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The Effect of Different Adhesive Types and Curing Methods on Microleakage and the Marginal Adaptation of Composite Veneers

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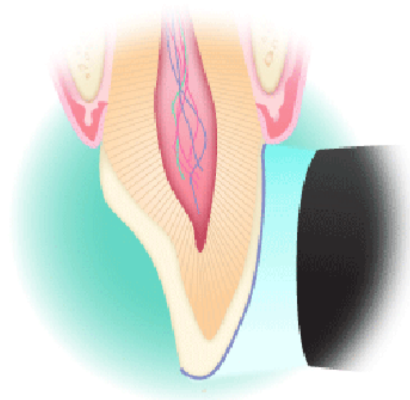

Abstract

Aim: The aim of this *in vitro* study was to evaluate the influence of application techniques (with pre-curing vs without pre-curing) for dentin adhesive on microleakage and marginal adaptation of indirect composite veneer restorations.

Methods and Materials: A total-etch bonding system, Excite/Variolink II (EXV), and a self-etching primer system, Panavia F2.0 (PF2), were used in the study. Forty-eight human central incisors were prepared for composite veneer restorations. The teeth were divided into two groups (n=24). For each resin cement, one half of each experimental group included an adhesive pre-cure (PC) with a halogen light source while the other half received no pre-cure (NPC) prior to resin cement insertion. Thus, four experimental groups were created: A (PC+EXV), B (NPC+EXV), C (PC+PF2), and D (NPC+PF2). Veneers made of Tetric Ceram resin composite were cemented using dual-cured resin luting agents. After storage in distilled water at 37°C for 24 hours, the teeth were prepared for marginal leakage. Two samples of each group were selected at random for scanning electron microscopic (SEM) observation and evaluation of marginal adaptation at 1050x magnification. Data were analyzed using the Kruskal-Wallis and Mann-Whitney tests (Ð <0.05).

Results: The highest and lowest microleakage values were observed in dentinal margins of groups B and A, respectively. Dentin margins opposite to enamel margins had a significant difference in microleakage values of

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PC and NPC groups (P<0.05). The influence of the adhesive pre-cure was more pronounced than the type of resin cement used. No adhesive layer was visualized for the adhesives used without employing the pre-curing step.

Conclusion: The effect of pre-cured adhesives was not material specific. The pre-cured adhesives showed the best resistance to dye penetration although the film thickness of these luting agents was only slightly increased.

Clinical Significance: Different curing methods (with pre-curing/without pre-curing) regardless of total-etch or self-etch adhesive systems influenced microleakage and the marginal adaptation, especially dentin margins of indirect composite veneers.

Keywords: Composite veneer, adhesive systems, microleakage, SEM, marginal adaptation, curing method

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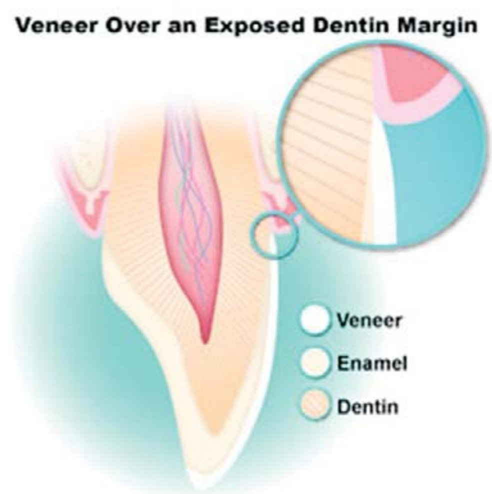
Introduction

Development of adhesive materials that facilitates placement of conservative restorations and the achievement of excellent esthetic outcome along with adequate strength accounts for the increased use of bonded restorations in dentistry.[1] The composite veneers bonded to enamel after minimal tooth preparation is among this type of restoration to gain popularity.[2,3]

Ceromer resin shows promise as a cost effective restorative material for the fabrication of esthetic anterior laminates as an alternative to porcelain laminates for restoration of discolored and malformed anterior teeth.[4] The longevity of indirect restorations fabricated with indirect composite resins is dependent on favorable clinical and cementation techniques.



