Effect of Er:YAG Laser on Tensile Bond Strength of Sealants in Primary Teeth

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ABSTRACT

Purpose: The purpose of this in vitro study was to evaluate the tensile bond strength of sealants in primary molars after the surface pretreatment with an Er:YAG laser.
Methods: Thirty primary molars were selected, and their roots were removed. Crowns were embedded in polyester resin and enamel surfaces were flattened. The bonding site was delimited, and samples were randomly assigned to 3 groups according to the surface pretreatment: (1) group 1=37% phosphoric acid; (2) group 2=Er:YAG laser; and (3) group 3=Er:YAG laser+37% phosphoric acid. Specimens were adapted to a metallic device, a split matrix was positioned on the surface of each sample and the FluroShield sealant was inserted into the matrix with a Centrix injector". Samples were stored for 48 hours, thermocycled, and subjected to a bond strength test (50 Kgf at 0.5 mm/minute).
Results: Means in MPa (±SD) were: (1) group 1=10.80±3.28; (2) group 2=4.17±2.31; and (3) group 3=12.85±2.14. Analysis of variance and Tukey test revealed a statistical similarity between groups 1 (37% phosphoric acid) and 3 (Er:YAG laser+37% phosphoric acid). Treatment with the Er:YAG laser solely produced the lowest average and was statistically different from the other groups.
Conclusion: Conditioning with the Er:YAG laser may influence the sealant's bond strength; nevertheless, the subsequent application of acid is mandatory. (J Dent Child 2007;74:104-8)

KEYWORDS: ER, LASERS, TOOTH BONDING, PIT AND FISSURE, SEALANTS, TOOTH, PRIMARY

Pit and fissure sealants act as a mechanical barrier in the prevention of occlusal caries lesions.[1-3] The adequate retention of the material to dental surfaces is fundamental during the preventive treatment.[4,5] The clinical impact on caries lesions reduction depends on the sealant's resistance to wear as well as the capacity of the sealing enamel interface, which hinders microleakage.[7] Studies have been conducted to verify the adhesion of sealants to dental substrates.[1-4,6]

Since the surface texture of the prepared tissue directly affects the clinical performance of dental restorations,[4-5] new technologies have been introduced to improve the adhesion and adaptation of restorative materials to dental structure.[8-12] Among these innovative devices, the Er:YAG laser has been studied as an alternative technique to conventional conditioning methods,[1,6,10,13-16] creating a microretaining pattern that can help retention of restorative materials.[14,15]

Wanderley et al,[15] using the Er:YAG laser followed by the acid conditioning, observed superficial irregularities, fissures, and some fused areas in deciduous enamel. In a microleakage study, Borsatto et al[6] verified that Er:YAG laser irradiation did not eliminate the need for acid etching enamel prior to the pit and fissure sealant since the lased-samples did not yield better marginal sealing at the primary enamel/sealant interface when compared to conventional acid etching.

The Er:YAG laser removes enamel via a thermomechanical ablation process. The incident energy is absorbed by water molecules present in dental crystalline structures and organic components, causing sudden heating and water vaporization.[17-19] The resulting high-stream pressure within

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the irradiated tissue leads to successive microexplosions that result in the ejection of microscopic particles.[18,19] This process successfully occurs due to the Er:YAG laser wavelength of 2.94μm that is close to the absorption spectrum of water and OH- groups in hydroxyapatite.[18,20] 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.[17-21]

Although some researchers have reported the effectiveness of Er:YAG laser irradiation on the surface pretreatment of permanent teeth,[14,15] controversial results have been shown due probably to the diversity of parameters and methodologies utilized.[10,16,22] Also, it has been reported that primary and permanent tooth enamel present distinct characteristics in chemical composition.[23,24] The fluoride concentration and the content of calcium phosphate are lower in primary enamel than in permanent enamel, resulting in a lower degree of mineralization in primary enamel[23] and, thereby, greater susceptibility to dissolution.[24]

Concerning the lack of published research analyzing Er:YAG laser as a surface conditioning in primary teeth, the aim of the present study was to investigate in vitro the tensile bond strength of sealants in primary molars after surface pretreatment with the Er:YAG laser.

METHODS

Thirty sound human primary molars, extracted within a 6-month period and stored in 0.4% sodium azide solution at 4°C, were selected and cleaned with a scaler and pumice/water slurry in dental prophylactic cups. Roots were sectioned 2 mm below the cementoenamel junction.

