IJHS

Original Article

The effect of three lining materials on microleakage of packable composite resin restorations in young premolars with cavity margins located on enamel and dentin/cementum - An *In vitro* study

Hazim Mohamed Rizk[1], Mohammed Al-Ruthea[2], Mohammed Ali Habibullah[3]

[1]Department of Dental Public Health, Pediatric Dentistry and Orthodontics, Al Rass College of Dentistry, Qassim University, Kingdom of Saudi Arabia, [2]Department of Restorative Dentistry, Al Rass College of Dentistry, Qassim University, Kingdom of Saudi Arabia,[3]Department of Dental Public Health, Pediatric Dentistry and Orthodontics, Al Rass College of Dentistry, Qassim University, Kingdom of Saudi Arabia

Address for Correspondence:
Hazim Mohamed Rizk,
Department of Dental Public Health,
Pediatric Dentistry and Orthodontics,
Al Rass College of Dentistry,
Qassim University, Kingdom of Saudi Arabia.
Phone: +966554605396.
E-mail: dr.hazem.rizk@qudent.org

WEBSITE: ijhs.org.sa
ISSN: 1658-3639
PUBLISHER: Qassim University

ABSTRACT

Objectives: The objective of our *in vitro* investigation was to assess the effect of a layer of three lining materials; flowable composite, flowable compomer, and light-curing glass ionomer cement as a liner on microleakage with Class V packable composite restorations in young premolar teeth.

Materials and Methods: A total of 40 premolars were assigned randomly into four groups of 10 teeth each (Groups 1, 2, 3, and 4). Class V cavities (3 mm × 2 mm × 1.5 mm) were prepared in a standardized technique on the buccal surface of every tooth with the cervical margin extending 0.5 mm below the cementoenamel junction, into the dentin. Cavities in the first group (control group) were filled with packable composite (Heliomolar HB) without liners. Cavities in Groups 2, 3, and 4 were restored with packable composite after placing flowable composite (Heliomolar Flow), light-curing glass ionomer cement (Vivaglass), and flowable compomer (Compoglass Flow) as liners, respectively. The 40 restored teeth were put in thermocycling machine, then immersed in 2% methylene blue solution for a period of 24 h to permit penetration of methylene blue into potential microgaps that might have been created between the restorative material and the tooth. Each tooth was then cut buccolingually into two halves through the center of the restoration parallel to their long axes. Photomicrographs of each group were captured, then examined using the ImageJ an analysis software.

Results: Control group (packable composite), Group 2 (flowable composite), and Group 3 (light-curing glass ionomer cement) showed no statistical significance between them. The difference between control group (packable composite) and Group 4 (flowable compomer) was statistically significant.

Conclusions: Flowable compomer as intermediate lining material can significantly reduce microleakage under packable composite.

Keywords: Compomer, flowable composite, light-curing glass ionomer cement, microleakage, packable composite

Introduction

Scare from potential mercury poisoning, allergy, the environmental impact, and objectionable appearance has all ensured the decreasing use of amalgam alloy in pediatric and restorative dentistry with an increasing need to develop an alternative. Resin composites were introduced as esthetic restorative materials for anterior teeth. However, the growing demand for esthetic restorations and conservative cavities has attracted renewed interest in posterior composites as a desired substitute to amalgams.[1-3]

Esthetic restorative materials are based on adhesive procedures and their clinical success depends on approaches for control of polymerization shrinkage and predictable adhesion. Composite resins demonstrate polymerization shrinkage on curing and the stresses generated threaten marginal integrity, leading to microleakage due to marginal gap formation. Tooth-colored restorations are greatly desired dental service when performed in a predictable manner with no post-operative sensitivity.[4,5]

Marginal percolation, post-operative hypersensitivity, secondary caries, and pathology of pulp all are potential consequences of microleakage. For this purpose, adequate sealing is indispensable for peak clinical performance.[6,7]

There have been continuous improvements in the properties of composite materials since their introduction. However, microleakage still remains an area of concern, affecting the longevity of composite restorations. Microleakage is not a major concern in restorations when their margins are in enamel, as bonding in enamel is reliable.[8] As stated by Yazici *et al*., a complete and long-lasting seal is difficult to attain when the restoration margins lie on dentine or cementum.[9]

A relatively new generation of resin composites has been introduced to the market with new filler contents that permit them to be packed with more force into prepared cavities. These materials are called packable or condensable resin composites. However, to replace amalgam, it has to demonstrate adequate mechanical properties and the ability to effectively seal the cavity margins. Packable composite resin with their higher viscosity may not adapt well to cavity margins. Therefore, flowable resin-based materials with their increased elasticity, wettability, and low viscosity have been recommended as liners beneath packable composites.[10,11]

Microleakage studies regarding this field have been inconsistent. Some authors support the use of flowable liners,[12-14] others demonstrated no benefit.[15,16] This leads to two questions: Are flowable liners really effective? In addition, if they are effective, what is the best material for this purpose?

Materials and Methods

The materials evaluated in this investigation were one restorative material, three different liner systems, and one bonding system [Table 1].

