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Effect of Pre-heating Resin Composite on Restoration Microleakage

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Clinical Relevance

The results of this study indicate that preheating composites can improve adaptation of resin composites to tooth structure. This technique significantly reduced microleakage. However, delaying light curing of the preheated composite after placement appears to be counterproductive and diminishes the positive effects from the preheating treatment. Flowable liner was less effective than preheating the composite in reducing microleakage.

SUMMARY

Improving the adaptation of resin composites during placement is necessary to increase durability and reduce microleakage. Flowable resin liners have been introduced to improve adaptation in composite restorations. In addition, a device that lowers the viscosity of regular dental composites has been introduced (Calset, AdDent Inc, Danbury, CT, USA). This device lowers the viscosity of composites by preheating them to 54.4°C, which should lead to improved adaptation. This study compared microleakage in Class II composite restorations prepared using: 1) preheated resin composite, 2) unheated composite and 3) a flowable liner followed by unheated composite. Class II cavities were prepared on the mesial and distal surfaces of extracted third molars. Ten preparations were restored with resin composite (Esthet-X, Dentsply, York, PA, USA) for each of the following four techniques: Control (Esthet-X with Prime & Bond NT, Dentsply), Flowable (f) (as Control but used Esthet-X Flow liner), Preheated (p) (as Control but with preheating composite to 54.4°C) and Delay (d) (as Preheated but followed by a 15-second delay before curing). The teeth were restored, finished, stored in distilled water for 24 hours, then thermocycled between water bath temperatures of 5°C and 55°C with a one-minute dwell time for 1000 cycles. Tooth apices were sealed with epoxy and varnish was applied to within 1 mm of the restoration margins. The teeth were placed in 0.5% basic fuschin dye for 24 hours, rinsed, then embedded in self-curing resin. The embedded teeth were sectioned mesiodistally with a slow-speed diamond saw, providing multiple sections per restoration. Microleakage was rated by two evaluators using

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a 0-4 ordinal scale at the occlusal and cervical margins of each restoration and light microscopy (40x). The data were analyzed with Kruskal-Wallis ANOVA and pairwise testing with the Sign test (α=0.05). No statistical differences were observed among materials at the occlusal margin. However, at the cervical margin, the preheated samples P showed statistically lower microleakage than the controls and all other treatments. The D samples showed higher microleakage than the P and F samples. Ranked sum scores for the cervical were D (4516), C (3974), F (2756) and P (1958). There was a statistically greater amount of leakage at the cervical margins compared to the occlusal *p*<0.05. Preheating the composite resulted in significantly less microleakage at the cervical margins compared to the flowable liner and control. Delaying light curing of the preheated composite for 15 seconds (D) was counterproductive and led to increased microleakage.

INTRODUCTION

With some types of restorations, it can be difficult to achieve complete interfacial sealing between the tooth structures and composites. One potential way to improve sealing would be to use lower viscosity flowable composites; however, these flowable composites are not generally considered as durable as higher viscosity materials, due to the lower levels of reinforcing filler particles present.[1] A second approach is to use a flowable liner in conjunction with regular composites.[2-7] A third alternative is to use conventional composites that have been heated to lower their viscosity.[8-13] In this way, higher durability conventional composites could be used, while utilizing lower viscosity to form more intact interfaces with tooth tissues. In addition, the extra step required for a flowable liner would not be necessary. This research investigated the second and third alternatives—flowable liners and preheating the composite. Therefore, this study compared microleakage in Class II composite restorations prepared using: 1) preheated resin composite, 2) unheated composite and 3) a flowable liner followed by unheated composite. The hypothesis was that preheating the composite allows it to better conform to the restoration walls and thereby reduce microleakage.

