Comparison of Marginal Microleakage of Flowable Composite Restorations in Primary Molars Prepared by High-speed Carbide Bur, Er:YAG Laser, and Air Abrasion

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ABSTRACT

Purpose: The purpose of this study was to assess in vitro the influence of 3 cavity preparation devices (carbide bur, Er:YAG laser, and air abrasion) on the microleakage of flowable composite restorations in primary teeth.
Methods: Fifteen primary second molars were selected, and Class V cavities were prepared on the buccal/lingual surfaces, being assigned to 3 groups (n=10). Group 1 (control) was prepared using a high-speed handpiece and was acid etched. Group 2 was prepared and treated with a Er:YAG laser (400mJ/4Hz and 80mJ/4Hz, respectively) and was acid etched. Group 3 was prepared and treated with an air abrasion system and was acid etched. Cavities were restored and stored for 7 days. Restorations were polished, thermocycled, immersed in 0.2% rhodamine B, sectioned, and analyzed for leakage.
Results: Er:YAG laser-prepared cavities showed the highest degree of infiltration. The performance of the air abrasion device was comparable to that of the high-speed handpiece.
Conclusion: It may be concluded that the method of cavity preparation affected the microleakage of Class V cavities restored with flowable composite in primary teeth. (J Dent Child 2006;73:122-126)
KEYWORDS: MICROLEAKAGE, COMPOSITE, PRIMARY TEETH, CARBIDE BUR, ER:YAG LASER, AIR ABRASION

Over the last few decades, dental research has notably improved restorative techniques and materials with the purpose of reproducing, as reliably as possible, the characteristics and appearance of lost dental tissue.

Moreover, the development of adhesive restorative systems minimized the need for resistance form or additional retention and enabled cavities to be prepared without excessive reduction and extension into sound tooth structure. In this context, resin materials with low viscosity[1] and low elasticity modulus[1,2] were introduced into the market. The so-called flowable composite materials have had good acceptance among clinicians, for its ease of handling, being particularly indicated for ultraconservative cavities.[3] In primary teeth, flowable composite materials have been reported to adhere even better than resin-modified glass ionomers and compomers.[4]

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Most recently, the applicability of newer methods for preparing dental hard tissues with the least discomfort for the patient, such as Er:YAG laser irradiation[5] and aluminum oxide air abrasion[6,7] has been increasingly widespread.

The yttrium-aluminum-garnet doped with erbium (Er:YAG) laser emits a wavelength of 2.94 µm that coincides with the major absorption band of water. This emitted energy is well absorbed by hydroxyapatite, and has been shown to remove dental hard tissues more effectively than other laser systems.[5] Little thermal damage has been reported,[5] especially when the laser beam is used in conjunction with water spray.[8] The first dental laser for use in cutting human teeth in vivo was cleared by the Food and Drug Administration for marketing in the United States in 1997. Since then, the use of the Er:YAG laser for caries removal and cavity preparation has been widely investigated.[9-12] Nevertheless, it has been demonstrated that the interaction of the Er:YAG laser beam with the target tissues depends on certain features, including focal distance, energy,[13,14] percentage of water in the tissue,[15] and water cooling.[16]

The use of air abrasion in primary teeth is considered of great interest for offering improved patient comfort by eliminating the pressure, heat, vibration, and noise, which usually cause anxiety to pediatric patients.[17] Therefore, certain parameters of aluminum oxide air abrasion have been assessed in primary dentition. Peruchi[18] reported that increasing the distance of the active point from the tooth surface increases the width and decreases the depth of the cavity, which certainly is a positive factor for preventing accidental pulpal damage while preparing primary teeth.

A review of the literature[9,11,12,19-21] has produced controversial results regarding the marginal microleakage on cavities prepared by the Er:YAG laser in permanent teeth. Little information regarding the use of the Er:YAG laser in primary dentition, however, is currently available. Stiesch-Scholz and Hanning[10] investigated the influence of Er:YAG laser preparation on the marginal integrity of restorations in primary teeth and found that the laser treatment can be recommended for composite restorations in Class V cavities in primary teeth. Likewise, Yamada et al[22] reported that cavities prepared by Er:YAG laser were capable of decreasing microleakage of composite resin restorations in primary teeth, and that the efficiency achieved was similar to that of etched carbide bur-prepared cavities. There is no published data on the marginal sealing of cavities prepared by aluminum oxide air abrasion in primary dentition and restored with flowable resin composites.