Sample size, specimen preparation, and criteria of selection

A total of 40 extracted human premolars with the following inclusion criteria were selected: Clinically sound, freshly extracted teeth for orthodontic reason. Teeth were extracted from patients with the age range of 13–16 years. Exclusion criteria were teeth with restorations, caries, cracks, or other defects and patients/parents refused to sign informed consent. All teeth were collected from an orthodontic private dental clinic through a 2 weeks period. A written consent was taken from the patients/parents to use their teeth in the current study. The first author washed the teeth thoroughly under running water immediately after extraction to remove debris, blood and mucous, scaled with periodontal scaler to remove any attached periodontal tissues, plaque, and calculus. The teeth were polished with slurry of pumice with soft polishing brush at low speed, then immersed in 10% formalin for 5 days for disinfection, then finally stored in normal saline solution at room temperature, to be used within one month from extraction.[17]

Microleakage study

Cavity preparation

On the buccal surface of teeth, standardized Class V box-like cavities (3 mm mesial-distal, 2 mm occlusal-gingival, and 1.5 mm depth), without any mechanical retention, were prepared using high-speed cylindrical carbide fissure bur No. 12 (Komet, Germany). Burs were replaced after every 10 preparations. The cavities were standardized using a transparent matrix band into which a window representing the required dimensions was cut into its middle [Figure 1]. The dimensions were measured with Graduated periodontal probe (Martin, Germany). Required area was then cut with a blade No. 12, [Figures 2]. The cementoenamel margins were marked with a thin marker, then cervical margins of the future cavities were extended apically and placed about 0.5 mm beyond the cementoenamel junction (CEJ). With the help of the prepared matrix, a colored marker was used to indicate the area of the window onto the buccal surface of each tooth. Bevel of approximately 0.5 mm was ground at the edge of enamel

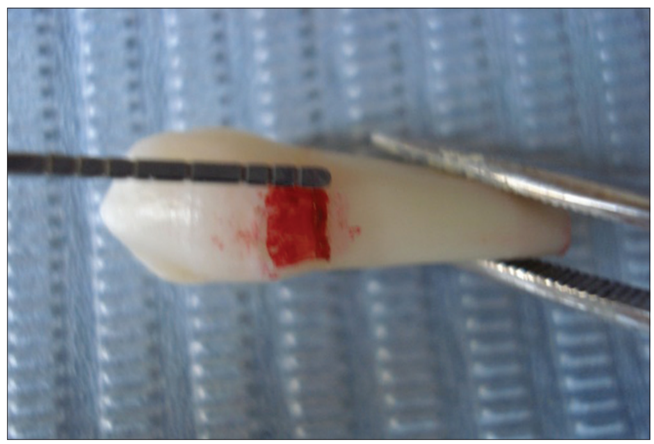

Figure 1: Tooth after Removal from Matrix Band with Marked Cavity Area

Figure 2: Window cut in the transparent No. 1 Band to standardize outer cavity dimensions

Table 1: Materials utilized in the study

Materials	Description	Manufacturer
Heliomolar HB	Light-activated packable resin composite	Ivoclar Vivadent AG, Schaan, Liechtenstein
Heliomolar flow	Light-activated flowable resin composite	Ivoclar Vivadent AG, Schaan, Liechtenstein
Compoglass Flow	Light-activated flowable compomer	Ivoclar Vivadent AG, Schaan, Liechtenstein
Vivaglass Liner	Light-curing glass ionomer cement, which is especially suitable for cavity lining	Ivoclar Vivadent AG, Schaan, Liechtenstein
ExciTE F	Light-curing adhesive in combination with the total-etch technique	Ivoclar Vivadent AG, Schaan, Liechtenstein

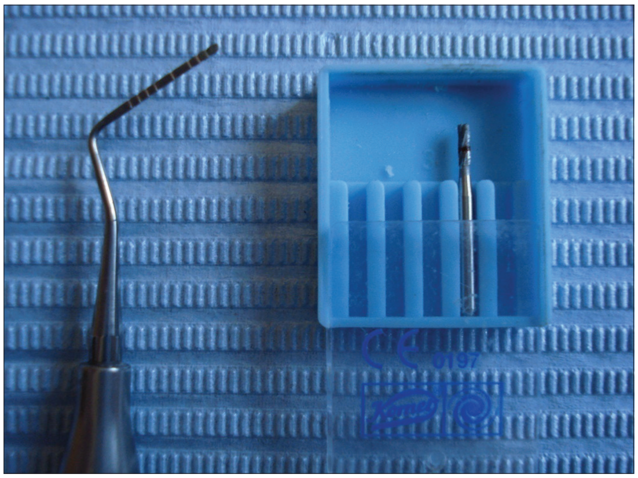

Figure 3: Standardizing the bur by marking the required depth 1.5 mm with permanent marker

margins. The cavity depth was standardized by making a mark on the bur used, at 1.5 mm length [Figure 3].

Grouping of teeth

The 40 prepared teeth were assigned randomly to four equal experimental groups.

Group (1) control: Cavities were filled with packable composite only.

Group (2) cavities were filled with packable composite with flowable composite liner.

Group (3) cavities were filled with packable composite after light-curing glass ionomer liner.

Group (4) cavities were filled with packable composite after flowable compomer liner.