Viscosity of Composites

The effect of lowering viscosity to improve adaptation of the composite and to improve ease of placement has been shown to be important.[1] This is the primary basis for the development of flowable resin composites and flowable liners. These flowable composites achieve their lower viscosity primarily by a reduction in reinforcing filler content and changes in the matrix chemistry. A variety of studies have shown that lower viscosity composites can improve adaptation and reduce microleakage.[14-17]

Many polymer resins exhibit lower viscosity when they are heated. The theoretical basis for this behavior is that thermal vibrations force the composite monomers or oligomers further apart, allowing them to slide by each other more readily. Studies have shown that heating general polymers and resin composites lowers viscosity and thereby improves adaptation. Holmes and others[8] have shown that increasing dental composite temperature lowers viscosity as indicated by decreased film thickness. Similar results were found by Broome.[11]

In some, but not all, the composites tested, Blalock and others[17] showed that viscosity, as determined by film thickness, was lowered by preheating.

Effect of Elevated Temperatures on Composite Properties After Curing

One concern is the effect of heating after curing on the cured composite properties. A few studies have investigated the conversion of double bonds (a measure of how completely the polymerization reaction progresses) and hardness of the composite after the preheating treatment. These studies are important in determining how quickly and completely the composite polymerizes. Preheating appears to either improve conversion and hardness in some cases or it produces no negative changes.

Increased conversion generally equates to better properties of the polymeric materials and composites; therefore, it is used to determine the effect of a treatment on dental composites. A variety of studies have shown that more conversion occurs at higher temperatures and occurs more rapidly.[18-23] Therefore, preheating may lead to more durable composite restorations.

When two light cured composites were preheated to 54.4°C, a previous study by the authors of the current study[24] found small but statistically non-significant increases in Knoop Hardness with curing depths between 0 and 6 mm. However, another study by Bortolotto and Krejci[25] showed that, with a light cured composite, when temperatures were raised from 5°C to 40°C, significant increases in Vickers Hardness were found at a curing depth of 0.5 mm. These results indicate that preheating may have a positive effect on the hardness of the set composite.

There has been concern that the higher temperature of preheated composite would lead to greater shrinkage during and after curing. Elhejazi[26] showed that raising the temperatures of resin composite led to greater shrinkage. In response to this concern, it was suggested that the preheated composite be allowed to cool for 15 seconds after placement but before curing. Therefore, in the current study, the authors also tested the microleakage associated with preheated composite with a 15-second delay before curing.

Another concern expressed in the literature was that of subjecting the composite to preheating cycles would reduce the shelf life of the unused composite. However, Daronch and others[13] showed that neither preheating cycles nor extended preheating for 24 hours caused any significant changes in monomer conversion.

METHODS AND MATERIALS

There were six phases to this project: 1) tooth preparation, 2) placement of the restorations, 3) thermocycling, 4) dye penetration, 5) cross-sectioning and 6) reading the amount of microleakage. These procedures are described below:

1. Specimens were prepared in extracted non-carious third molars, previously stored in 0.2% sodium azide at room temperature. The teeth were cleaned with a slurry of flour of pumice and water, prior to preparation. Two Class II preparations were made in each tooth (mesial and distal) with a high-speed handpiece using water spray and a #256 carbide bur (Brasseler USA, Savannah, GA, USA). Since these restorations were prepared on extracted teeth, the exact size of the preparations varied. The goal was to provide sound tooth structures at the cavosurface interface. The actual width of each preparation was defined by the anatomy of each tooth. Pulpal floor depth was approximately 2 mm, and the proximal boxes were approximately 3 mm wide, 4 mm long and 1.5 mm deep. The cervical margin was placed on cementum (root surface dentin) 1.0 to 1.5 mm apical to the CEJ. At least 1.5 mm of sound tooth structure remained occlusally between the two cavities. The amount of extension on the occlusal surface was typically about 3 mm. Five specimens were randomly assigned to each of the four treatment groups.
2. All restorations were placed by a single operator. Four treatments were evaluated: Control (C), Preheated (P), Delayed (D) and Flowable (F). Each treatment group had five specimens, each with two restorations (10 restorations in each group). All preparations were treated with Prime & Bond (Densply/Caulk) adhesive. The adhesive was applied to thoroughly wet the surfaces for 20 seconds; the excess solvent was removed by gently air-drying, then the adhesive was light cured for 10 seconds. Restorations in the Control and Flowable liner groups were placed according to the manufacturer's instructions with and without a flowable liner (Table 1). The flowable liner (Esthet-X Flow liner, Dentsply Caulk) was placed in a 1 mm thick layer to cover the cavosurface interface and internal aspect of the box, then it was light cured for 20 seconds. Restorations in the Preheated group were placed using resin composite heated externally by a Calset unit (AdDent) to a temperature of 130°F. This unit was used with the standard tray that heats four compules. For restorations utilizing the preheated composite, the compule was inserted into the composite gun and placed immediately after removing it from the Calset unit. Previous research has shown that there is an approximate 25°F decrease in temperature in the two minutes after removing the composite compule from the heating unit.[13] Therefore, it is important to place the composite as quickly as possible. Approximately 2 mm composite increments were placed. All composite increments were preheated in the Preheated and Delay groups. Restorations in the Delay group were placed similarly to those in the Preheated group, but with a 15 second delayed cure. A mylar matrix was adapted to the prepared tooth before incremental insertion of the restorative material (Esthet-X, Dentsply Caulk). In all specimens, the material was light-cured according to the manufacturer's instructions with an Optilux 401 (Kerr/Demetron) light-curing unit. The curing unit was tested using a Cure Rite Visible Light Curing Meter (Model #8000, EFOS Inc, Williamsville, NY, USA) to verify that the output was sufficient to cure the restorative material (the manufacturer recommends greater than 300mW/cm^2). A curing time of 20 seconds was used, as specified by the manufacturer. Within 15 minutes following placement and curing, the occlusal aspects of each restoration were grossly contoured, and all cavosurface margins were finished flush using a gold shank football finishing bur and Sof-Flex discs (3M/ESPE) to mimic interproximal finishing strips. Specimens for all treatments were stored under identical conditions before the thermocycling treatment (room temperature and distilled water for a minimum of 24 hours).
3. Thermocyling was used to simulate the effect of the thermal changes in the oral environment. The specimens were thermocycled between 5°C and 55°C water baths with a one-minute dwell time for 1000 cycles.
4. Dye penetration around the restorations was used to determine the presence of a gap around the restoration. To prevent the dye from entering the tooth by other mechanisms, the apex of each tooth was sealed with epoxy cement and

Table 1: *Sample Treatments*

Technique	Composite/Adhesive	Variable	Surface	Statistics Coding
Control (C)	Esthet-X + Prime & Bond NT	None	Occlusal Cervical	C occlusal C cervical
Flowable (F)	Esthet-X + Prime & Bond NT	Esthet-X Flow liner	Occlusal Cervical	F occlusal F cervical
Preheated (P)	Esthet-X + Prime & Bond NT	Preheat (with immediate cure after placement)	Occlusal Cervical	P occlusal P cervical
Delay (D)	Esthet-X + Prime & Bond NT	Preheat (with a 15 second delay before curing)	Occlusal Cervical	D occlusal D cervical

