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Cervical Margin Integrity of Class II Resin Composite Restorations in Laser- and Bur-Prepared Cavities Using Three Different Adhesive Systems

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Clinical Relevance

Bur-prepared cavities represented less interfacial gap width than laser-prepared cavities. A self-etching adhesive system showed the least interfacial gap compared to etch-and-rinse adhesives and performed similarly in bur- and laser-prepared cavities.

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SUMMARY

One of the challenges in durability of posterior tooth-colored restorative materials is polymerization shrinkage, which results in gap formation between the restoration and tooth structure. The aim of the present study was to investigate marginal adaptation of Class II composite restorations using a self-etching and two etch-and-rinse adhesive systems in cavities prepared either with bur or Er,-Cr:YSGG laser. A total of 45 extracted sound human premolars were selected. In each tooth, mesial and distal Class II cavities were prepared either by a diamond bur or by Er,-Cr:YSGG laser with the margins 1 mm apical to the cemento-enamel junction. Then the teeth were randomly divided into three groups of 15 each, according to the type of the adhesive system used (Single Bond, Single Bond 2,

and Adper Easy One adhesive systems). Subsequent to restoring the teeth, the specimens were subjected to thermal cycling between 5 ± 2°C and 55 ± 2°C for 500 cycles and were then cut longitudinally into two halves using a diamond disk. Marginal adaptation was evaluated using a stereomicroscope, and the values for gap widths were obtained in micrometers. Data were analyzed using two-factor analysis of variance and *post hoc* tests. There were statistically significant differences in mean marginal gap widths between the adhesive type and preparation groups ($p<0.05$). The interfacial gap width in bur-prepared cavities was significantly less than that in laser-prepared cavities, and the lowest gap width was observed in Adper Easy One regardless of the type of the preparation.

INTRODUCTION

Adhesive dentistry combined with tooth-colored restorative materials plays a significant role in minimally invasive dentistry.[1] Since their development, several improvements have been made to the physical and mechanical properties of resin composites and have permitted their successful use in posterior restorations.[2] However, one of the challenges in durability of tooth-colored restorative materials is polymerization shrinkage, which results in stress and gap formation between the restoration and tooth structure.[3] Bacteria and fluids present at this interface compromise the durability of the restoration. This is more prominent in the cervical margins of proximal boxes.[4] In addition to polymerization shrinkage, surface characteristics of prepared enamel and dentin can influence shrinkage stress and gap formation at the tooth-resin composite interface.[5] Surface characteristics of teeth are different, depending on the preparation procedure.[6] In light of minimal-invasive dentistry, laser technology has been widely used as an alternative to the conventional use of diamond burs.[7] The ability of laser to remove enamel and dentin was found comparable to that achieved with the conventional dental drills. It has been reported that laser-irradiated surfaces are rough, clean, and free of debris with most of the dentinal tubules visible and wide open. These characteristics would favor the adhesion procedure.[6] Moreover, some studies have reported that the dentin layers that have undergone a beam of pulsed erbium lasers might resist the removal of minerals by the acid-etch technique and, as a result, can prevent the penetration of resin tags into the intertubular dentin, which might give rise to an incomplete hybridization with the resultant low bond strength.[8,9]

The quality of the margins of composite fillings is a frequently discussed topic in relation to the use of a laser for dental hard tissue preparation.[10] In addition, the interaction of lasers with newly developed dental materials is not fully understood.[6] To date, little information is available about the quality of margins of composite fillings in cavities prepared with Er,Cr:YSGG laser using gap analysis. Therefore, the aim of this comparative study was to investigate the marginal adaptation of Class II composite restorations in cavities prepared with bur or Er,Cr:YSGG laser, using a self-etching and two etch-and-rinse adhesive systems.

METHODS AND MATERIALS

Forty-five human premolars were selected from extracted teeth that met the inclusion criteria (sound, without cracks and wear facets). The selected teeth were stored in 0.5% chloramine T solution at 4°C and used within three months.