In each group, restorations were placed with the respective restorative material as per manufacturer's instructions, by the first author as follows:

- Before bonding procedures, the prepared cavities were cleaned using water spray, then dried using compressed dry air.
- Excessive drying of the dentin was avoided.
- Manipulation of materials tested in each group was done strictly according to their manufacturer's instructions as follows:

(Group 1, control) Heliomolar HB

- Total etch was applied on enamel and subsequently on dentin with a brush, allowing a reaction time of 30 s on enamel and 15 s on dentin,
- All etchant gel was then removed with vigorous water spray for 30 s,
- Cavity surfaces were then dried with application of two bursts of clean, dry air,
- Excessive drying of the dentin was avoided,
- The etched enamel surface showed chalky white appearance,
- Enamel and dentin were saturated with an even coat of ExciTE,
- The adhesive agitated onto all prepared dentin surfaces for 20 s, then gentle clean dry stream of air for 2 s,
- Pooling or insufficient coverage of adhesive was avoided,
- ExciTE was then cured with halogen light (BlueLuxcer™ Monitex industrial Co., M-835, Taiwan) autoadjustable curing system with built-in radiometer of light intensity of 600 mW/cm³ for 40 s,
- Before application of restorative material, a convenient transparent matrix was selected and checked for extension beyond the cavity margins (Healthco International Inc., USA),
- The necessary amounts of the restorative material were dispensed from the syringe directly into cavities,
- Teflon-coated condenser was used to adapt the material to all of the internal cavity aspects. Cavities were slightly overfilled to permit extension of the material beyond the cavity margins. The transparent matrix was applied on top of the restorative material. The resin composite was light cured for 60 s while maintaining direct contact of the light emitting tip with the transparent cervical matrix,
- All restorations were finished flush to the margins using Optrafine (Ivoclar Vivadent AG, Schaan, Liechtenstein). After finishing the restoration, the teeth were stored in normal saline at room temperature for 24 h

Group 2: Packable composite Heliomolar HB after Heliomolar flow application

Cleaning of the cavity, etching, and adhesive material application was performed as mentioned in previous section.

- Heliomolar flow was applied directly into the cavity, limited to line dentin only and was pre-contoured by round condenser; the increment was limited to approximately 0.5 mm and then light cured for 40 s. Light emission window held as close as possible to the restorative material,

- Etching and adhesive material application then Heliomolar HB was applied as previously described.

Group 3: Packable composite Heliomolar after Vivaglass Liner
- The cavity washed and dried without being desiccated, GC Cavity Conditioner was used to remove the smear layer.
- The standard powder/liquid ratio of 1.4 g/1.0 g was achieved with a level Vivaglass measuring spoon of powder and one drop of liquid onto the mixing pad, holding the bottle vertically when dosing the liquid to avoid the formation of bubbles. Divide the powder into two equal parts. Mix the first half with the liquid for approximately 5–10 s. Add the second half of the powder and mix for another 10–15 s. The total mixing time should not exceed 20 s. More powder was added to obtain a thicker consistency and to shorten working time.
- Vivaglass Liner was applied into the cavity with a suitable applicator.
- Vivaglass Liner was light cured for 20 s and was pre-contoured by round condenser; the increment was limited to approximately 0.5 mm thickness and then light cured for 40 s.
- Etching and adhesive material were applied, then Heliomolar HB was applied as previously described.

Group 4: Packable composite Heliomolar HB after Compoglass Flow application
Cleaning of the cavity, etching, and adhesive material application was done as previously described.
- Compoglass was applied directly into the cavity, limited to line dentin only and was pre-contoured by round condenser; the increment was limited to approximately 0.5 mm thickness and then light cure for 40 s. Light emission window held as close as possible to the restorative material,
- Etching and adhesive material were applied, then Heliomolar HB was applied as mentioned before.

Thermocycling procedures

Manual thermocycling machine (JULABO F25 MP, Germany) [Figure 4] was used for thermal fatigue (5 ± 0.2 and 55 ± 0.2°C for 500 cycle).[18] Distilled water was used as liquid medium within machine compartments. All the samples were aged together. Thermocycling was performed in the Measurement and Standardization Institute, Giza, Egypt.

Assessment of microleakage (marginal integrity assessment)

Microleakage was evaluated using dye penetration method. 2% methylene blue solution was prepared by mixing 2 g of methylene blue powder in 0.1l distilled water. As the prepared solution is acidic, so it was adjusted to pH 7 by buffering with sodium carbonate [Figure 5]. This would prevent demineralization of the tooth structure and associated false readings.

Figure 4: Thermocycling machine used

Figure 5: PH Meter Measuring 2 % Methylene Blue after Buffering

Sealing of teeth
The root apices were sealed with melted impression compound as all the teeth showed open apices with varying degrees. Then, each tooth was totally brushed with three coats of nail varnish (Maybelline Express finish 10017 UK) exposing 1 mm all around the restoration margins. The roots were wrapped with aluminum foil, then one last layer of the varnish was secured to ensure perfect seal against dye penetration.

Dye penetration
All the teeth were dipped in the dye for a period of 24 h 37°C in a thermostat (JULABO F25 MP, Germany) to allow dye penetration into potential gaps at the tooth restoration interface to simulate leakage in an environment close to the oral cavity.

After removal of teeth, the varnish coatings were scraped using periodontal scaler, then washed for 5 min to eliminate all traces of dye then left in air to dry completely for 6 h.