The cementation technique used is determined by the type and composition of restorative material as well as the selected cement.[5] Despite the increased efficiency achieved with dental adhesives during the last decade, the seal and marginal adaptation of bonded composite veneers remains a critical problem, especially when the cervical margin is placed on dentin.[6]

In these cases the cementation procedure becomes even more critical, and the strength and durability of bond between composite, luting cement, and enamel/dentin interference play an important role in the long-term success of composite veneers. High failure rates with veneers have been associated with large exposed dentin cervical margins which have been regarded as a problematic area of tooth preparations to achieve a perfect marginal seal.[3] Exposure of dentin is common, particularly in the gingival third of a veneer preparation due to the thin enamel layer located in this region of a prepared tooth.[7]

Both total-etch and self-etch bonding systems are designed for adhesion of indirect veneers to tooth structure. In both of these systems manufacturers recommend applying the adhesive on the tooth surface without light curing before cementation. However, the lack of pre-curing may cause the adhesive layer to become too thin and insufficient for adequate bonding.

The clinical success of cemented restorations has been evaluated by measuring marginal fit and microleakage for many years. However, there is no restoration or luting material able to achieve a complete marginal seal.[8,9] In bonded composite restorations microleakage is associated with the loss of margin integrity and bonding to the tooth structure, which leads to other problems such as secondary caries, post-operative sensitivity, pulpal inflammation, staining, and plaque accumulation.[9,10,11] This is due to the passage of bacteria, fluids, molecules, and ions between tooth structure and the cemented restoration.[12]

The aim of this study was to test the null hypothesis that the application of various resin cements with different curing methods (with pre-curing vs without pre-curing) leads to similar marginal adaptation and microleakage in dentin and enamel margins.

Methods and Materials

Specimen Preparation

Forty-eight sound human maxillary incisors, recently extracted for periodontal reasons, were selected for the study. Residual soft tissues were removed by scaling and storing the teeth in distilled water containing thymol crystals during the interval between extraction and use in this *in vitro* study. One clinician prepared all teeth for facial indirect composite veneers using chamfer-ended, parallel-sided diamond burs (Brasseler USA, Savannah, GA, USA) in a high speed handpiece with air water spray. The bur was replaced after every four preparations.

The veneer cavities were prepared using the window method. The margins ended as a butt joint at the incisal edge and as a chamfer extending 1 mm apically from the cementoenamel junction along the cervical margin. The preparation was extended about halfway into the interproximal surfaces of the teeth. The cavities were finished using a matching diamond finishing bur (40 µm particle size, Brasseler, Savannah, GA, USA).

Thereafter, all veneers were fabricated by placing Tetric Ceram A2™ resin composite (Ivoclar-Vivadent, Schaan, Liechtenstein) directly into each preparation using water as a separating medium. Each increment was photocured for 20 seconds using a visible light-curing unit (Optilux 500, Demetron-Kerr, Orange, CA, USA) at 500mW/cm^2. Then veneers removed on the prepared tooth and additional polymerization was performed for 7 minutes at 125°C in a Coltene® D.I.-500 oven specified for resin composite (Coltène AG, Alstätten, Switzerland). The internal surfaces of the veneers were then sandblasted with 50 µm Al_2O_3 powder at bars of pressure. Then the teeth were divided randomly into four groups according to type of cement and curing method to be used for cementation of the veneers as follows:

- **Group A:** The veneers were cemented on the teeth using Excite® (Ivoclar-Vivadent AG, Schaan, Liechtenstein) adhesive with pre-curing and Variolink® II (Ivoclar-Vivadent AG, Schaan, Liechtenstein) resin cement (PC+EXV).
- **Group B:** The veneers were cemented on the teeth using Excite® adhesive without pre-curing and Variolink® II resin cement (NPC+EXV).
- **Group C:** The veneers were cemented on the teeth using ED Primer II (Kuraray Medical, Okayama, Japan) adhesive with pre-curing and Panavia F2.0 (Kuraray Medical, Okayama, Japan) resin cement (PC+PF2).
- **Group D:** The veneers were cemented on the teeth using ED Primer II adhesive without pre-curing and Panavia F2.0 resin cement (NPC+PF2).