In each tooth, mesial and distal standard Class II cavities were prepared either by cylindrical diamond burs (SS White Burs, Inc, Lakewood, NJ, USA) or by the Er,Cr:YSGG laser. The axial wall depth and the buccolingual dimension of the cavities were 1.5 mm and 2 mm, respectively (Figure 1). The cervical margins of Class II cavities were placed 1 mm apical to the cemento-enamel junction (CEJ). The Er,Cr:YSGG laser used was the Waterlase (Biolase Europe GmbH, Floss, Germany). The system emits light with a wavelength of 2870 nm. The pulse frequency is a constant 20 Hz, and the pulse length is 140 μs. A power of 6 W (300 mJ) was used for enamel preparation, and 5 W power was used (250 mJ) for dentin preparation.[10] The working distance

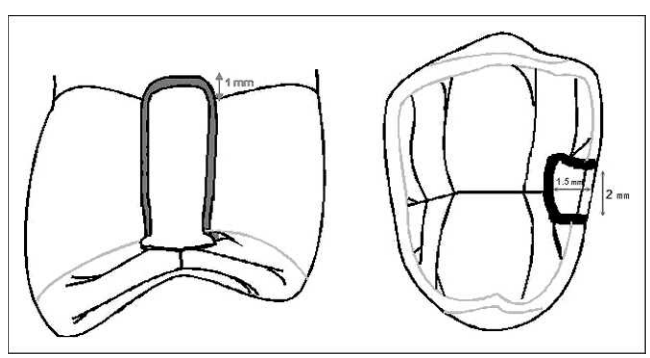

Figure 1. *Schematic representation showing Class II cavity dimensions.*

Table 1: *Chemical Composition and Application Mode of Adhesive Systems Used*

Adhesive system	Composition	Application mode
Single Bond; two-step etch and rinse	Etchant: 37% phosphoric acid gel Adhesive: HEMA, Bis-GMA, ethanol, water, polyalkenoic acid copolymer	Apply the etchant for 15 s; rinse for 10 s; apply two coats of adhesive; gently air-dry the surface for 5 s and light cure for 10 s.
Single Bond 2; two-step etch and rinse	Etchant: 37% phosphoric acid gel Adhesive: HEMA, BisGMA, dimethacrylates, ethanol, water, a novel photoinitiator system and a methacrylate functional copolymer of polyacrylic and polyitaconic acids, silica nanoparticles	Apply the etchant for 15 s; rinse for 10 s; apply adhesive for 15 s; gently air dry the surface for 5 s and light cure for 10 s.
Adper Easy One; one-step self-etch	HEMA, Bis-GMA, methacrylated phosphoric esters, 1,6 hexanediol dimethacrylate methacrylate functionalized polyalkenoic acid (Vitrebond™ copolymer), finely dispersed bonded silica filler with 7-nm primary particle size, ethanol, water, initiators based on camphorquinone, stabilizers	Apply adhesive to tooth surface for a total of 20 s; dry the adhesive for 5 s and light cure for 10 s.

Abbreviations: HEMA, hydroxyethyl methacrylate; BisGMA, bisphenol-glycidyl methacrylate.

was 0.5 mm while the air and water pressures for tooth preparation were 65% and 55%, respectively.

Then the teeth were divided into three groups of 15 each according to the type of the adhesive system used. In the first group, Single Bond adhesive system (3M ESPE, Dental Products, St. Paul, MN, USA) was used according to the manufacturer's instructions (Table 1). Then Filtek Supreme (3M ESPE), a nanohybrid composite, was filled into the cavities incrementally using Tofflemire matrix, and each layer was cured using Australis 7 light-curing unit (Ivoclar Vivadent, Schaan, Liechtenstein) at a light intensity of 500 mW/cm^2 for 40 seconds. Subsequent to the matrix removal, postcuring was carried out for 60 seconds at an intensity of 700 mW/cm^2.

In the second and third groups, Single Bond 2 (3M ESPE) and Adper Easy One (3M ESPE) adhesive systems were used according to the manufacturer's instructions (Table 1). The restoration procedure was the same as that in the first group.

The specimens were subjected to thermal cycling between 5 ± 2°C and 55 ± 2°C for 500 cycles with a dwell time of 20 seconds per bath.[10] Then the teeth were stored in distilled water for 24 hours and cut longitudinally (mesiodistally) into two halves using a diamond disk (Diamant GmbH, D&Z, Berlin, Germany). Marginal adaptation evaluation was performed using a stereomicroscope (Olympus SZX9, Tokyo, Japan). The selected areas were photographed with a digital imaging system (Olympus, DP12-BSW, version 01.03) and then the images were transferred to a computer for measuring the gap.

Interfacial gap width was measured with Olysia software (Olympus soft imaging system (SIS), Build 0831), which measured the marginal gaps at three locations (the mean values in Table 2). Gap width measurement was performed by determining two points on each gap vector (restoration-side vector) and (root-side vector) and by measuring the distance between them. The previously mentioned procedure was carried out at three locations that are specified in Figure 2 (outer part, middle part, and inner part of the cervical margin). The mean values in Table 3 have been obtained by averaging the three measurements for each specimen. The values for gap width were obtained in micrometers. One-way analysis of variance (ANOVA) was used to compare mean gap width values at three locations of the cervical margin, and two-by-two comparisons were performed using Tukey HSD test. For each treatment group, the mean values of marginal gaps at the three locations were calculated. Two-factor ANOVA was used to determine the effect of the type of adhesive and preparation on gap width. Pairwise comparisons of the study groups were performed using Tukey HSD and Mann-Whitney U-tests. Significance level was defined at $\alpha = 0.05$ for comparison of the groups.