Teeth sectioning
Each tooth was then cut in two halves buccolingually through the center of the restoration parallel to their long axes using

diamond disc at low speed (Lab Micromotor, NSK, Ultimate 500, Nakanishi Inc., Japan) which resulted in 80 specimens. To remove any debris created by sectioning, each sectioned half was swabbed with moistened gauze.

Evaluation of dye penetration

For each sample, the area of interest was photographed by Camera (DP10-Olympus, Japan) positioned on a stereo microscope (SZ-PT, Olympus, Japan) using fixed magnification of ×20 to give total of 80 examined sections. The captured stereo photomicrographs were automatically transferred to computer system. The extent of dye penetration was evaluated by scoring system ranging from 0 to 3 [Figure 6].

80 photographs were examined using image analysis software (ImageJ 1.37v NIA, USA) computerized program to calculate the linear dye penetration (LDP) at the tooth restoration interface both occlusally/enamel and cervically/dentin or cementum in millimeters. For each tooth, the higher score and LDP were selected as each tooth was divided into two halves.

Both sections of each restoration were scored and the section with greatest amount of microleakage was recorded as the score for that restoration/tooth. Microleakage scores were recorded for both the enamel and dentin (gingival) margins. The LDP corresponding to higher score was taken to quantify that scores in millimeters (mm) units.

Statistical analysis

The collected data were recorded, tabulated, and statistically analyzed using the SPSS (version 22.0, SPSS Inc., USA). Kruskal–Wallis and Mann–Whitney tests were used for comparisons between groups in case of LDP due to the diversity of the collected data which resulted in high standard deviation, thus non-parametric ANOVA statistical test was more appropriate for analysis.

Results

Samples from each group were presented as shown in Figures 7-10 are stereophotomicrograph at ×20, showing dye penetration at the gingival (cervical) and occlusal margins of samples representing different tested groups. Leakage scores and LDP in millimeters at both margins are recorded beside each figure.

Table 2 shows the effect of restorative materials on the microleakage at the occlusal margins. Statistical analysis performed using Chi-square test to compare the leakage score of different restorative systems used at the occlusal margin showed that there was statistical significant difference between packable composite and light-curing glass ionomer.

Table 3 shows the effect of restorative materials on the microleakage at the cervical margins. Statistical analysis performed using Chi-square test to compare the leakage scores of different restorative systems at the cervical margins showed that there was statistical significance difference between packable composite and flowable compomer.

Discussion

In this study, we used packable composite as a filling material in Class V cavities, with margins ending on both enamel and dentin were prepared, even though the packable composite resin materials are not marketed to be used in such preparations. This allowed us to assess the behavior of restorative materials used in a high C-factor situation, permitted for easy standardization of the cavity design[19] and also to locate cavity margin in enamel and dentin or cementum to test leakage in both margins.

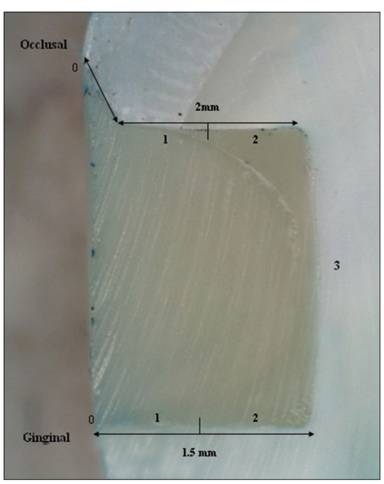

Figure 6: Scoring system used; 0=No evidence of dye penetration. 1=Dye penetration up to less than half the cavity depth. 2=Dye penetration up to more than half the cavity depth, but not extending to the axial wall. 3=Dye penetration up to the axial wall and beyond

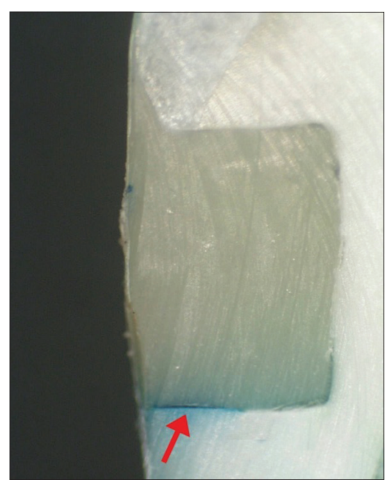

Figure 7: Stereophotomicrograph showing dye penetration at the cervical and occlusal margins for packable composite Heliomolar HB (control group). Occlusal score=0, occlusal linear dye penetration (LDP)=0 mm, gingival score=1, gingival LDP=0.731 mm

Table 2: Statistical analysis of the effect of different restorative groups on the leakage score along the tooth-restoration interface at the occlusal/enamel margins

Score	Restorative materials (occlusal/enamel)				
	Packable composite	F. composite	Light-curing glass ionomer	F. compomer	Total
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
0	8 (80.00)	8 (80.00)	7 (70.00)	10 (100.00)	33 (82.50)
1	0 (0.00)	2 (20.00)	3 (30.00)	0 (0.00)	5 (12.50)
2	2 (20.00)	0 (0.00)	0 (0.00)	0 (0.00)	2 (5.00)
3	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)
Total	10 (100.0)	10 (100.0)	10 (100.0)	10 (100.0)	40 (100.0)
Chi-square χ_2			15.553		
P value			0.016*		
Packable and F. composite	**Packable and light-curing glass ionomer**	**Packable and F. compomer**	**F. composite and light-curing glass ionomer**	**F. composite and F. compomer**	**Light-curing glass ionomer and F. compomer**
0.063	0.03*	0.237	0.95	0.237	0.105