The teeth treatment strategies and materials used for each group are summarized in Table 1.

The systematic technique employing veneer and tooth preparations for veneer placement with Excite/Variolink (EXV) is shown in Table 2.

The systematic technique employing veneer and tooth preparations for veneer placement with ED Primer II/ Panavia F2.0 (PF2) is shown in Table 3.

Table 1. Dentin treatments and materials used for each experimental group.

Group	Substance	n	Etching	Priming	Bonding
Group A (PC+EXV)	Excite PC	12	• Etch with 35% phosphoric acid 15 seconds • Rinse 20 seconds	N/A	• Apply with brush for 10 seconds • Air thin for 3 seconds • Light cure for 20 seconds
Group B (NPC+EXV)	Excite NPC	12	• Etch with 35% phosphoric acid 15 seconds • Rinse 20 seconds	N/A	• Apply with brush for 10 seconds • Air thin for 3 seconds • Do not light cure
Group C (PC+PF 2.0)	Panavia F2.0 PC	12	N/A	• Apply with brush for 10 seconds • Wait for 30 seconds • Dry with air spray for 3 seconds • Light cure for 20 seconds	
Group D (NPC+PF 2.0)	Panavia F2.0 NPC	12	N/A	• Apply with brush for 10 seconds • Wait for 30 seconds • Dry with air spray for 3 seconds • Do not light cure	

Table 2. Technique used for Excite/Variolink (EXV).

Excite /Variolink II (EXV)	
Veneer Preparation	• Sandblast with 50 μ alumina powder at 2 Bar pressure for 7 seconds • Etch with 35% phosphoric acid for 60 seconds • Rinse for 30 seconds and dry • Apply the silane to the internal surface of veneer with brush for 60 seconds • Wait for 30 seconds and then dry the silane with air spray • Apply the adhesive to the internal surface of veneer • Air thin the adhesive
Tooth Preparation	• Clean the prepared surface with pumice and water • Etch the enamel surface for 15-30 seconds and the dentinal surface for 10-15 seconds • Remove excess water but DO NOT over dry dentinal surfaces • Apply adhesive • Dry the adhesive with air spray for 1-3 seconds • Light cure the adhesive for 20 seconds just in PC group
Veneer seating	• Apply base cement to veneer • Seat the veneer on the tooth with mild pressure and maintain pressure for 10-20 seconds • Remove excess cement from the borders • Light cure for 40 seconds from each side

Table 3. Technique used for ED Primer II/Panavia F2.0 (PF2).

ED Primer II/ Panavia F2.0 (PF2)	
Veneer Preparation	• Sandblast the internal surface of the veneer with 50 μ alumina powder at 2 Bar pressure for 7 seconds • Etch with k-etchant gel for 60 seconds • Rinse for 30 seconds and dry • Mix Clearfil SE Bond primer and Clearfil porcelain bond activator in 1:1 ratio and apply the mixture to the internal surface of veneer with brush • Wait for 30 seconds to dry
Tooth Preparation	• Clean the prepared surface with pumice and water • Mix ED Primer II A & B in 1:1 ratio and apply the mixture to the internal surface of veneer • Wait for 30 seconds and then dry with air spray for 30 seconds • Light cure for 20 seconds just in PC group
Veneer Seating	• Apply base cement to veneer • Seat the veneer on the tooth with mild pressure and maintain pressure for 10-20 seconds • Remove excess cement from the borders • Light cure for 40 seconds from each side

Microleakage Test

Following cementation, finishing and polishing procedures were done; the veneered teeth were stored in distilled water at body temperature for 24 hours. Next, they were thermocycled in water at 5-55°C for 1000 cycles with a 20 second dwell time at each temperature and a 10 second transfer time for a total of 60 seconds per cycle. The roots and tooth surfaces were then covered with two layers of quick drying fingernail varnish that extended to within 1 mm of the margins of the composite veneer restorations to prevent dye penetration from these parts of the teeth. The teeth were then stored in 0.5% basic fuchsine solution (Fluka, Buchs, Switzerland) for 24 hours at 37°C.

