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Microleakage and Marginal Integrity of Surface-Coated and Laser-Pretreated Class V Composite Restorations in Primary Teeth

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Abstract
Introduction: Despite the advanced formulations of resin composites, microleakage is still among the commonest causes of clinical failure of these restorations. We evaluated the effect of surface coating and laser pretreatment on the microleakage of Class V resin composite restorations in primary teeth.
Methods: Sixty extracted primary molar teeth having intact lingual or facial surfaces were randomly allocated into the control, G-Coat Plus surface coating, and erbium-doped yttrium aluminum garnet (Er:YAG) laser pretreatment groups. Class V cavities were provided with the coronal and gingival margins in the dentin and enamel, respectively. Restoration of the cavities was done with Z250 resin composite and they were thermocycled, followed by immersing in 2% basic Fuchsin dye for 24 hrs. Samples underwent sectioning occlusogingivally and the microleakage was assessed under a stereomicroscope (40×). Statistical analysis was done via SPSS and Kruskal-Wallis test ($\alpha = 0.05$).
Results: The control and G-Coat plus groups were significantly different regarding the microleakage ($P < 0.001$), and G-Coat Plus and laser pretreatment groups ($P < 0.001$) at both gingival and occlusal margins. However, it showed no significant difference between the laser and the control group on the enamel ($P = 0.063$) and dentin margins ($P = 0.757$). Microleakage at the gingival margins was significantly greater compared to the occlusal margins in the control and laser groups ($P < 0.001$), but not in the G-Coat Plus group ($P = 0.051$).
Conclusion: G-Coat plus coating significantly reduced microleakage at dentin and enamel margins of Class V composite restorations in primary teeth, in comparison with other groups of the study. Also, dentin margins showed more significant amounts of microleakage versus enamel margins in all groups, except for the G-Coat Plus group.
Keywords: Laser; Leakage; Primary teeth; Resin composite; Surface coating.

Introduction
Pediatric restorative dentistry mainly aims to maintain the carious primary teeth until the normal exfoliation time, which is biologically and functionally justified. Tooth-colored restorative materials like resin composites are preferred for direct restorations due to esthetic demands, advanced adhesive technology and mechanical properties, as well as their conservative technique.[1] Despite their upgraded formulation and excellent physical and mechanical characteristics, resin composite restorations are likely to clinically fail due to microleakage, particularly where the cementum is involved, and exacerbate the clinical problems.[2]

Microleakage is the microscopic penetration of fluid, microorganisms, ions, and molecules in between the prepared cavity walls and the restorative material.[3] It is closely related to marginal adaptation as an interfacial distance between the tooth structure and the restoration.[4] Several factors contribute to microleakage, such as the material properties, adhesive systems and adequacy, polymerization parameters, location, size and configuration of the cavity, and variations in the thermal expansion coefficient of the restorative material and tooth.[3,5,6] Microleakage is clinically associated with staining around the restoration margins, postoperative sensitivity, secondary caries, pulpal pathology, lower bond strength, and the subsequent partial or total failure of the restoration.[7]

Since restoration durability highly depends on the integrity and longevity of the marginal seal, various methods and compensatory mechanisms have been tried to decrease the marginal gap at the tooth-restoration interface.[8] As a novel recommended technique, surface coating materials can be applied on the finished restoration cavosurface margins to penetrate the marginal gaps and structural microdefects by capillary

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action, thereby enhancing the marginal seal of esthetic restorative materials.[6] It can also increase abrasion resistance, help color stability, facilitate cleaning, and enhance restoration brightness.[3] Coating materials are said to bond strongly with enamel, composite, dentin, ionomer, glass and resin-modified glass ionomers.[7]

G-Coat Plus is a methyl methacrylate-based photopolymerized resin-based coating material with low viscosity that is filled with nanofillers for better wear resistance.[9] In permanent teeth, coating restores the marginal integrity and reduces the gingival microleakage in Class V restorations at enamel and dentin margins.[10]

Laser is another recently-introduced technology to manage microleakage in composite restorations.[11] Hard-tissue laser systems like erbium-doped yttrium aluminum garnet (Er:YAG) have recently become popular in pediatric dentistry.[12] Laser radiation alters the physical structure and chemical composition of enamel and dentine through melting and recrystallizing while creating countless pores and tiny bubble-like inclusions. Similar profiles have been achieved with acid-etching. Pretreating enamel and dentin with laser and acid etching has been suggested to create better bonding of restorative adhesive materials and reduce microleakage.[13,14] This technique opens the dentin tubules without demineralization of peritubular and intertubular dentin, causes dentin surface sterilization, and produces a bonding surface with micro-irregularities without a smear layer, and thereby enhances the restorations bonding.[11]

Wide research has been dedicated to the conditioning effects of lasers.[11,15] However, the findings regarding the primary teeth are controversial due to the differences in specimen preparation methods, laser irradiation types, laser energy densities, and employed dental materials.

