Microleakage at Sealant/Enamel Interface of Primary Teeth: Effect of Er:YAG Laser Ablation of Pits and Fissures

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ABSTRACT

Purpose: The objective of this study was to assess microleakage at sealant/enamel interface after treatment of primary teeth occlusal surfaces with 3 etching techniques.
Methods: Thirty sound primary molars were randomly assigned to 3 groups (N=10): (1) group I=acid etching for 30 seconds; (2) group II=Er:YAG laser (120 mJ; 4 Hz) plus acid-etching; and (3) group III=Er:YAG laser (120 mJ; 4 Hz). Pits and fissures were sealed with a resin-based sealant (Fluroshield, Dentsply/Caulk). Teeth were isolated, thermocycled, immersed in a 0.2% rhodamine B solution for 24 hours, and serially sectioned. Cuts were analyzed for leakage using an optical microscope connected to a video camera. The images were digitized, and a specific software (Axion Vision) assessed microleakage quantitatively (millimeters). The sealant extension on buccal/lingual cusp heights was measured separately, and the percentage of dye penetration along enamel/sealant interface, in relation to the sealant extension, was calculated. Means of dye penetration were: (1) group I=2%(±3.75); (2) group II=2%(±3.38); and (3) group III=4%(±6.26). Data were submitted to ANOVA and Tukey test.
Results: A statistically significant difference ($P<.05$) was observed between the nonetched lased specimens (group III) and those in the other groups. No significant difference ($P>.05$) was found between the acid-etched and lased/acid-etched groups (I and II). Fissures prepared with Er:YAG laser alone showed the highest degree of microleakage. All specimens exhibted some degree of leakage.
Conclusions: Laser irradiation did not eliminate the need for acid etching enamel prior to the placement of a pit-and-fissure sealant. The ablation of pits and fissures with an Er:YAG laser device did not yield significantly better marginal sealing at primary enamel/sealant interface, compared to conventional acid etching. (*J Dent Child*. 2004;71:143-147)
KEYWORDS: ER:YAG LASER, MICROLEAKAGE, PIT AND FISSURE SEALANT

Pit and fissure sealants are considered an outstanding adjunct to oral health care strategies and fluoride therapy in decreasing occlusal caries onset and/or progression.[1,2] The sealing material acts as an effective mechanical obstacle to plaque retention, minimizing the harmful action of cariogenic microorganisms on enamel surfaces.[3,4] Nevertheless, the preventive benefits of such treatment rely directly upon the sealant's ability to thoroughly:

1. fill pits, fissures, and/or anatomical defects;
2. remain completely intact and bonded to enamel surfaces without marginal microleakage at resin/tooth interface and consequent development of a carious process underneath the sealant.[1,5-8]

The effect of laser irradiation on dental enamel and dentin, especially regarding microleakage and bonding of resin-based materials to tooth structure, has been a subject of increasing interest for dental research. Emitted at 2.94 μm, the erbium:yttrium-aluminium garnet (Er:YAG) laser has been

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considered a promising wavelength for multiple dental applications. Many investigations[9-19] have reported its ability to selectively remove carious lesions, prepare cavities, and modify dentin and enamel surfaces with the prospect of increasing bond strength. Due to its highly efficient absorption in both water and hydroxyapatite,[9,10] the Er:YAG laser has been claimed to ablate dental hard tissues effectively with minimal pulp injury and without causing severe thermal side effects, such as cracking, melting or charring, to the remaining tooth structure and/or surrounding tissues.[9,10,20-22]

Scanning electron microscopy (SEM) examinations of Er:YAG laser-irradiated permanent teeth enamel revealed scaly, rough zones with altered hydroxyapatite crystals.[23-25] The superficial microroughness of lased enamel surface derives from the microexplosive ablation process that characterizes the Er:YAG laser's thermomechanical irradiation.[9,10,23-25] Some authors[11,23,24,26-28] have shown that the surface topography of the lased permanent enamel exhibits a microroughened appearance similar to that obtained with conventional acid etching. They also have speculated that the conditioning of enamel surface with an Er:YAG laser device, either associated or not with acid etching, could result in bond strength similar to or higher than that achieved with acid etching alone. On the other hand, other studies[14,21-23,29] have found that, even though Er:YAG laser irradiation is able to alter dental substrate structure, the morphological changes observed on laser-ablated permanent enamel were not sufficient to yield an effective resin material bonding.