After rinsing the teeth under pressured water, the specimens were mounted in polyester resin and sectioned in a bucco-lingual direction perpendicular to the long axis of the teeth with the aid of a slowly rotating diamond disc (Isomet Low Speed Saw 11-1180, AB Bühler Ltd, Chicago, IL, USA) under a water coolant to obtain three slices from each tooth. The sectioned surfaces were polished using sandpaper descending in abrasivity to a fine 2000 grit and analyzed for microleakage at the cervical (dentinal) and

incisal (enamel) margins using a steromicroscope (Blue light industry, Waltham, MA, USA) at 40x magnification. Microleakage values were obtained by measuring stain penetration for the total surface length. Measurements were done separately for the dentin and the enamel and were expressed as a percentage of the total length of the veneer preparation.

The nonparametric Mann-Whitney U and Kruskal-Wallis tests were used for statistical analysis. The statistical difference was considered significant if $P<0.05$ and performed using SPSS version 11.5 software (SPSS Inc., Chicago, IL, USA).

Randomly two sectioned specimens from each group were prepared for scanning electron microscope (SEM) analysis. Each section was sequentially polished with 600 up to 2000 grit silicon carbide papers, 6 and 1 μm diamond slurries, and then with 0.04 μm aluminum oxide. The specimens were dehydrated in an ascending series of ethanol then critical-point dried with HMDS and mounted on aluminum stubs then gold-sputter coated. The SEM (LEO, Model VP-1450, Germany) was then used to assess marginal adaptation, hybrid layer, and cement layer thickness at enamel and dentinal margins at 1050x magnification.

Results

Evaluation of Microleakage

Figures 1 and 2 and Table 4 show microleakage of dentinal and enamel margins of specimens.

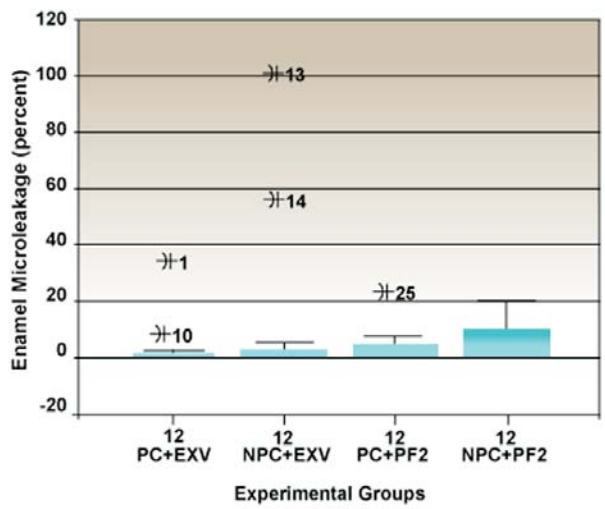


Figure 1. The enamel microleakage percentage in experimental groups.

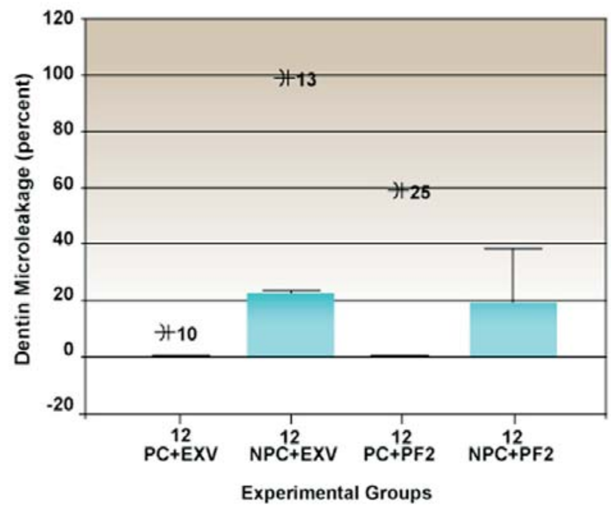


Figure 2. The dentin microleakage percentage in experimental groups.