*Significant (P<0.05), **highly significant (P<0.01*)

Table 3: Statistical analysis of the effect of different restorative groups on the leakage score along the tooth-restoration interface at the cervical/dentin or cementum margins

Score	Restorative materials (cervical/dentin or cementum)				
	Packable composite	F. composite	Light-curing glass ionomer	F. compomer	Total
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
0	1 (10.00)	3 (30.00)	3 (30.00)	2 (20.00)	9 (22.50)
1	2 (20.00)	0 (0.00)	5 (50.00)	8 (80.00)	15 (37.50)
2	5 (50.00)	3 (30.00	0 (0.00)	0 (0.00)	8 (20.00)
3	2 (20.00)	4 (40.00)	2 (20.00)	0 (0.00)	8 (20.00)
Total	10 (100.0)	10 (100.0)	10 (100.0)	10 (100.0)	40 (100.0)
Chi-square χ^2			30.985		
P value			<0.001*		
Packable and F. composite	**Packable and light-curing glass ionomer**	**Packable and F. compomer**	**F. composite and light-curing glass ionomer**	**F. composite and F. compomer**	**Light-curing glass ionomer and F. compomer**
0.244	0.25	0.003**	0.008**	<0.001**	0.159

*Significant (P<0.05), **highly significant (P<0.01*)

Moreover, thermocycling (artificial aging) procedure has been used to simulate what happens in the patient's mouth. The restorative materials continuously undergo alterations as a result of thermal insults in the oral cavity, as a result of exposure to food and fluids at different temperatures.[20] Laboratory simulations thermally stress the tooth-restoration interface by subjecting the restored tooth to thermal changes consistent with intraoral temperature changes and determine the relationship between coefficient of thermal expansion between the tooth and restorative material.[18]

This study agrees with other studies[8-10,13] on microleakage in relation to resin composite restorations in that it found leakage to be the rule rather than the exception. Furthermore, in keeping with previous work, microleakage could not be totally eliminated by variation in different intermediate materials used.

Packable composite demonstrated satisfactory adhesion to enamel margins although 20% of cavities showed leakage. This could be explained on the basis that polymerization shrinkage due to contraction of the resin during curing resulted in the formation of a marginal gap which can ultimately lead to increased microleakage. When the material is in more rigid state, most of the polymerization cannot be observed and is transmitted to the adhesive interface. Hence, the release of contraction stresses, during thermocycling, might be responsible for opening a marginal gap and microleakage even if the margins were in enamel.[21,22]

Etching of the beveled enamel margins was achieved using 37% phosphoric acid gel and rinsed. This ensured the removal of smear layer and formation of a porous layer. The adhesive easily infiltrates into these microporosities forming resin tags

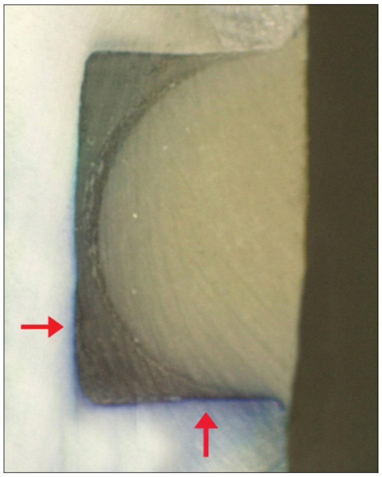

Figure 8: Stereophotomicrograph showing dye penetration at the cervical and occlusal margins of flowable composite Heliomolar flow (Group 1). Occlusal score=0, occlusal linear dye penetration=0 mm, gingival score=3, gingival linear dye penetration=2.571 mm

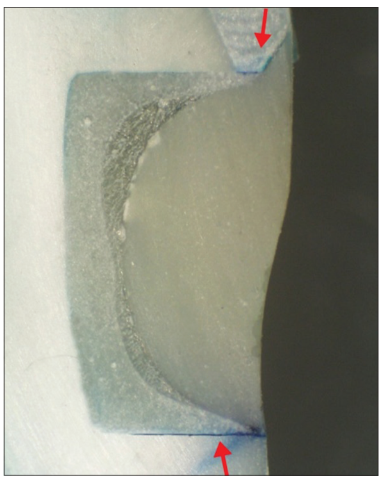

Figure 9: Stereophotomicrograph showing dye penetration at the cervical and occlusal margins of Vivaglass light-curing glass ionomer liner (Group 2). Occlusal score=0, occlusal linear dye penetration=0.482 mm, gingival score=2, gingival score=1.391 mm

on polymerization that interlocks with the acid-etched enamel surfaces. The result is a resin-enamel hybrid layer. Many *in vitro* investigations are consistent with our study that acid etching with phosphoric acid provides a long-lasting marginal seal.[21,22] 37% phosphoric acid etches the enamel deeper when compared to self-etching primer, allowing deeper penetration of resin forming longer and wider tags.[23]