Concerning primary dentition,[30] Borges et al reported that Er:YAG laser-ablated primary enamel surfaces showed rough craters exhibiting a scaly, flaky pattern along the walls, in addition to gaps and partial vaporization of enamel prisms. Another SEM study[31] examined cavities prepared by the Er:YAG laser in primary teeth and reported that the enamel prisms exhibited a honeycomb-like appearance characteristic of the photomechanical ablation.

Whether Er:YAG laser ablation of occlusal pits and fissures prior to sealant application produces a highly microretentive surface advantageous to infiltration and mechanical entanglement of the resin-based sealant has been studied.[32,33] The highly microretentive surface produced is caused by the disorderedly arranged pattern of craters and grooves derived from laser etching. Little published data is available assessing the marginal sealing of cavities prepared by Er:YAG laser on primary dentition.[34,35] The literature is rare that investigates either the feasibility of placing pit-and-fissure sealants after laser preparation of enamel surface or the microleakage at fissure sealant/lased enamel interface on primary teeth.

This in vitro study assessed microleakage, at the sealant/enamel interface on primary molars, after treatment of occlusal pits and fissures with 3 different etching techniques: (1) conventional acid etching; (2) Er:YAG laser ablation plus acid etching; or (3) Er:YAG laser ablation alone.

METHODS

SPECIMEN PREPARATION

Sound human primary molars, extracted within a 6-month period, were cleaned and rinsed to remove residual debris from pits and fissures and examined under a ×20 magnifier to discard those with structural defects. Thirty teeth were selected for the study and stored in 0.9% saline solution with 0.4% sodium azide at 4°C. The apices were sealed with a light-cured resin composite, and the teeth were randomly assigned to 3 groups (N=10) corresponding to the surface treatments accomplished.

GROUP I

The occlusal surfaces for group I children were etched with a 37% phosphoric acid gel (Gel Etchant, Kerr Corporation, Orange, Calif) for 30 seconds, rinsed thoroughly with air/water spray for 20 seconds, and air dried for 5 seconds with an oil-free air stream to obtain a uniformly white, dull, chalk-like appearance.

GROUP II

The occlusal surfaces for group II children were irradiated with a very short pulsed Er:YAG laser device (Fidelis, Fotona Latin Med. Inc., Stuart, Fla) emitted at a 2.94-μm wavelength, with a pulse energy of 120 mJ and a repetition rate (frequency) of 4 Hz. The laser beam was delivered on noncontact, defocused mode, with a fine water mist at 5 mL/minute. The irradiation distance was standardized using a:

1. custom-designed apparatus consisting of a holder, which positioned the handpiece (no. 2051) so the laser beam could be delivered perpendicular to the occlusal surface, at a constant working distance of 17 mm from the target enamel surface;
2. semiadjustable base, in which the teeth were individually and firmly fixed with wax (Figure 1).

Two previously gauged operators manipulated the micrometer screws of the semiadjustable base so the tooth surface could

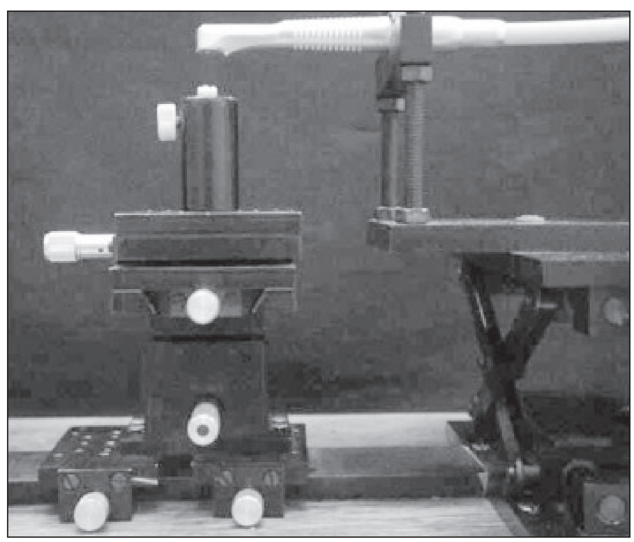

Figure 1. Custom-designed apparatus used to standardize the irradiation distance (lateral view). Note the laser equipment handpiece (no. 2051) positioned so the laser beam could be directed perpendicular to the occlusal surface—at a constant working distance of 17 mm from the target enamel surface—and the semiadjustable base in which the teeth were fixed with wax.