Table 4. The microleakage mean ranks of enamel and dentinal margins in the experimental groups.

Tooth Structure	Group	N	Mean Rank
Enamel	PC+EXV	12	22.67
	NPC+EXV	12	23.75
	PC+PF2	12	24.50
	NPC+PF2	12	27.08
	Total	48	
Dentin	PC+EXV	12	18.50
	NPC+EXV	12	31.08
	PC+PF2	12	19.50
	NPC+PF2	12	28.92
	Total	48	

Table 5. Descriptive statistics of mean, standard deviation, maximum, and minimum of dye penetration in enamel and dentinal margins.

Tooth Structure	Group	N	Mean	Std. Deviation	Minimum	Maximum
Enamel	PC+EXV	12	3.7050	10.075	.00	35.00
	NPC+EXV	12	13.3775	31.618	.00	100.0
	PC+PF2	12	3.1508	6.420	.00	21.74
	NPC+PF2	12	4.5167	6.707	.00	20.00
Dentin	PC+EXV	12	.5950	2.0611	.00	7.14
	NPC+EXV	12	17.376	27.842	.00	100.00
	PC+PF2	12	5.000	17.320	.00	60.00
	NPC+PF2	12	10.287	13.011	.00	38.46

The Kruskal-Wallis and Mann-Whitney tests revealed the method of curing had significantly affected microleakage in dentin margins (P=0.03), but the type of material had no significant effect. The minimum and maximum mean rankings in dentinal margins were found in Group A and Group B in dentinal margins, respectively. Significant differences were detected for the values of microleakage in dentin margins (P=0.01). The Mann-Whitney test showed the differences between Groups A and B (P=0.02).

Table 5 shows descriptive statistics of microleakage in enamel and dentinal margins of each group.

SEM Evaluation

Prior to sectioning of the specimens the veneered material seemed clear, smooth, and without any gaps when viewed macroscopically. However, when viewed microscopically, excess cement was observed in all specimens. The SEM analysis revealed the thickness of the resin cement layer to be more similar in Groups A and B compared to Groups C and D.

While the marginal adaptation in the enamel margins was suitable in all groups, the gaps between the enamel and the cement were less in all groups than the gaps found in dentin margins. This finding was consistent with the microleakage values achieved. More gaps appeared in the dentin margins of Group D, which was somewhat