Packable composite alone without intermediate material demonstrated the highest microleakage gingivally. This is in accordance with previous studies.[24,25] It follows that packable composite, being relatively a rigid material, with high modulus of elasticity can intensely stress the adhesive interface. The bond strength, if inadequate, allows the marginal seal to be interrupted, leading to microleakage. It has been proposed that the incorporation of an "elastic" basal layer may act as a "shock" absorber against functional loading and internal tensions triggered by polymerization. Furthermore, materials with a lower modulus of elasticity are said to be more flowable and undergo plastic deformation. This inherent flow, which allows the molecules to slip into new positions and orientations, compensates for any stresses caused by polymerization shrinkage, thereby allowing for the maintenance of the adhesive bond.[21,25-28]

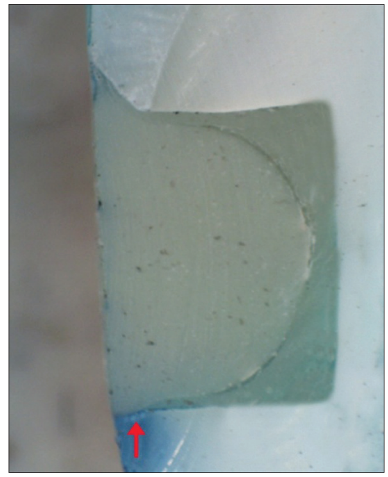

Figure 10: Stereophotomicrograph showing dye penetration at the cervical and occlusal margins of flowable compomer (Compoglass Flow) (Group 3). Occlusal score=0, occlusal linear dye penetration (LDP)=0 mm, gingival score=1, gingival LDP=0.554 mm

However, fluid composites are more prone to shrinkage than traditional composites because they have less filler loading. The use of a relatively thin layer can minimize this effect. The current study revealed that flowable resin composite as an intermediate material under packable composite resin did not reduce microleakage significantly at the occlusal or the gingival margins compared to using packable composite resin alone. These results are in agreement with other studies.[29-31]

The current study contradicts those of Leevailoj *et al*. and Unlu *et al*. who found that flowable resin liner helped in reducing microleakage in all resin composite restoration at the cervical margin. However, in these two studies, the cavity margins were placed 0.5 mm above CEJ.[14,32]

Tredwich found that flowable resin composite liner, when placed in cavities with cementum or dentin margins, was associated with more microleakage as flowable resin composite undergoes more shrinkage than traditional composite because of its low filler content. Such variations in reported findings may be due to difference in materials quality, cavity types, cavity location or site, and operator skills.[33]

The current study revealed that the use of light-curing glass ionomer cement as intermediate material under packable resin composite did not reduce microleakage significantly at the occlusal or at the gingival margins compared to using packable resin composite alone. These findings were consistent with those of Chuang *et al*.[15] At the gingival margin, light-curing glass ionomer cement had lower microleakage than flowable composite.

For the liner to be effective, it must not debond under polymerization stresses to create a gap at the liner-tooth or liner-composite interface. Flowable composites require a resin-bonding agent, whereas light-curing glass ionomer cement liners are self-adhesive, eliminating the need for bonding. Light-curing glass ionomer cement has low shrinkage and lower adhesion than the flowable composites.

Another requisite for a liner is a low modulus of elasticity. This permits it to act as a stress absorber for the polymerization forces, reducing the chances of gap formation, and cuspal deformation.[34] Light-curing glass ionomer cement materials have a low modulus of elasticity and a dual-setting reaction that gives light-curing glass ionomer cement an extended period of maximum flexibility to absorb stresses from the adjacent shrinking composite. Light-curing glass ionomer cement undergoes controlled hygroscopic expansion after complete polymerization in a humid environment and this allows additional compensation for the polymerization shrinkage.[35] The modulus of elasticity of flowable composites is significantly higher than light-curing glass ionomer cement, making them less effective at counteracting the polymerization shrinkage. Furthermore, their higher polymerization shrinkage makes them less effective than light-curing glass ionomer cement in preventing cusp deformation.

Light-curing glass ionomer cement possesses a coefficient of thermal expansion similar to a natural tooth, decreasing the potential for microleakage. Clinically, light-curing glass ionomer cement and flowable composites have shown superior performance when compared with composite restorations without a liner.[36]

Among the experimental groups in this study, packable composite with flowable compomer as intermediate material exhibited significantly the lowest microleakage. This is in agreement with Chuang *et al*.[15] the adhesive properties of compomer may affect the leakage pattern. The bonding mechanism between a tooth and a compomer is accomplished through the ion reaction of the carboxyl groups to the calcium ions in the enamel and dentin tissues. Manufacturer instructions for Compoglass Flow state that this restorative system can be used with or without acid conditioning. However, in this study, dentin conditioning of the cavity walls was performed before applying Compoglass Flow. Owens et al. found greater marginal leakage when compomer restorative material was used without an acidic conditioner. Therefore, etching the cavity may further improve the adaptation of the compomer materials.[37,38]

The bonding between restorative material and tooth structure may be subjected to stresses due to differences in their coefficient of thermal expansion resulting in an interfacial gap, and microleakage.[39] The combination of the packable composite with the flowable compomer group showed the least microleakage at the cervical margin and overall leakage reduction. Compomer and tooth structure have similar coefficient of thermal expansion compared to the resin composites. This may be significant for maintaining marginal integrity in thermocycling. Furthermore, the amount of resin content and filler particles of the materials placed at the cavosurface margin might affect the amount of microleakage, as polymerization shrinkage increase with increased resin content. The fact that compomer has a smaller resin component than traditional composite material may contribute to the reduced microleakage scores found in this study with the compomer liner.