Table 2: *Mean Marginal Gap Width (μm) ± SEM at Three Locations of the Cervical Margin in Study Groups*

	Type of preparation					
	Bur			Laser		
	Outer	Middle	Inner	Outer	Middle	Inner
Single Bond	0.11 ± 0.01	0.08 ± 0.008	0.06 ± 0.008	0.21 ± 0.02	0.19 ± 0.01	0.14 ± 0.01
Single Bond 2	0.22 ± 0.02	0.09 ± 0.01	0.02 ± 0.01	0.28 ± 0.03	0.21 ± 0.03	0.10 ± 0.04
Adper Easy One	0.09 ± 0.01	0.05 ± 0.01	0.01 ± 0.01	0.08 ± 0.01	0.07 ± 0.01	0.05 ± 0.01
p-value[a]		0.001			0.001	

[a] *Results of one-way analysis of variance for different locations of all adhesives. Bur group: all locations (p<0.017); laser group: inner part-middle part (p=0.04), inner part-outer part (p=0.001), middle part-outer part (p=0.4).*

RESULTS

The mean values of marginal gap width ± standard error of the mean (SEM) for the study groups at three locations of the cervical margin (outer part, middle part, and inner part) are shown in Table 2. In all the groups, the highest gap width was recorded in the outer part of the cervical margin, while the lowest gap width was observed in the inner part of the cervical margin. The results of one-way ANOVA revealed that there were statistically significant differences in gap width among the three locations of the cervical margin in laser- and bur-prepared cavities (p=0.001). In two-by-two comparisons, there were statistically significant differences in gap width in the bur-prepared group between all parts of the cervical margin (p<0.017), whereas in the laser-prepared group, there were statistically significant differences in gap width between the inner part and outer part and between the inner part and middle part of the cervical margin (p=0.001 and p=0.04, respectively); however, the differences in gap width between the middle part and outer part were not statistically significant (p=0.4).

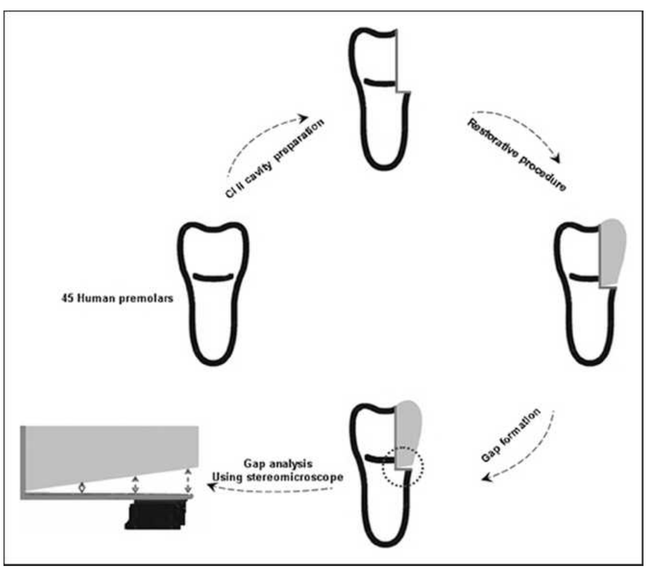

Figure 2. *The schematic representation showing the method to evaluate marginal adaptation. Gap width was measured at three locations (outer part, middle part, and inner part) of the cervical margin.*

The mean values of marginal gap width ± SEM for each treatment group are represented in Table 3. The results of two-factor ANOVA showed that there were statistically significant differences in mean marginal gap widths between the adhesive groups (p<0.001) and preparation groups (p<0.001). In addition, interaction effects between the type of the adhesive and cavity preparation were statistically significant (p=0.006).