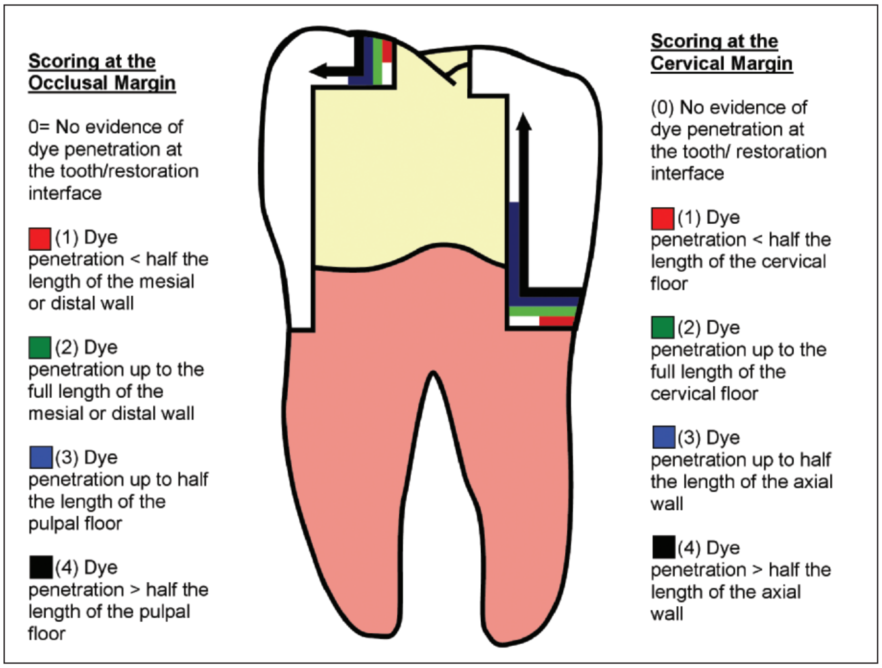

Figure 1: *Method used to score microleakage. The distance that the fushin dye penetrated is indicated by the red, green, blue and black zones. The scores (1 to 4) associated with these distances are show in the sidebars.*

the tooth was painted with two coats of fingernail varnish to within 1 mm of the restoration margins. The specimens were then placed in a solution of 0.5% basic fuschin dye for 24 hours to produce a visible stain where microleakage occurred.

5. Following dye exposure, the teeth were rinsed with distilled water and embedded in self-curing resin. The embedded specimens were cross-sectioned longitudinally through both restorations on each tooth from mesial to distal using a slow-speed water-cooled diamond saw (Isomet) to produce three to six cross sections per tooth.
6. Microleakage was determined by the amount of dye penetration at both the cervical and occlusal aspect of all restorations (Figure 1). The extent of microleakage was determined visually under 40x light microscopy. Two examiners scored the extent of dye penetration using a category evaluation scale by consensus. The examiners were blinded as to the material and technique used. Ranked data were analyzed utilizing the Kruskal-Wallis test for non-parametric data (α=0.05) and the Wilcoxon Signed Rank tests for paired non-parametric comparisons.

RESULTS AND DISCUSSION

Microleakage Differences Between Treatments at the Occlusal Margins

At the occlusal margins, the various treatments to lower microleakage (Preheated, [P], Delayed [D] and Flowable [F]) had minor and statistically insignificant effects (p>0.05). In addition, the range of microleakage rank sum values at the occlusal margins was not as wide as with the cervical margins (Tables 2 and 3). Rank sum scores for the occlusal were C (3904), D (3058), P (3155) and F (3248).

The median microleakage scores were much lower at the occlusal margins (all 0) than at the cervical margins (either 3 or 4) (Table 4). This indicates that most restorations showed no microleakage along the mesial or distal walls at the occlusal margins.

Microleakage Differences Between Treatments at the Cervical Margin

At the cervical margins, far more microleakage was observed. In most specimens, the dye penetrated the full length of the cervical floor and at least half way up the axial wall (greater than 50% of the total potential microleakage length).

More variation in microleakage was also observed at the cervical margins. Significantly lower microleakage at the cervical margins was observed with the Preheated group that was immediately cured after placement (Table 3). This lowest microleakage was statistically different from all other treatments. Ranked sum scores for the cervical were Delayed (4516), Control (3974), Flowable (2756) and Preheated (1958). Other treatments, Control, Delayed and Flowable, resulted in higher microleakage rank sum values than Preheated. Treatments Control and Flowable produced statistically similar results ($p>0.05$) except in comparisons with the Delayed group. Delayed showed significantly higher microleakage than the Preheated or Flowable groups but not significantly higher than the Controls.

As expected, preheating resulted in the lowest microleakage. However, the higher microleakage values for the preheated treatment with a 15-second delay (Delayed) before curing were not anticipated. The delayed cure was originally suggested to reduce the amount of thermal contraction that would occur if the composite was cured immediately at the high temperature—the higher temperature range would seemingly cause greater thermal contraction. However, the 15-second delay actually produced more microleakage.