Considering the lack of studies, the aim of this study was to assess in vitro the influence of 3 cavity preparation devices—carbide bur, Er:YAG laser, and aluminum oxide air abrasion—on the marginal microleakage of flowable composite Class V restorations in primary teeth.

METHODS

Fifteen primary second molars, extracted within a 6-month period and stored in a saline solution at 4°C, were selected for the study. The teeth were carefully cleaned with a hand scaler and water-pumice slurry in dental prophylaxis cups. Class V cavities (N=30), with the occlusal and cervical margins located in enamel, were prepared on the buccal and lingual surfaces. Cavity dimensions were standardized utilizing a template to trace an outline onto both surfaces with a mesiodistal width and an occlusogingival measurement of 2 mm. The depth of the cavity was approximately 1 mm, calibrated by measuring it with a marked periodontal probe. Three preparation methods were accomplished and, in each tooth, the cavities were cut and treated by different techniques. The specimens were randomly assigned to 3 groups of equal size (N=10; Table 1).

For group 1 (control), the cavities were prepared using a no. 329 carbide bur at high speed with air/water spray coolant and finished with sharp hand instruments. New burs were used after every 5 preparations.

For group 2, the cavities were prepared via a 2.94-micrometer wavelength Er:YAG laser device (KaVo KEY Laser 2, KaVo Co, Biberach-Alemanha, Germany) with 400 mJ pulse energy and a 4-Hz repetition rate (frequency). A no. 2051 handpiece, attached to the flexible fiber delivery system, was used. The laser beam, with a 0.63-mm spot size, was delivered on noncontact, focused mode, with a fine water mist at 5 ml/minute. The irradiation distance was standardized using a custom designed apparatus consisting of:

1. a holder that positioned the handpiece in such a way that the laser beam was delivered perpendicular to the specimen surface at a constant working distance of 12 mm (focused mode) from the target site; and
2. a semiadjustable base on which the specimen was fixed with wax.

Two previously trained operators manipulated the apparatus' micrometer screws in such a way that the semi-adjustable base with the specimen was alternately moved in right-to-left and forward-to-back directions, thereby allowing the laser beam to provide a more accurate irradiation (preparation/treatment) of the entire demarcated buccal/lingual site.

Table 1. Groups Studied

Group	Cavity preparation	Surface treatment	Restorative system
1	High-speed air turbine (no. 329 carbide bur)	37% phosphoric acid (30 seconds)	Bond 1 + Flow-It!
2	Short-pulsed Er:YAG laser (400 mJ/4 Hz)	Short-pulsed Er:YAG Laser (80 mJ/2 Hz)+37% phosphoric acid (30 seconds)	Bond 1 + Flow-It!
3	Aluminum oxide air abrasion (27 µm, 80 psi)	Aluminum oxide air abrasion (27 µm, 60 psi)+37% phosphoric acid (30 seconds)	Bond 1 + Flow-It!

The laser parameters were selected on the control panel according to the procedure to be accomplished, so that higher dosimetries were chosen to cut enamel and dentin and lower dosimetries were used to treat the tooth surface.

For group 3, cavities were prepared with the handpiece of the air abrasive system (Mach 4.1, Kreativ Inc, Albany, Ore), with a 0.011-inch nozzle opening, using a 27.5-μm aluminum oxide particle stream at 80 psi air pressure with intensity of 7 g/minute on enamel and 4 g/minute on dentin, at a distance of approximately 5 mm at a 45° angle with the occlusal surface. After air abrasion, the dental surface was thoroughly rinsed for 40 seconds.

Once cavities were prepared, the enamel and dentin surfaces were treated according to the experimental group. For group 1, cavities were etched with a 37% phosphoric acid gel (Gel Etchant, Kerr Corporation, Orange, Calif) for 15 seconds, rinsed for 20 seconds, and gently dried with absorbent paper to keep the tooth surface moist. For group 2, cavities were first treated by Er:YAG laser (80 mJ/2Hz) for 30 seconds (KaVo KEY Laser 2, KaVo Co, Biberach, Germany), on noncontact, defocused mode, at a distance of 20 mm from the target tissue, followed by subsequent acid etching for 15 seconds. For group 3, the cavities were treated by air abrasion system (60 psi) plus acid etching for 15 seconds.