Knowing that primary and permanent teeth are structurally and morphologically different and that the literature on microleakage reduction methods for primary teeth is remarkably limited, we evaluated the effect of recent modalities regarding this issue (surface coating with G-Coat Plus and pretreatment with Er:YAG laser) on the microleakage of Class V resin composite restorations in primary teeth compared to the control group. The null hypothesis is that the laser pretreatment of the cavity surfaces after acid etching and the usage of coating materials over the restoration margins have no significant effect on the resin composite restoration microleakage.

Materials and Methods

Sample Selection

This *in vitro* research was conducted on 60 freshly-extracted maxillary and mandibular primary molar teeth with intact facial or lingual surfaces selected from the pool of teeth extracted for reasons other than this study (orthodontic purposes, abscess formation, etc) from June to August 2021. Macroscopic and microscopic examination of the teeth was done (at 20 × magnification) using a stereomicroscope (SZ51/61, Olympus, Tokyo, Japan) to rule out any fracture, fissure, carious lesion, abrasion or erosion, and restoration. The remaining soft tissue was eliminated by using a hand scaler (Zeffiro; Lascod, Florence, Italy). Disinfection of the teeth was done with 0.1% chloramine T for 48 hours followed by storing in distilled water (DW) at 4°C until used; the DW was replaced weekly.

Cavity Design

Rectangular Class V cavities characterized by non-beveled 90° cavosurface angles were made on the lingual or buccal surfaces, with the gingival and coronal margins in the dentin and enamel, respectively (1 mm under the cementoenamel junction), by a 0.8 mm diamond fissure bur (Diamant GmbH, Germany) on a high-speed handpiece with an air-water cooling spray. Uniformity was maintained by measuring the dimensions with a periodontal probe (occlusogingival height = 3.0 mm, cavity depth = 1.5 mm, and mesiodistal width = 3.0 mm,).

Study Groups

The specimens were assigned randomly to three groups (n = 20) as follows:

The control samples were simply restored using resin composite (3M ESPE, USA), without any laser pretreatment or surface coating.

One group of specimens was restored using resin composite, coated with a thin G-Coat Plus layer (GC, Japan) used via a microtip applicator, gently air blown for 5 seconds, and light-cured by an LED curing unit with a 440–480 nm wavelength and an output of 1500 mW/cm^2 (Woodpecker Medical Instrument Co., Guilin, China), as recommended by the manufacturer.

In the other group of specimens, the prepared cavities were pretreated with the Er:YAG laser (Fotona Fidelis Plus III, Slovenia) at 1 mm enamel margin with the laser settings of 70 mJ, 20 Hz, 1.5 W, air 4, water 8, in medium-short pulse mode (pulse length 100l s). The dentin surface was irradiated at 50 mJ, 10 Hz, and 1.5 W.[16] The laser beam spot size of 0.8 mm was considered. Laser irradiation scanned the surface perpendicularly with the R14 handpiece (100°) and the irradiation of the whole cavity surface was done at 2 mm/s for 10 seconds. Water irrigation was in process all along the lasing procedure. Laser irradiation was performed following acid etching and before applying the bonding agent.[17] Then the resin composite was used to restore the teeth.

Restorative Procedure

The 37% phosphoric acid (Scotchbond Etchant Gel, 3M ESPE, USA) was used to etch cavities for 30 and 15 seconds on the enamel margins and dentin surface, respectively, followed by rinsing for 5 seconds and mild air-drying for 5 seconds, while cautiously preventing the dentin surface from being desiccated, as instructed. Enamel and dentin walls received Adper Single Bond 2 (3M ESPE, USA), air-dried, and light-cured for 20 seconds. Z250 resin composite (3M ESPE, USA) was incrementally located in the cavities in layers ≤ 2 mm which were light-cured for 20 seconds. The samples were stored in DW at 37°C for 24 hours before finishing and polishing. Finally, coarse, medium and soft polishing disks were used to polish the samples (Sof-Lex, 3M ESPE, USA) with light pressure.