The results of Mann-Whitney U-test showed that there were statistically significant differences in the mean marginal gap widths between the laser and bur preparation in Single Bond 2 (p=0.042) and Single Bond (p<0.001), but the differences were not statistically significant in Adper Easy One (p=0.39). Pairwise comparison with the *post hoc* Tukey test in the bur-prepared samples showed statistically significant differences between Single Bond 2 and Adper Easy One (p=0.02). There were no significant differences between Single Bond and Single Bond 2 (p=0.98) and Single Bond and Adper Easy one (p=0.55). In addition, pairwise comparison with the *post hoc* Tukey test in the laser-prepared samples

Table 3: *Mean Marginal Gap Width (μm) ± SEM in Study Groups*

Type of adhesive	Type of preparation		
	Bur	Laser	*p*-value[a]
Single Bond	0.08 ± 0.007 (0.4-0.14)	0.18 ± 0.01 (0.07-0.31)	<0.001
Single Bond 2	0.11 ± 0.02 (0-0.3)	0.20 ± 0.03 (0-0.6)	0.042
Adper Easy One	0.05 ± 0.01 (0-0.14)	0.07 ± 0.009 (0-0.14)	0.39
p-value[b]	<0.001	<0.001	

[a] *Results of Mann-Whitney U-test.*
[b] *Results of two-factor analysis of variance. Bur group: Single Bond-Single Bond 2 (p=0.98), Single Bond-Adper Easy One (p=0.55), Single Bond 2-Adper Easy One (p=0.02); laser group: Single Bond-Single Bond 2 (p=0.81), Single Bond-Adper Easy One (p=0.007), Single Bond 2-Adper Easy One (p=0.01). Figures inside parentheses are the maximum and minimum values.*

showed statistically significant differences between Adper Easy One and Single Bond 2 (p=0.01) and between Adper Easy One and Single Bond (p=0.007), while the differences between Single Bond and Single Bond 2 were not significant (p=0.81).

DISCUSSION

The longevity of a resin composite restoration depends on several factors, including sealing of the cavity-composite interface. From this viewpoint, investigations related to the gap formation mechanism and factors related to this phenomenon are crucial to improving the clinical longevity of resin composite restorations.[11] If there is insufficient bonding to the dental hard tissue, polymerization shrinkage can result in a gap between the filling material and the cavity wall.[12] In addition, marginal adaptation of composite resins is influenced by a variety of other factors, including the cavity size, the angle at which enamel prisms and dentin tubules are cut based on their location, the procedure in which dental hard tissues are conditioned, the layering protocol, and the polymerization technique used.[13]

Invasion of marginal gaps by bacteria would be expected to be in the range of 0.5-1.0 μm or larger. Smaller gaps may not allow the bacterial penetration but may allow the diffusion of toxins and other bacterial products that could be harmful to the tooth.[10] In the current study, the majority of the gap sizes were less than 0.25 μm; therefore, extensive bacterial penetration would not be expected. However, toxins and other bacterial products could diffuse through the smaller gaps.[10] It has been reported that bacterial products that diffuse toward the pulp can activate the immune system, provide chemotactic stimuli and cytokine production, and produce pain and pulpal inflammation.[14] To overcome such a discrepancy at the margin, various clinical protocols have been proposed, including the control of curing light irradiance (such as soft-start or pulse-delay techniques), use of a cavity liner with a low modulus of elasticity (such as a flowable resin liner), use of incremental techniques, and the use of composite resins with low polymerization shrinkage rates (such as silorane-based composite resins). Nevertheless, no single method has been totally efficacious in counteracting the effects of polymerization shrinkage.[15]

In all the groups, the gap width decreased from the outer part of the cervical margin to the inner part which represents a V-shaped gap formation in composite restorations on root surfaces. It has been reported that this phenomenon occurs because polymerization shrinkage forces are greater than the initial bond strength of composite to root dentin.[16]

The results of the present study showed that the mean interfacial gap width in bur-prepared cavities is significantly less than that in the laser-prepared cavities regardless of the type of adhesive resin used, which might be attributed to different dentinal surface characteristics in laser- and bur-prepared cavities. It has been demonstrated that surfaces irradiated by Er:YAG and Er,Cr:YSGG lasers have a characteristic rough, clean, and debris-free surface with most of the dentinal tubules visible and wide open.[6] Although Ceballos and others[17] and Aoki and others[18] demonstrated that adhesion to lased dentin would be explained by the mechanical retention provided by resin tag formation and the infiltration of adhesive resin into the irregularities in lased, mineralized dentin, the main mechanism of bonding to dentin surface relies directly on the infiltration of hydrophilic monomers to the exposed dentin collagen web.[19] Therefore, bonding depends on the exposure and integrity of the collagen fiber network. The potential impact of the Er:YAG and Er,Cr:YSGG lasers on the collagen network has not been completely elucidated. It is known that laser irradiation is able to develop micro-structural alterations as well as micro-rupture of collagen fibers.[6] If the collagen structure collapses or is altered, the penetration of primers and monomers will be incomplete.[20] Similarly, Benazzato and Stefani[21] reported that Er:YAG laser dentin ablation plus air/water spray denatures dentinal collagen fibers in deep regions of dentin and structurally modifies dentinal collagen in the intertubular area. Moreover, De Munck and others[22] reported that cavities prepared by laser appear less receptive to adhesive procedures than conventional bur cavities. Ceballos and others[19] have reported that there exists a 3-4-μm dentin subsurface where denatured collagen fibrils are fused and cross-banding is lost in the Er:YAG-irradiated dentin. Other studies[23,24] have also shown that laser irradiation can negatively influence the dentin/adhesive system interface, hampering the hybrid layer formation. Laser irradiation of the dentinal substrate not only can result in consequences on collagen fibers but also can influence the quality of the mineral content of this substrate. Laser effectively influences the acid resistance of the dentin, as demonstrated by Schein and others[25] in Er:YAG lased dentin. Therefore, it seems that the quality of the hybrid layer is not satisfactory in laser-ablated dentin.