Each tooth was rinsed and embedded in polyester resin (Milflex Indústira Química, São Bernardo do Campo, São Paulo, Brazil) surrounded by a polyvinyl chloride (PVC) cylinder (2.1 cm diameter and 1.1 cm high). After resin polymerization, the polyvinyl chloride cylinder was removed and the enamel vestibular face was grounded with no. 180- to 400-grit silicon carbide (SiC) paper under water cooling in a polishing machine (Struers A/S, Copenhagen, Denmark) to flatten the surface. Complementary grinding was accomplished with no. 600-grit SiC paper for 20s to produce a standardized smear layer. To demarcate the bonding site, a piece of insulating tape with a 3-mm-diameter central hole, made by means of a modified Ainsworth rubber-dam punch (Duflex S.S. White Ltda, Rio de Janeiro, Brazil), was attached to the specimen surface. This procedure aimed to define a fixed test surface and ensure that the sealant cone would be precisely adhered to the treated enamel surface.

The specimens were randomly assigned to 3 groups of equal size (N=10), according to the surface pretreatment:

- group 1: 37% phosphoric acid (etching gel, 3M ESPE, St Paul, Minn);
- group 2: Er:YAG laser (Kavo Key Laser 2, Kavo, Biberach, Germany); and
- group 3: Er:YAG laser+37% phosphoric acid.

The phosphoric acid was applied for 30 seconds, followed by rinsing for 20 seconds and gentle air drying. In the laser conditioning group, the Er:YAG laser was utilized in defocused mode under a 1.5 mL/minute water spray for 30 seconds, at 80 mJ energy output, 2Hz frequency, and a focal distance of 17 mm.[16] The laser beam spot size was 0.63 mm, and a handpiece (2051) with a removable tip attached to a flexible fiber delivery system was used.

After the surface treatment, each specimen was individually fixed in a metallic clamping device (developed by Houston Biomaterial Research Center), and a split Teflon matrix was positioned on the dental surface—resulting in an inverted conical cavity 4-mm high, with a larger diameter of 6 mm, with the smaller diameter matching the delimited bonding area (3 mm). The FluroShield sealant (Caulk-Dentsply, Milford, Del) was inserted into the Teflon matrix with a Centrix injector (Shelton, Conn) to prevent blister formation. The material was polymerized for 20 seconds using a light-curing unit (XL 3000, 3M Dental Products, St. Paul, Minn) with an output of 450 mW/cm^2 and checked with a radiometer (NewDent Equipamentos, Ribeirão Preto, São Paulo, Brazil) every 3 samples. The specimen was removed from the champing device and each part of the matrix was carefully separated, leaving an inverted resin sealant cone adhered to the enamel surface. A complementary polymerization for 20 seconds was accomplished to ensure that the specimen was adequately polymerized.

The specimens were submitted to a thermocycling regimen (Ética Equipamentos Científicos SA, São Paulo, Brazil) of 400 cycles with water baths of 5°C and 55°C. Dwell time was 30 seconds, with a 3-second transfer time between baths. After storage in distilled water at 37°C for 24 hours, samples were placed into an apparatus with an internal shape that corresponds to the specimens' shape. This configuration was loaded in a tension bond using a Universal Testing Machine (MEM-2000, EMIC, São José dos Pinhais, Paraná, Brazil), at a 0.5-mm/minute cross-head speed and a 50 kgf load cell until fracture. Shear bond strength values were registered in Kgf and transformed into MPa. Averages and standard deviations were calculated, and the data were analyzed by analysis of variance (ANOVA). Multiple comparisons were done using Tukey test at a 0.05 significance level.

Fracture types at the sealant/enamel interface were analyzed under a stereoscopic microscope at X40 magnification (Nikon Inc Instrument Group, Melville, NY), and displayed in percent. Failure was considered:

1. adhesive if it occurred at the enamel/adhesive interface;
2. cohesive if it occurred in the material on the substrate; and
3. mixed if it involved both the interface and the material. Bond failure sites were not statistically analyzed.

RESULTS

The mean values obtained and their standard deviations for each tested group are presented in Table 1, and the ANOVA analysis is shown in Table 2.

In general, data analysis showed no statistically significant differences (P>.05) between groups 1 (37% phosphoric acid) and 3 (Er:YAG laser+37% phosphoric acid). These groups, however, were statistically different (P<.05) from group 2 (Er:YAG laser). Surface conditioning with the Er:YAG laser+37% phosphoric acid presented the highest bond strength value. Treatment solely with the Er:YAG laser produced the lowest average.

The analysis of the bonding sites after tensile strength test revealed that, in groups conditioned with phosphoric acid, the predominating type of fracture was cohesive (80%). Nevertheless, the groups treated by Er:YAG laser combined with phosphoric acid exhibited a higher percentage of adhesive fracture (80%). Superficial pretreatment with Er:YAG solely presented 70% of adhesive and 30% of mixed fractures.