Marginal integrity has inverse relation with the elastic modulus of the composite, and therefore, materials with a high elastic modulus produce high shrinkage stresses and less deformation if strained equally. On the contrary, packable composites and compomers possess a lower modulus of elasticity, which could be responsible for reduced contraction stress during curing and may also provide an additional buffer during masticatory loading as a result of its elastic deformation.[40]

In our study, microleakage was significantly lesser in enamel than in dentine or cementum margins. This is in agreement with previous studies that show that dentinal microleakage remains a significant problem.[24,41]

Enamel is considered a reliable substrate for bonding as enamel possesses higher bond strengths compared to dentin. These significant differences can be attributed to tissue composition. Enamel is composed of hydroxyapatite with minor organic tissue when compared to dentin. Superficial layer of approximately 10 micrometers is removed during acid etching, leaving an irregular high energy surface. Dentin, on the other hand, contains higher amount of water, which is expected to interfere with the adhesive particles.[23]

Hypomineralized and more organic substrate of cementum present in the cervical cavity margins do not provide satisfactory conditions for the micromechanical retention. Even after etching, resin tags were absent in the hybridized layer in the first 150–200 micron from the cervical margin which resulted in low quality of the bonding at this level.[42]

Contraction stresses of composite can also challenge the marginal integrity. Resin-based materials are prone to shrinkage, as related to chemistry of the polymerization reaction. It is proven that some amount of the polymerization shrinkage can be absorbed through the material if its molecules are free to flow at the exposed surfaces of the restoration. When the material is in a more rigid state, most of the polymerization shrinkage cannot be compensated for and is subsequently transmitted to the adhesive interface. This can cause opening of marginal gaps or microfractures.[43]

Conclusion

The results of this study with respect to the materials and methods used showed: Microleakage in resin composite restorations was found to be the rule rather than the exception, especially at the cervical (gingival) margins. Flowable compomer material as intermediate layer underneath the more rigid composite filling significantly reduces microleakage of the restorations. The flowable composite and resin-modified glass ionomer did not significantly reduce marginal microleakage underneath packable composite. Restoring cavities with gingival margins located in dentin still present a clinical challenge in achieving perfect and long-standing bonding.

Recommendations

1. When microleakage is the main concern with composite restorations, lining the cavities with flowable compomer effectively overcomes this problem.
2. The present study is *in vitro* in nature and cannot allow definite conclusions to be made. Long-term experimental studies are recommended.
3. Further, research is required to overcome the gingival leakage of composite restoration completely.