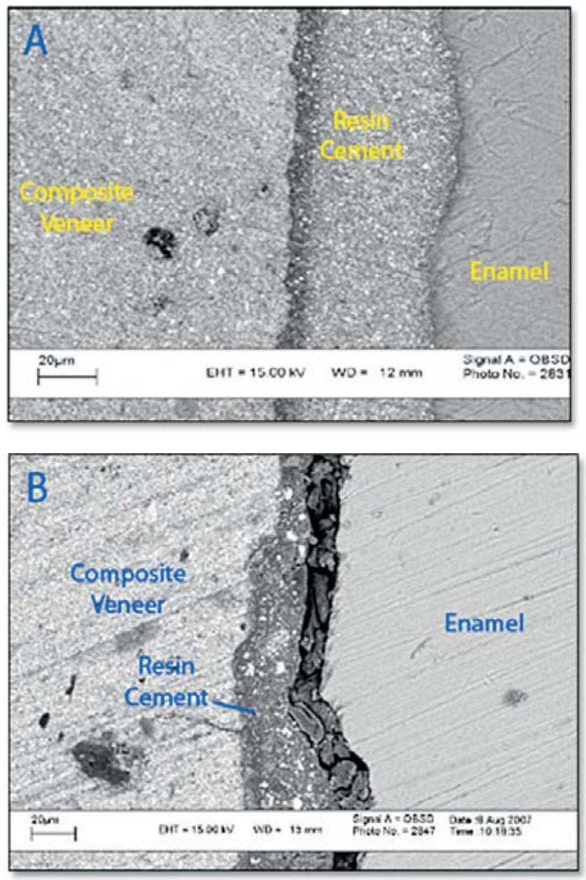


Figure 3. Interface area of composite veneer to enamel in groups. **A.** Photomicrograph of PC+EXV. **B.** Photomicrograph of PC+PF2. Magnification: 1050x.

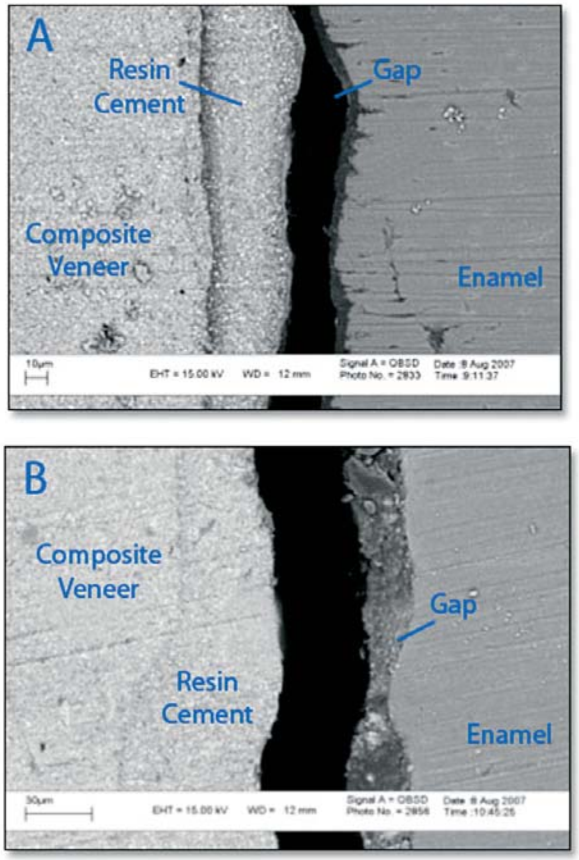


Figure 4. Interface area of composite veneer to enamel in groups. **A.** Photomicrograph of NPC+EXV (A) **B.** Photomicrograph of NPC+PF2. Magnification: 1050x.

similar to Group B, which confirmed the dye penetration and microleakage values according to the gap numbers and volumes. In both luting systems the gaps appeared in the adhesive/resin cement interface in the PC groups and in the tooth/adhesive interface or in the adhesive layer in the NPC groups (Figures 3 and 4).

Discussion

Microleakage and marginal adaptation of indirect composite veneers luted with two resin cements using different application procedures were evaluated in this study. Resin composite veneers were chosen for this research because they offer the advantage of being more user-friendly clinically and in the dental laboratory.[13]

Marginal leakage is one of the major drawbacks of tooth colored restorations so the dye penetration method was used in this study to assess microleakage while the marginal fit of cemented restorations can be estimated by either invasive or non-invasive techniques. A non-invasive technique leaves the tooth intact and can be a quantitative SEM analysis describing the entire margin area from replicas and microphotographs or from a microscopic assessment of the width of the luting cement at selected points along the margin.[14,15] The quantitative SEM analysis provides information of the surface area but not of the overall fit of the restorations.