For all cavities, 2 coats of Bond 1 single-bottle adhesive system (Pentron, Inc, Wallingford, Conn) were successively applied on the etched surface. The last one was light cured for 20 seconds with a visible light curing unit with 400 mW/cm^2 output (XL 3000, 3M/ESPE, St Paul, Minn). Flow-It! flowable resin composite (Pentron, Inc, Wallingford, Conn) was inserted incrementally and light cured for 40 seconds. The specimens were stored for 7 days in distilled water at 37ºC, and then the restorations were polished with Super Snap disks (Shofu Inc, Kyoto, Japan). The specimens 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 dried superficially, the apices of all teeth were sealed off with epoxy resin, and the entire tooth received 2 coats of a colorless nail varnish, except for a 2-mm window around restoration margins. As the nail varnish dried, the teeth were immersed in a 0.2% Rhodamine B solution for 24 hours. Then, the surface-adhered dye was rinsed in tap water and the epoxy resin and nail varnish were removed with a sharp instrument. The teeth were embedded in chemically activated acrylic resin (JET, Clássico, São Paulo, Brazil) and bisected longitudinally in a mesiodistal direction with a water-cooled diamond saw at low-speed (Minitom, Struers A/S, Copenhagen, Denmark). The separated buccal and lingual halves were embedded again in acrylic resin and sectioned in a buccolingual direction, providing 2 to 3 cuts (1-mm thick) for each restoration. After sectioning, the cuts were initially thinned in a polishing machine (Politriz, Struers A/S, Copenhagen, Denmark) with water-cooled 280- to 600-grit silicon carbide (SiC) paper, and then manually smoothed with 1000- to 1200-grit SiC paper to obtain a flat surface and a final thickness of approximately 0.25 mm.

The cuts were identified and carefully fixed on microscopic slides, and the margins were analyzed separately. Each margin was viewed under a X5 magnification optical microscope (Axiostar Plus, Carl Zeizz Vision GmbH, München-Hallbergmoos, Germany) connected to a digital camera (Cyber-shot 3.3 MPEG Movie EX, model no. DSC-S75, Sony Corporation, Tokyo, Japan). The images obtained were transmitted to a personal computer. After digitization, the images were analyzed by Axion Vision 3.1 software (Carl Zeizz Vision GmbH, München-Hallbergmoos, Germany), which performs a quantitative measurement of the tracer agent's penetration in millimeters. The depth of the cavity wall and dye penetration along occlusal and cervical margins toward the axial wall were determined, and the percentage of dye penetration was calculated. The means of dye penetration for both interfaces were calculated for each group.

Data were analyzed for distribution and subjected to statistical analysis using Wilcoxon and Kruskal-Wallis nonparametric tests.

RESULTS

The means of dye penetration and standard deviation at both margins for the experimental groups are shown in Table 2.

There was a statistically significant difference (P<.05) between the occlusal and cervical margins solely for group 2 (laser preparation+laser conditioning+acid etching), with the best marginal sealing at the occlusal margin.

Regarding the cavity preparation methods, irrespective of the margin (occlusal/cervical), it was observed that bur-prepared and air-abraded groups showed a lesser degree of microleakage (P<.01) than the Er:YAG-lased group.

Comparing the 3 techniques, there was no significant difference (P>.05) in the amount of marginal leakage at occlusal margins. Only group 3 (aluminum oxide air abrasion+air abrasion conditioning+acid etching), however, provided leak-free restorations.