One explanation is that the 15-second delay allowed for viscoelastic behavior in the composite, which caused it to pull away from the walls of the tooth preparation. Two basic types of viscoelastic deformation come into play when placing resin composites—viscous deformation and retarded elastic deformation. Viscous deformation is responsible for the majority of the forming of the composite. Retarded elastic deformation occurs at the same time as viscous deformation, and it is also present during shaping of the composite; however, this retarded elastic deformation is temporary and the composite slowly tries to return to a previous shape. In a sense, it has a "memory." The retarded elastic deformation is not instantaneous; instead, it occurs slowly, depending on a number of factors, including temperature. Higher temperatures could cause the material to try to return more rapidly to a previous shape. The authors of this study believe that the 15-second delay allowed the preheated composite to pull away from the tooth, which caused higher leakage with the delayed preheated samples (D) compared to the preheated samples with no delay (P).

From the results of this study, it should be recommended that the preheated composite should be light cured immediately after placement, without a delay. In this way, the positive effects of reduced microleakage could be obtained without the negative influence of retarded elastic deformation.

The flowable composite liner did not lower microleakage as much as had been expected. The cervical ranked sum scores for the flowable liner (F) and the control (C) were 2756 and 3974, respectively. However, this difference was not statistically significant at $\alpha=0.05$.

Microleakage Differences Between the Cervical and Occlusal Margins

Within each treatment, statistically different amounts of microleakage were found between the cervical and occlusal margins ($p\leq0.05$). Similar results have been observed in previous microleakage studies by the authors of the current study.[7] These findings indicate that better sealed interfaces are formed at the occlusal margins than at the cervical margins. This could result from: 1) stronger bonding of the unset and set composite to enamel, 2) the geometry of the restoration or 3) from the composite conforming better to the occlusal mar-

Table 2: *Occlusal Margins Kruskal-Wallis One-way ANOVA*

Technique	Count	Rank Summary	Statistical Groupings (Different letters indicate statistical difference between groups [$p\leq0.05$])
Control (C)	47	3904	A
Flowable (F)	53	3248	A
Preheated (P)	39	3155	A
Delay (D)	40	3058	A

Table 3: *Cervical Margins Kruskal-Wallis One-way ANOVA*

Technique	Count	Rank Summary	Statistical Groupings (Different letters indicate statistical difference between groups [$p\leq0.05$])
Control (C)	45	3974	AB
Flowable (F)	37	2756	A
Preheated (P)	38	1958	C
Delay (D)	42	4516	B

Table 4: *Median Values*

	C Occlusal	C Cervical	F Occlusal	F Cervical	P Occlusal	P Cervical	D Occlusal	D Cervical
# of Sections	47	45	53	37	39	38	40	42
Minimum	0	2	0	0	0	0	0	1
Maximum	4	4	4	4	4	4	4	4
Median	0	4	0	3	0	3	0	4

gins. The most accepted theory is that the greater amount of enamel at the occlusal margins allows for better sealing and reduced microleakage. However, the geometry of the restoration could have also been important—the longer vertical dimension would result in more composite shrinkage in that direction. This, in turn, would then put more strain on the cervical margins. Finally, the shape of the restoration could affect the ease of placing the composite between the occlusal and cervical margins; although most of the authors of the current study believe that this would have minor effects.

CONCLUSIONS

The four treatment groups in this study: Control, Preheated, Delayed (Preheated with a 15-second delay before curing) and Flowable resin liner produced relatively low microleakage at the occlusal margins when compared to the cervical margins. In addition, the difference between these treatments at the occusal margins was statistically insignificant. In contrast, the four treatments resulted in statistically different levels of microleakage at the cervical margins. The Preheated treatment resulted in significantly less microleakage at the cervical margin compared to the Control or the Flowable resin liner treatment. Preheating the composite was shown to be valuable in reducing microleakage in the more sensitive cervical margins. Delaying curing for 15 seconds after placing the preheated composite in the cervical margins was counterproductive and caused increased microleakage over the Preheated or the Flowable treatments. Therefore, based on the results of this study, delaying the curing of preheated composite after placement is not recommended.

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