Another important finding in the present study was the lowest gap width observed in both laser- and bur-prepared cavities when using the self-etching system (Adper Easy One). In addition, in this adhesive system there were no statistically significant differences in gap widths between laser and bur preparations. Different adhesive systems can interact differently with lased surfaces.[26] Adper Easy One, a one-bottle self-etching adhesive formulation, includes a carefully balanced combination of phosphoric acid esters, water, and methacrylates in order to optimize stability. In addition, it contains bonded nanosilica fillers. The etching and subsequent penetration of resin monomers into the demineralized dentin is carried out as one step with self-etching Adper Easy One Adhesive. A major benefit of this procedure for dentin bonding is that the etching depth and the depth of penetration of the adhesive are identical.[27] Because of lower acidity, there are smaller openings at the end of dentinal tubules that are etched. This leads to better infiltration and proper coverage of demineralized dentin.[9]

Cardoso et al.[26] reported that the bonding efficacy of adhesives to laser-irradiated dental tissue depends not only on the structural substrate alterations induced by the laser but also on the characteristics of the adhesive employed. Adper Easy One contains nanofiller particles in its composition. It has been demonstrated that the collagen fibril network mostly filters out the nanofillers, holding them at the hybrid layer surface, thus acting as an intermediate shock absorber.[28,29] Therefore, the bond strength can be preserved, and the marginal gap and microleakage might be reduced.

Even though Single Bond 2, an etch-and-rinse adhesive system, contains filler particles in its chemical composition, it resulted in the highest gap width in both laser- and bur-prepared cavities in the current study. It seems that the interaction of adhesives with the substrate and their bonding mechanism can affect the gap formation more than the filler content.

However, the results of a previous study on flat dentin surfaces showed that etch-and-rinse adhesive systems produce better interfacial adaptation in dentin either in bur- or laser-prepared cavities.[27] Furthermore, in a study carried out by Yazici and others,[30] the Er,Cr:YSGG laser-prepared cavities exhibited the same amount of microleakage as that with bur-prepared cavities with etch-and-rinse and single-step self-etch adhesive systems in Class V composite resin restorations. In another study, no significant differences were observed in the cementum microleakage of bur- and laser-prepared Class V cavities in nanorestorative materials.[31] The differences in the results might be attributed to differences in preparation techniques of the samples, cavity configurations, restorative materials, and adhesive systems.

Considering the effect of acidity of self-etch systems and hybrid layer thickness formed by these adhesives on interfacial dentin gap formation,[27] it is suggested that the effect of hybrid layer thickness and pH of different self-etch adhesive systems on marginal gap formation in laser-prepared cavities be investigated.

Evaluation of marginal adaptation provides a more reliable prognosis about the efficacy of adhesive systems in composite resin restorations compared to bond strength tests.[13] Therefore, in the present study, gap analysis was used to compare the marginal integrity of different adhesive systems in laser- and bur-prepared cavities. Several studies have reported a positive correlation between gap size and secondary caries; however, some other studies have not been able to correlate the results of gap analysis with the clinical performance of restorative materials. As a result, there is no conclusive evidence supporting this relationship or vice versa.[13,32,33] Furthermore, in clinical circumstances, patient-related factors, including caries activity and oral hygiene status, can have an influence on the quality of marginal adaptation and seal.[13] Therefore, long-term clinical studies are warranted to evaluate the clinical outcome of laser-prepared cavities with different adhesive systems.

CONCLUSIONS

Within the limitations of the present study, it can be concluded that the gap width in the samples prepared by bur is less than those prepared by laser and that the gap width is adhesive system dependent. The self-etching system revealed less gap width in bur- and laser-prepared cavities.

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