According to Hung et al.[16] the invasive method based on multiplied sectioning can be more precise than the non-invasive method. A possible explanation might be the absolute marginal discrepancy appears better defined and easier to determine in a section in comparison to an intact surface. The present investigation confirmed this hypotheses: the clinical success of indirect composite veneers correlates with the properties of the resin cement luting agent and its method of application. Although Excite/VarioLink II is a total-etch resin cement system and Panavia F2.0 is a self-etch bonding system, both performed similarly in this study. The NPC method suggests by not pre-curing the adhesive prior to seating an indirect restoration, interference by the thickness of cured adhesive with complete seating is prevented. However, insufficient curing of the adhesive can lead to incomplete consistency of the hybrid layer and create the potential of marginal percolation and bacterial penetration in the dentin/adhesive interface as well as marginal discoloration, secondary decay, and post-operative sensitivity.[17]

Despite the film thickness of both luting systems used in this study, film thickness is usually thin enough not to interfere with the seating of indirect restorations, the thickness is not identical in all positions on the prepared tooth. As a result, it can be assumed a cured adhesive layer could interfere with the seating of indirect restorations. In the present study pre-curing the adhesive with both the Panavia F2.0 and Excite/VarioLink II systems significantly reduced microleakage despite manufacturer recommendations not to pre-cure their adhesives prior to cementation.

The favorable results achieved using the pre-curing method in this study were consistent with previous investigations.[6,12,17] The absence of a visible adhesive layer when the adhesive is not pre-cured can be explained by the incorporation of the adhesive resin into the fluid resin cement.

In the present study pre-curing of the adhesive increased the luting space but reduced microleakage; the effect of pre-curing of the adhesive was not dependent on the type of material. The thickness of the adhesive layer was occasionally too thin in the NPC groups and microleakage was greater especially in dentin margins. Because dentin bonding is more sensitive than enamel bonding, pre-curing the adhesive in dentin margins is critical and will yield better results in terms of reduced microleakage than not pre-curing the adhesive. Compared to direct veneer restorations, the volumetric shrinkage of resin composite is less in indirect composite veneers due to the favorable C-factor associated with veneer preparations.[18]

For the bond between the bonding layer and dentin to remain intact, stress associated with material shrinkage has to be relieved by an elastic response of surrounding materials.[19] Although the beneficial effect of pre-curing the adhesive can be attributed to an increase in the degree of polymerization, the creation of an "elastic cavity" wall that absorbs some of the shrinkage stress of the luting resin cement might have contributed to the improvements observed which suggests the resin dentin hybrid layer can act as a stress-absorbing layer during functions.[20]

According to the results of this study, no significant differences were achieved between the two systems, and the microleakage appeared independent of material type, but the effect of curing method was significant. On the other hand, the quality of marginal adaptation is dependent on the combination of bonding system and luting resin cement rather than each material by itself.[21] Despite the achievement of a thinner adhesive and hybrid layer using the Panavia F2.0 system, its effect on reducing microleakage and marginal defects was similar to the Excite/VarioLink II system during this investigation.

According to Stavridakis et al.[22] the incidence of marginal gap is found to be independent of the width of the luting space ranging from 50 to 1000 µm. From a clinical viewpoint, the luting gap should be kept as small as possible in order to avoid pulling out any uncured material from the gap during removal of excess cement.[23] Although curing the adhesive prior to cementation increases the luting space, this negative effect may be tolerable if a careful technique is used. Further investigations are necessary to determine the real influence of the pre-curing and adhesive thickness on the internal and marginal adaptation of indirect restorations and bond strength.

Conclusion

1. The effect of adhesive pre-curing on the microleakage and marginal adaptation was not related to material type.
2. Minimal microleakage was achieved in pre-cured specimens with both cements studied.
3. Microleakage in dentin margins as opposed to enamel margins was significantly related to curing methods.
4. Adhesive pre-curing causes a greater film-thickness of resin cement.
5. The border between the adhesive and cement were not detectible by SEM analysis in the specimens with no pre-curing of the adhesive.

Clinical Significance

Different curing methods (with pre-curing/without pre-curing) regardless of total-etch or self-etch adhesive systems influenced microleakage and the marginal adaptation, especially dentin margins of indirect composite veneers.

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