Microleakage Assessment

The specimens underwent 1000 thermal cycles in different water baths (5°C and 55°C (± 2°C)) using a 60-second dwell time and 3-second transfer time. When the root was sealed with utility wax, the tooth surface was covered with 2 coats of nail varnish, and a 1-mm window was left surrounding the restoration margin to penetrate the dye through the cavity margins. Using a 2% basic Fuchsin dye solution (Ranbaxy Fine Chemicals Ltd, India), the specimens were immersed for 24 hours. at room temperature, then removed and thoroughly washed using pumice slurry for the removal of the residual dye, and allowed to dry. By using a low-speed diamond saw (IsoMet; Buehler Ltd, USA) under water-coolant, the specimens were transversely sectioned through the restoration center in the occlusogingival direction from the buccal to the lingual surface. Section examination was done at 40 × magnification by a stereomicroscope (SZ51/61, Olympus, Japan); each tooth block was measured twice at the gingival and coronal margins. According to an ordinal ranking system, the microleakage was scored as:

- 0: without dye penetration
- 1: dye penetration up to 1/3 of the depth of the cavity
- 2: dye penetration up to 2/3 of the depth of the cavity
- 3: dye penetration up to the floor of the cavity
- 4: involvement of the axial surface.

Marginal Adaptation Evaluation

Through scanning electron microscopy (SEM; TE-SCAN, MIRA3, USA), the adhesion between the restoration material and the dental hard tissue was inspected with respect to the microleakage score at dentin and enamel margins. The sectioned specimens underwent drying, mounting on aluminum stubs, followed by gold sputter coating. SEM images (up to 1000 × magnifications) were taken to demarcate and measure the marginal gap (μm) on enamel and dentin margins.

Statistical Analysis

The data analysis was done by SPSS 22 at a significance level of 0.05. The Kruskal-Wallis test compared the microleakage at the enamel and dentin margins separately among the groups. The Mann-Whitney test was applied for the intragroup comparison (enamel versus dentin margin in each group).

Results

Table 1 displays the distribution frequency of different microleakage scores at the dentin and enamel margins in the groups. Figure 1 shows the stereomicroscopic images of microleakage scores in the groups. None of the groups could completely prevent the microleakage. However, the G-Coat Plus group showed the best marginal seal and the least microleakage, with a significantly higher frequency of zero microleakage at both dentin (65%) and enamel (90%) margins.

The Kruskal-Wallis test results showed the microleakage to be significantly different between the G-Coat Plus and control groups ($P < 0.001$) and between G-Coat Plus and laser groups ($P < 0.001$) at both dentin and enamel margins. Nonetheless, the control and laser groups showed no significant difference at the enamel ($P = 0.063$) and dentin margins ($P = 0.757$). The microleakage scores of dentin margins were significantly greater compared to the enamel margins in all the study groups ($P < 0.001$), except for the G-Coat Plus group ($P = 0.051$).

SEM Results

SEM images showed that in specimens with zero microleakage, the restorations were perfectly adapted to the cavity walls, leaving no gap. However, in specimens with a microleakage score above zero, fissures and gaps were found more at the composite-dentin interfaces compared to the composite-enamel interface, suggesting that adhesion to the dentin was more likely to be compromised (Figure 2).

Discussion

Resin-based restorative materials are the dental practitioners' material of choice for restoring cervical lesions.[18] However, polymerization shrinkage of resin composites, especially at dentin margins, can cause stress at the restoration-tooth interface.[18,19]

There are several methods for decreasing the microleakage of resin composite restorations in permanent teeth.[8] However, the primary and permanent dentitions are chemically and morphologically different in terms of resin composite bonding (thicker aprismatic layer of enamel, and also higher tubular density and smaller intertubular dentin area in primary teeth). Hence, specific protocols used to increase the performance of Class V resin composite restorations must be determined to provide more effective treatments for both dentitions.[20]

We assessed the effect of a coating material and laser pretreatment (Er:YAG) on the microleakage at the dentin and enamel margins of Class V resin composite restorations in primary teeth in comparison with a control

Table 1. Frequency Distribution of Microleakage Scores at the Enamel and Dentin Margins (n = 20 per group)