Table 1. Means and Standard Deviations of Each Group's Bond Strength Values

Enamel superficial pretreatment	Mean±(SD)*
1). 37% phosphoric acid	10.80±3.28a
2). Er:YAG laser + 37% phosphoric acid	12.85±2.14a
3). Er:YAG laser	4.17±2.31b

** Same letter indicates statistical similarity (P<.05); Tukey critical value=3.51.*

Table 2. One-way Analysis of Variance With Data Obtained

Source trm	Sum of squares	DF	Mean square	F-ratio	Probability level (=0.05)
Between groups	412.2865	2	206.1433	29.93	0.000000*
Total (adjusted)	**598.2691**	**29**			

** Term significant at alpha=0.05.*

DISCUSSION

In the present study, it was noticed that the application of the Er:YAG laser followed by phosphoric acid promoted the highest bong strength values, statistically similar to the surface treatment with the phosphoric acid solely. This could probably be due to the fact that the laser irradiation—combined with the acid application—created morphological alterations on enamel surfaces of primary teeth. The laser device promotes a rough aspect on the dental surface, with irregularities and fissures[8,9,13,25] that can facilitate the mechanical interlocking of restorative materials.[14,15] The phosphoric acid application after laser treatment is suitable for adhesion, since it provides a uniform microretentive pattern due to the selective dissolution and removal of hydroxyapatite crystals.[4,5,26] Together, these features could contribute to the deep penetration of the sealant into the microporosity network, thus forming tags upon light curing.

The application of the Er:YAG laser solely on the enamel surface resulted in the lowest bond strength values. Similar results were reported by other studies using permanent teeth.[10,16,22] On this respect, Sasaki et al[9] verified that the topographical alterations caused by the Er:YAG without subsequent acid conditioning extended to 30µm. Conversely, the phosphoric acid creates microporosities on dental surfaces that extended to 50 µm, depending on the acid concentration and application time.[4,26] Er:YAG laser irradiation on enamel surfaces does not promote a well-defined standard conditioning,[1,6,16,27] as provided by the phosphoric acid application.[5,24] Besides, treating the surface exclusively by Er:YAG laser may increase the enamel/sealant interface microleakage[1,6]—probably due to excessive fissuring on the subsurface.[22]

Another factor to be considered is that some chemical alterations occur in enamel after laser irradiation due to liquefaction of the crystals when the tooth is submitted to high temperatures[25,27] and rapid cooling of the dental tissues. This rapid cooling leads to an increase in the obliteration of enamel micropores[23] and is responsible for an increase in the hydroxyapatite crystal that obliterates enamel micropores.[25] The melted and resolidified enamel might contain products (-tricalcium phosphate or -tricalcium phosphate) of phase transformation that might reduce dental susceptibility to caries attack.[20,28] In this study, low parameter settings (80 mJ and 2 Hz for 30 seconds) were selected to avoid irreversible thermal side effects on the dental surface and pulp tissue.

Regarding the types of failure observed in the fractured specimens, a cohesive-failure pattern (into the material or the substrate) was predominantly observed in the nonlased group, indicating that the adhesive interface was preserved. In contrast, failure mode in the lased groups was mostly adhesive, which may be attributed to the fact that the Er:YAG laser beam does not provide a uniform, homogeneous etching pattern, concentrating stress on the enamel-sealant interface. Adhesive failure for lased-irradiated samples were also reported by Lee et al.[14]

The outcomes of the present research seem to corroborate the assumption that Er:YAG laser irradiation prior to enamel conventional conditioning did not increase the adhesion of sealant to the dental substrate. Due to the low bond strength values obtained in laser-treated group, it seems feasible to speculate that laser irradiation solely on the enamel surface was not clinically adequate for sealant retention. The phosphoric acid is still necessary after laser conditioning because the portions and structures of the laser-affected area would be dissolved by acid, creating an almost similar pattern to that of the acid-etched group.[14,22] Furthermore, the vast variety of current dental materials is a crucial feature to be considered. Depending on the recommended material and bonding protocol, a peculiar interaction pattern with the lased substrate should be expected.

The lack of published researches investigating the Er:YAG laser's effects on primary teeth, in addition to the different methodologies, hinders the settlement of reliable comparisons. There is too much yet to be learned about the ultimate effect of lasing on dental substrate before the use of laser devices becomes routine in dental practice.

CONCLUSION

Based on the findings of this research and within the limitations of an in vitro study, it may be concluded that conditioning enamel surfaces of primary teeth with the Er:YAG laser may influence the sealant's bond strength. Nevertheless, the subsequent application of phosphoric acid is mandatory.

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