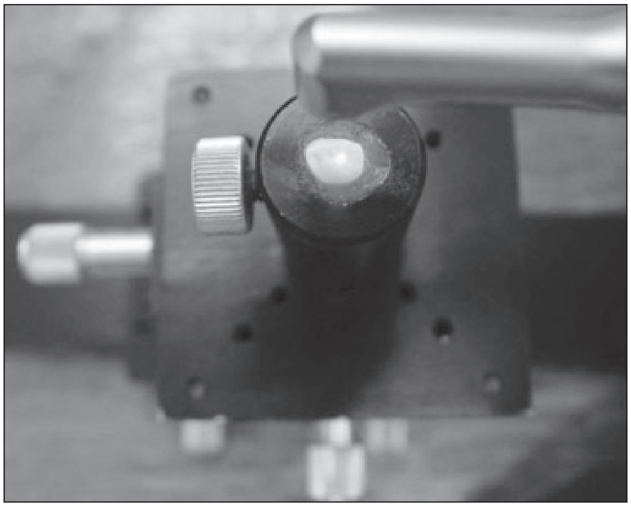

Figure 2. Close-up upper view of Er:YAG laser irradiation. The micrometer screws on the semiadjustable base were manipulated so the tooth could be alternately moved in right-to-left (mesiodistal) and forward-to-back (buccal-lingual) directions, thereby allowing the laser beam to provide a complete and more accurate ablation of pits and fissures.

be alternately moved in right-to-left (mesiodistal) and forward-to-back (buccal-lingual) directions. This allowed the laser beam to provide a complete and more accurate ablation of the occlusal pits and fissures (Figure 2). The length of irradiation was, on average, 40 seconds. After irradiation, teeth were rinsed and dried, and the laser-ablated occlusal surfaces were acid etched for 30 seconds, rinsed, and dried with compressed air.

GROUP III

The occlusal surfaces for group III children were treated solely with the Er:YAG laser device (not acid etched), following the aforementioned parameters and experimental conditions.

Afterwards, pits and fissures were sealed. For all groups, a uniform layer of a filled, resin-based, pit-and-fissure sealant (Fluroshield, Dentsply/Caulk, Milford, Del) was applied on treated surfaces from the central fissure to the cusp height to prevent air entrapment or voids and bubbles formation. The material was light cured for 20 seconds using a visible light-curing unit with a 450 mW/cm^2 output (XL 3000, 3M/ESPE, St Paul, Minn). Hardening and retention of all sealants were confirmed with the tip of an explorer.

ASSESSMENT OF MICROLEAKAGE

Teeth were subjected to a thermocycling regimen of 500 cycles between 5°C and 55°C waterbaths. Dwell time was 1 minute, with a 3-second transfer time between baths. In preparation for the dye penetration test, the specimens were:

1. dried superficially;
2. sealed entirely with epoxy resin and 2 coats of nail varnish—except for the occlusal surface and a 1-mm window around the enamel/sealant interface;
3. immersed in a 0.2% rhodamine B solution for 24 hours.

Then, the epoxy resin and nail varnish were removed with a sharp instrument, and the teeth were rinsed, dried, and embedded in chemically activated acrylic resin. After polymerization, the teeth/resin blocks were sectioned longitudinally in a buccolingual direction with a water-cooled diamond saw (Minitom, Struers A/S, Copenhagen, Denmark), which provided 4 to 51-mm thick cuts for each tooth. The sections were initially thinned in a polishing machine (Politriz, Struers A/S, Copenhagen, Denmark) with 320- to 600-grit silicon carbide paper and then manually smoothed with 1000- to 1200-grit SiC paper to obtain a flat, polished surface and a final thickness of approximately 0.25 mm.

The cuts were identified and fixed on microscopic slides. The sealant/enamel interfaces were assessed for leakage by viewing at ×25 magnification (Axiostar Plus Optical Microscope, Carl Zeizz Vision GmbH, München-Hallbergmoos, Germany) connected to a digital camera (Cyber-shot 3.3 MPEG Movie EX, model no. DSC-S75, Sony Corp, Japan). The images obtained were transmitted to a personal computer. After digitization, the images were analyzed using Axion Vision 3.1 software (Carl Zeizz Vision GmbH, München-Hallbergmoos, Germany), which performs a standardized assessment of the tracer agent's extent and allows a quantitative measurement of infiltration in millimeters.