DISCUSSION

The findings of the reported research disclosed that the use of an Er:YAG laser device for cavity preparation in primary teeth resulted in defective marginal sealing at the flowable

Table 2. Means (%) of Tracer Agent Penetration for the Experimental Groups at Both Regions*

Cavity preparation	High-speed air turbine	Er:YAG laser	Aluminum oxide air abrasion
Margins	(1)	(2)	(3)
Occlusal	1.20(±3.79)^a	2.76(±8.72)^a	0^a
Cervical	5.70(±10.33)^a	92.30(±15.14)^b	0^a

composite/tooth interface, particularly in the cervical margin. Although the laser mechanism has not yet been well defined, a suitable explanation for such performance would be that the laser creates a specific cavity configuration that clearly differs from that produced by conventional bur-preparation. Indeed, lasing of dental substrate promotes a disorganized destruction of enamel prisms, possibly due to its great ability to remove substance. Consequently, laser-prepared cavities do not resemble conventional, precise, clearly identifiable outlines. It may be speculated that the irregularity of walls, internal angles, and margins interfered with the interaction between restorative material and tooth structure, thereby compromising the marginal sealing of the restorations and favoring marginal leakage.[13]

Additionally, it should also be considered that Er:YAG laser's selective ablation of collagen-rich intertubular dentin coupled with the photothermal effect causes decomposition of organic contents and degradation, collapse, or even melting of collagen fiber mesh, which obliterates the tubules' openings and restricts the subsequent interdiffusion of both acid etchant and resin monomers.[8]

Another important feature that may explain the higher degree of marginal leakage at the tooth/interface of Er:YAG laser-prepared cavities is the morphological appearance of dental substrate after irradiation utilizing a high pulse repetition rate (4 Hz). It has been shown that the higher the frequency, the lower the cooling of the irradiated tissue between pulses and, therefore, the higher the temperature of the lased substrate.[23,24] According to these authors, the consequence is the formation of extensive, multiple areas of fusion and recrystallization that appear to interfere with the bonding procedure.

In dentin, the ablation resulting from successive pulses of the same energy density provides an increase in crater depth.[15] A linear relationship is observed between crater depth and the volume of removed tissue as a function of the energy applied. Severe superficial damage with extensive and deep fissures (15 μm, on average), however, has been reported when different energies were used with a 4-Hz repetition rate.[25]

With respect to the margins evaluated in this study, there was no significant difference between the occlusal and cervical margins for air-abraded and bur-prepared cavities. It may possibly be ascribed to the fact that the gingival wall was located in enamel. On the other hand, there was a significant difference between the margins for the cavities prepared/treated by Er:YAG laser associated with acid etching. A suitable explanation for such results may be the fact that, since the cavities were prepared with high-energy density (400 mJ/4 Hz), a remarkable removal of dental substance occurred. As result, the thickness of available enamel at the cervical region was reduced, probably interfering with the marginal sealing at this interface. Nevertheless, divergent results were found by Kohara et al,[26] (2002) who reported that cavities prepared with Er:YAG laser in primary teeth showed a lesser degree of marginal leakage than those prepared with a conventional high-speed air turbine.

The absence of dye penetration in the cavities prepared by aluminum oxide air abrasion may be attributed to the formation of an enamel halo or bevel around the cavity margins, which may have favored the performance of this preparation device. In addition, the air abrasion technique consists of a mechanical removal of dental substance without heat generation. Therefore, it does not affect the composition and/or ultrastructure of either organic or inorganic components of tooth substrate.

It may be speculated that the occurrence of marginal microleakage in the conventional bur-prepared cavities derives from the fact that the high-speed air turbine produces a well-defined cavosurface angle, which was not beveled, thereby maintaining the aprismatic layer present on primary dentition. The disposition of the hydroxyapatite crystals in the aprismatic layer—constituted of hydroxyapatite crystals arranged parallel to each other and perpendicularly to the enamel surface—have been reported to affect the quality of the adhesion.[27-29]

The outcomes of the reported research suggest that air abrasion may be a viable alternative for preparation of cavities in primary teeth. Nevertheless, it is important to highlight that the current study measured microleakage, specifically in Class V cavities restored with a flowable composite. Different types of resin composites and cavities should be assessed as well. Further studies are required to corroborate or confront these findings and warrant a reliable and more widespread applicability of this technology in pediatric dentistry.

CONCLUSION

The marginal microleakage of Class V cavity preparations in primary teeth restored with flowable composite was significantly greater for preparations made with the Er: YAG laser when compared to carbide bur and air abrasion techniques.

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