also stated that laser decreased the bond strength because dentin ablation fuses collagen fibrils and decreases interfibrillar spaces resulting in subsequent reduction in resin diffusion into inter-tubular spaces and consequently less inter-tubular retention [20]. The results of our study were in accord with those by Jaber Ansari et al, [13] Koliniotou-Koumpia et al, [19] Brulat et al, [18] Ceballo et al, [20] and Dunn et al [16].

In a study by Jaber Ansari et al, the highest bond strength in enamel samples was seen in the acid-etched and bur group, while the lowest was seen in the group that bur, laser, and acid etching were used in combination. Also, in dentin samples, the surfaces prepared by bur showed significantly higher bond strength levels than those prepared by laser. They explained that this reduction in bond strength in the laser group was due to two reasons. First, although surfaces prepared by laser were mostly rough, they had irregular porosities and did not follow a uniform pattern. The second reason was reported to be the thermal denaturation of collagen fibers. This bond strength reduction was also reported in enamel samples, which have approximately 0.5% collagen. They stated that the conventional

method of cavity preparation and etching would yield the best results and if laser is used, it must be followed by phosphoric acid etching to improve bond strength [13]. It should be noted that the type of laser (Er, Cr: YSGG), the type of bond (microshear) and teeth (permanent molars) used in their study were different from those in the current study. Using electron microscopy, Dunn et al. noted the lack of resin penetration (resin tags) in samples prepared by erbium laser and reported that fusion of collagen fibrils was the main explanation for the decrease in bond strength in this group [16]. In studies conducted by Armengol et al, [24] Lin et al, [25] and Lessa et al, [26] no significant difference was found between the laser (Er, Cr: YSGG) and conventional rotary cavity preparation methods. They said that the laser preparation method could be as effective as the conventional method (bur preparation). Bertrand et al, also obtained the same results with Er: YAG laser [27].

Lessa et al. evaluated the effect of distance of laser from the surface (12,14,16 and 17 mm) on bond strength of composite to enamel of permanent canines. The laser parameters were 80 mJ and 2 Hz. They found no significant difference among the experimental and control (no laser irradiation) groups [26]. According to a study by Koliniotou-Koumpia et al, in their Total Etch groups, the bond strength in laser preparation subgroup was more than that in bur subgroup; but in the self etch groups, no significant difference was found between the two methods [19].

The results of our study were also in contrast to the results of studies by Mahmodian et al, [17] Wanderley et al, [14] and Gurgan et al [15]. Wanderley et al. carried out a study on the effect of different laser energies on shear bond strength of composite to enamel of primary teeth. They stated that erbium laser could be a suitable alternative for enamel preparation before the application of adhesive agent [14]. The difference between their results and ours may be due to differences in the type of teeth

studied (deciduous canines) and energy of laser (60, 80 and 100 mJ) used.

Zhang et al. stated that 200 and 300 mJ and 10 Hz were suitable parameters for Er: YAG laser treatment of primary teeth, and higher parameters can damage the pulp [28]. Osman et al, also found the highest bond strength in 200 mJ, rather than 300 and 400 mJ power in permanent teeth. In their study, laser energies higher than 200 mJ obstructed the dentinal tubule openings and decreased resin penetration [6]. do Amaral et al. found that different methodology of studies including the duration of water storage and the thermocycling protocol can affect the bond strength in both the Er: YAG laser and bur groups; but the bond strength in laser groups was more affected by the study method than that in bur groups. Thus, they concluded that laser treatment was more technique sensitive [29]. In general, in laser treatment, a variety of factors may affect the bond of resin to tooth structure such as the type of laser wavelength, pulse duration, exposure time, laser power, amount of water and air steam created and the distance from the tooth surface to laser tip [30]. Also, type of tooth (deciduous or permanent), type of tissue (enamel or dentin), healthy or carious state of tooth surface, type of dentin (superficial or deep) and type of adhesive agent can all affect the results. Further studies with different laser types and laser parameters are recommended. Also, the mode of failure (adhesive or cohesive) and its frequency must be evaluated in future studies.

CONCLUSION

According to the results of this study, laser preparation reduced the shear bond strength of composite to primary teeth compared to rotary bur preparation.

ACKNOWLEDGMENTS

The authors wish to thank the Vice-Chancellery of Shahid Sadoughi University of Medical Sciences, Yazd, Iran, for supporting this

research. This article is based on the thesis by Dr. M. Kabudan.

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