Groups	Margins	Frequency Distribution of Microleakage Scores (%)				
		0	1	2	3	4
Control	Enamel	6 (30%)	12 (60%)	1 (5%)	0 (0%)	1 (5%)
	Dentin	0 (0%)	2 (10%)	2 (10%)	2 (10%)	14 (70%)
G-Coat plus	Enamel	18 (90%)	1 (5%)	0 (0%)	0 (0%)	1 (5%)
	Dentin	13 (65%)	0 (0%)	1 (5%)	1 (5%)	5 (25%)
Laser pretreatment	Enamel	1 (5%)	15 (75%)	4 (20%)	0 (0%)	0 (0%)
	Dentin	1 (5%)	1 (5%)	1 (5%)	2 (10%)	15 (75%)
P value		< 0.001				

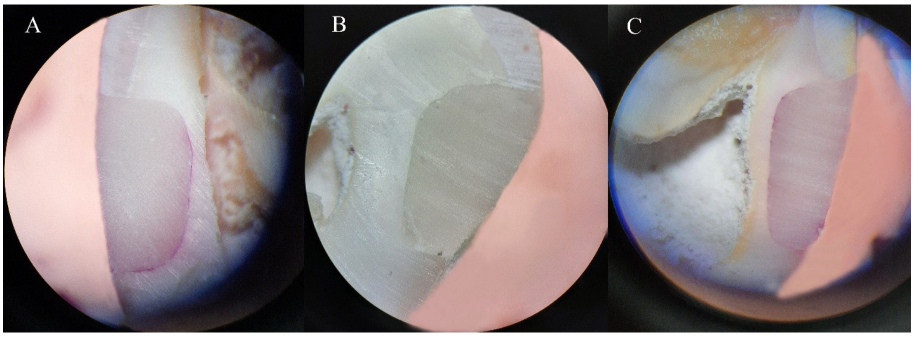

Figure 1. Representative Stereomicroscopic Images. (A) control group: zero microleakage at the enamel margin and score of 4 at the dentin margin; (B) G-Coat Plus group: zero microleakage at the dentin and enamel margins, (C) laser pretreatment group: microleakage score of 4 at the dentin and enamel margins

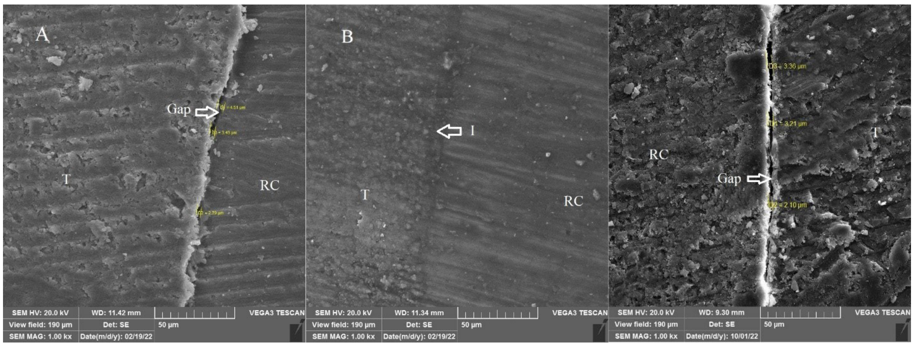

Figure 2. SEM Images of Microleakage Scores of 0 and Higher. (A) control group: the gap at the resin composite-dentin tissue interface, (B) G-Coat Plus group: complete resin composite adaptation to the enamel tissue, (C) laser pretreatment group: the gap at the resin composite-dentin tissue interface (RC = resin composite, I = interf ace, T = tooth)

group. It was found that the application of G-Coat Plus coating yielded significantly better marginal sealing and consequently more frequent zero microleakage.