Dye penetration along the resin/tooth interface was assessed separately for both buccal and lingual cusp heights, and a mean value was determined. First, sealant extension on the occlusal fissure, and then rhodamine B penetration along the enamel/sealant interface, was measured in millimeters. Afterward, both values were compared, and the percentage of dye penetration (microleakage) was obtained. This approach was chosen because, considering the great variability in fissures' length, it is likely that solely recording infiltration quantity in millimeters would not provide a consistent idea about whether or not the value obtained was, indeed, representative. Determining the infiltration percentage based on the dye penetration amount recorded would enable a more accurate parameter for microleakage assessment.

STATISTICAL ANALYSIS

Sample distribution and homogeneity were analyzed. Since a normal and homogeneous distribution was observed, data were submitted to analysis of variance parametric test. Multiple comparisons were conducted via Tukey statistical test at a 0.05 significance level.

RESULTS

Means of dye penetration along enamel/sealant interface, for the 3 experimental groups, are displayed in Table 1.

Comparing experimental groups revealed a statistically significant difference (P<.05) between the microleakage percentage recorded for the nonetched lased specimens

Table 1. Means of Dye Penetration (%) and Standard Deviation at Enamel/Sealant Interface for the Experimental Groups

Acid etching	Er:YAG laser+acid etching	Er:YAG laser
2.27 (±3.75)	1.94 (±3.38)	3.51 (±6.26)

(group III) and that obtained for specimens in the other 2 groups. Fissures prepared exclusively with Er:YAG laser irradiation showed the highest microleakage degree at the enamel/sealant interaface. No significant difference (*P*>.05) was observed between the acid-etched and lased/acid-etched groups (I and II).

Regardlless of the surface treatement, all specimens exhibited some degree of leakage.

DISCUSSION

The reported research findings suggest that preparing occlusal pits and fissures exclusively with a Er:YAG laser did not result in optimal entanglement of the resin-based sealant into laser-treated enamel. A recent in vitro study evaluated, under SEM, the morphological changes in occlusal fissure enamel of permanent molars irradiated by Er:YAG laser using contact and noncontact fiberoptics. The results showed that specimens conditioned with 200 mJ and 2 Hz, on noncontact, focused mode (12 mm) under water cooling, exhibited fissures free from debris and predominantly enamel etching-like patterns, with no signs of melting and recrystallization enamel.[36]

In the present study, laser ablation alone was not able to produce a high-quality, dye penetration-resistant interface. Therefore, the nonetched lased specimens exhibited the highest degree of microleakage. A suitable explanation for such performance would be that, due to its thermally induced microexplosive ablation process, the Er:YAG laser does not provide a selective dissolution of the mineral phase. Hence, it doesn't create an even, uniform etching pattern similar to that obtained with etchant solutions.[23,32,37]

Instead, laser ablation yields a random fragmentation and removal of dental substance, with a real cleavage of the enamel prism pathway.[14,27] The resultant morphological recesses clearly differ from the well-arranged microporosities characteristic of acid etching. In addition, the Er:YAG laser beam does not have a continuous emission and, therefore, does not provide a homogeneous etching of tooth surface,[38] leaving nonlased areas between the pulses. Consequently, it is likely that such irregular microstructure leads to bonding failures and undermined marginal sealing.

The current investigation's outcomes, however, also revealed that, when 37% phosphoric acid conditioning was accomplished after laser irradiation, the marginal sealing at enamel/sealant interface was considerably enhanced. It may be speculated that the association of acid etching allowed a more accurate etching of enamel and seemed to optimize the adhesion of the resin sealant to the lased occlusal surface. These observations are consistent with those of previous studies,[32,33] which stated that Er:YAG laser irradiation of pits and fissures does not eliminate the need for adjunctive acid etching. The results of studies on bond strength and microleakage in laser-prepared cavities corroborate the assumption that, even on laser-ablated surfaces, the chemical treatment with a chelating agent is mandatory and must not be suppressed from the bonding protocol.[14,17,32,39-41]

CONCLUSIONS

Present research findings indicate the use of a laser device appeared not to optimize the marginal sealing at the enamel/sealant interface on primary teeth. Laser treatment followed by the use of an etchant solution led to results that were as good as those found with classical phosphoric acid etching, even without previous mechanical preparation via the widening of pits and fissures with rotary instrumentation.

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