Except for the G-Coat Plus group, microleakage was higher at the dentin margins compared to the enamel margins because the structure of dentin tissue is more permeable than the enamel.[21] Resin composite bonding to the dentin margin of restorations may be weaker and more challenging than enamel margins due to some factors such as more organic constituents, different mineralization degrees, the outward flow of dentinal fluid, absence of dentinal tubules, and lower probability of hybrid layer formation on cementum.[22,23]

Consistent with other studies, the present study found that surface coating efficiently reduced the microleakage at dentin and enamel margins in Class V resin restorations.[4] Hajilou et al[7] reported that G-Coat Plus coating effectively reduced the microleakage at both gingival and occlusal margins. They detected that applying a low-viscosity resin over the restoration margins penetrated deeply into the microgaps and surface microdefects. Likewise, Hepdeniz et al[3] observed that Fortify Plus, Fortify, and G-Coat Plus surface sealants prevented microleakage at Class V resin composite restoration enamel margins in third molars. They also found that dentinal margin microleakage was most efficiently reduced by unfilled or nanofilled surface sealants.[3] In Magni and colleagues' study,[10] the preparation of Class V cavities was done in premolar teeth, coated with G-Coat Plus, restored using either resin composite or glass ionomer cement in two groups of polished and unpolished. In line with the present study, their SEM evaluations confirmed that coating restored the marginal integrity and reduced the gingival microleakage.

No study has ever been so narrowed down to the microleakage of surface-coated or laser-pretreated resin composite restorations in primary teeth, and the present study is the first of this type. Recent investigations reported significantly lower microleakage in the resin-modified and conventional glass ionomer cement restorations in primary dentition coated with G-Coat Plus in primary teeth.[24,25] Conclusively, the surface coating would benefit all types of glass ionomer restorations.[26]

The current study also assessed laser pretreatment, which showed no significant effect on the microleakage, compared with the control group. However, controversies exist about laser applications and sealing ability.[27]

Evidence shows that using the Er:YAG laser per se or along with acid-etching would produce a surface with similar or better sealing properties compared to non-laser surfaces.[14,28] On the other side, laser irradiation was detected to interfere with hybrid layer formation through damaging the dentin-adhesive system interface.[29-33] The lower bond strength can be attributed to the lack of resin penetration in laser-ablated dentin, showing the fusion of collagen fibrils, and the lack of interfibrillar space.[30]

Consistent with our findings, Onay et al[34] found that neither the conditioning modality (Er:YAG laser) nor the adhesive systems affected the microleakage in class II composite restorations at enamel and dentin margins. Borsatto et al[35] assessed the effect of acid-etching and Er:YAG laser (120 mJ; 4 Hz) per se and in combination on the fissure sealant microleakage on primary teeth. Like the present study, the acid-etched and lased/acid-etched groups were not significantly different in this regard. Similarly, earlier findings on the effect of laser pretreatment on the bonded fissure sealant microleakage in primary teeth comply with our results.[36-38] The results of laser studies might be different with respect to the laser types (CO_2, neodymium-doped yttrium aluminum garnet, and Er:YAG), laser power outputs and settings, water and mineral composition, as well as the employed adhesives and restorative materials.[39]

In our study, the laser irradiation parameters were set based on previous studies regarding the morphology and temperature of the enamel and dentin tissues of primary teeth exposed to laser irradiation with the purpose to cause the least pulpal irritation and substrate heating and achieve the best bond between the adhesive and the primary tooth structure.[16,39] Noteworthily, each laser device has specific settings for wavelength, peak energy, pulse duration, delivery system, etc.[40]

Although G-Coat plus coating reduced the microleakage in our study, the findings might be clinically different as the oxygen in the oral environment may prevent the polymerization of the surface sealant[41]; besides, the coating might be detached by the saliva, food, brushing, antagonistic surfaces or other agents.[42] Moreover, the microleakage was assessed immediately after bonding and thermocycling, which might be different if assessed after a longer period. Further *in vivo* long-term investigations with a larger sample size are recommended to confirm the current results. Trying different laser settings and adhesive systems is also suggested to broaden the scope and establish the basis for the rational applicability of laser technology in pediatric dentistry.

Conclusion

Considering the limitations of this study, we can conclude that G-Coat plus coating is able to improve the marginal sealing and significantly reduce microleakage at the dentin and enamel margins of Class V composite restorations in primary teeth. However, laser pretreatment did not create significant differences from the control group. Also, dentin margins showed more significant amounts of microleakage versus enamel margins in all groups of the study, except for the G-Coat Plus group.

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Competing Interests

The authors declare no conflict of interest.

Data Availability Statement

All data used to support the findings of this study are available from the corresponding author upon request.

Ethical Approval

The procedures performed in this study were in accordance with the ethical standards of the local Ethics Committee of Shiraz University of Medical Sciences (IR.SUMS.DENTAL.REC.019). The parents or guardians signed the informed written consent form at the time of tooth extraction, and the study purpose, data anonymity, and privacy preservation were explained to them.

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