References

1. Mortazavi G, Mortazavi SM. Increased mercury release from dental amalgam restorations after exposure to electromagnetic fields as a potential hazard for hypersensitive people and pregnant women. Rev Environ Health 2015;30:287-92.
2. Rathore M, Singh A, Pant VA. The dental amalgam toxicity fear: A myth or actuality. Toxicol Int 2012;19:81-8.
3. Brownawell AM, Berent S, Brent RL, Bruckner JV, Doull J, Gershwin EM, *et al.* The potential adverse health effects of dental amalgam. Toxicol Rev 2005;24:1-0.
4. Soares CJ, Faria-E-Silva AL, Rodrigues MP, Vilela ABF, Pfeifer CS, Tantbirojn D, *et al.* Polymerization shrinkage stress of composite resins and resin cements - what do we need to know? Braz Oral Res 2017;31:e62.
5. Schneider LF, Cavalcante LM, Silikas N. Shrinkage stresses generated during resin-composite applications: A Review. J Dent Biomech 2010;2010: pii: 131630.
6. Patel MU, Punia SK, Bhat S, Singh G, Bhargava R, Goyal P, *et al.* An *in vitro* evaluation of microleakage of posterior teeth restored with amalgam, composite and zirconomer - A stereomicroscopic study. J Clin Diagn Res 2015;9:ZC65-7.
7. Eakle WS, Ito RK. Effect of insertion technique on microleakage in mesio-occluso-distal composite resin restoration. Quintessence Int 1990;21:369-74.
8. Scotti N, Comba A, Gambino A, Paolino DS, Alovisi M, Pasqualini D, *et al.* Microleakage at enamel and dentin margins with a bulk fills flowable resin. Eur J Dent 2014;8:1-8.
9. Yazici AR, Celik C, Ozgünaltay G. Microleakage of different resin composite types. Quintessence Int 2004;35:790-4.
10. Arora R, Kapur R, Sibal N, Juneja S. Evaluation of microleakage in class II cavities using packable composite restorations with and without use of liners. Int J Clin Pediatr Dent 2012;5:178-84.
11. Hoseinifar R, Mortazavi-Lahijani E, Mollahassani H, Ghaderi A. One year clinical evaluation of a low shrinkage composite compared with a packable composite resin: A Randomized clinical trial. J Dent (Tehran) 2017;14:84-91.
12. Tung FF, Estafan D, Scherer W. Microleakage of a condensable resin composite: An *in vitro* investigation. Quintessence Int 2000;31:430-4.
13. Tung FF, Estafan D, Scherer W. Use of a compomer in class V restoration: A microleakage study. Quintessence Int 2000;31:668-72.
14. Leevailoj C, Cochran MA, Matis BA, Moore BK, Platt JA. Microleakage of posterior packable resin composites with and without flowable liners. Oper Dent 2001;26:302-7.
15. Chuang SF, Jin YT, Lin TS, Chang CH, García-Godoy F. Effects of lining materials on microleakage and internal voids of class II resin-based composite restorations. Am J Dent 2003;16:84-90.
16. Chuang SF, Liu JK, Chao CC, Liao FP, Chen YH. Effects of flowable composite lining and operator experience on microleakage and internal voids in class II composite restorations. J Prosthet Dent 2001;85:177-83.
17. El Sayed HY, Abdalla AI, Shalby ME. Marginal microleakage of composite resin restorations bonded by desensitizing one step self-etch adhesive. Tanta Dent J 2014;11:180-8.
18. Wahab FK, Shaini FJ, Morgano SM. The effect of thermocycling on microleakage of several commercially available composite class V restorations *in vitro*. J Prosthet Dent 2003;90:168-74.
19. Feilzer AJ, De Gee AJ, Davidson CL. Setting stress in composite resin in relation to configuration of the restoration. J Dent Res 1987;66:1636-9.
20. Sidhu SK, Carrick TE, McCabe JF. Temperature mediated coefficient of dimensional change of dental tooth-colored restorative materials. Dent Mater 2004;20:435-40.
21. Dietschi D, Monasevic M, Krejci I, Davidson C. Marginal and internal adaptation of class II restorations after immediate or delayed composite placement. J Dent 2002;30:259-69.
22. Nakabayshi N, Pashley DH. Hybridization of dental hard tissues. Quintessence Int 1998;30:361-9.
23. Li Q, Jepsen S, Albers HK, Eberhard J. Flowable materials as an intermediate layer could improve the marginal and internal adaptation of composite restorations in class-V-cavities. Dent Mater 2006;22:250-7.
24. Attar N, Turgut MD, Güngör HC. The effect of flowable resin composites as gingival increments on the microleakage of posterior resin composites. Oper Dent 2004;29:162-7.
25. Neme AM, Maxson BB, Pink FE, Aksu MN. Microleakage of class II packable resin composites lined with flowables: An *in vitro* study. Oper Dent 2002;27:600-5.
26. Feilzer AJ, De Gee AJ, Davidson CL. Quantitative determination of stress reduction by flow in composite restorations. Dent Mater 1990;6:167-71.
27. Hilton TJ. Packable composites. J Esthet Restor Dent 2001;13:69-75.
28. Hilton TJ, Ferracane JL. Cavity preparation factors and microleakage of class II composite restorations filled at intraoral temperatures. Am J Dent 1999;12:123-30.
29. Loguercio AD, Zago C, Leal K, Ribeiro NR, Reis A. One-year clinical evaluation of a flowable resin liner associated with a microhybrid resin in noncarious cervical lesions. Clin Oral Investig 2005;9:18-20.
30. Peris AR, Duarte S Jr. de Andrade MF. Evaluation of marginal microleakage in class II cavities: Effect of microhybrid, flowable, and compactable resins. Quintessence Int 2003;34:93-8.
31. Ziskind D, Adell I, Teperovich E, Peretz B. The effect of an intermediate layer of flowable composite resin on microleakage in packable composite restorations. Int J Paediatr Dent 2005;15:349-54.
32. Unlu N, Krakaya S, Ozer F, Say EC. Reducing microleakage in composite resin restorations: An *in vitro* study. Eur J Prosthodont

Restor Dent 2003;11:171-5.

33. Tredwin CJ, Stokes A, Moles DR. Influence of flowable liner and margin location on microleakage of conventional and packable class II resin composites. Oper Dent 2005;30:32-8.
34. Alex G. Adhesive dentistry: Where are we today? Compend Contin Educ Dent 2005;26:150, 152-5.
35. Tolidis K, Nobecourt A, Randall RC. Effect of a resin-modified glass ionomer liner on volumetric polymerization shrinkage of various composites. Dent Mater 1998;14:417-23.
36. Diwanji A, Dhar V, Arora R, Madhusudan A, Rathore AS. Comparative evaluation of microleakage of three restorative glass ionomer cements: An *in vitro* study. J Nat Sci Biol Med 2014;5:373-7.
37. Owens BM, Halter TK, Brown DM. Microleakage of tooth-colored restorations with a beveled gingival margin. Quintessence Int 1998;29:356-61.
38. Witcht MJ, Fritz UB, Noack MJ. Influence of enamel etching on class V Dyract restorations. J Dent Res 1998;77:189.
39. Demarco FF, Ramos OL, Mota CS, Formolo E, Justino LM. Influence of different restorative techniques on microleakage in class II cavities with gingival wall in cementum. Oper Dent 2001;26:253-9.
40. Blunk U, Roulet JF. Marginal adaptation of compomer class V restorations *in vitro*. J Adhes Dent 1999;1:143-51.
41. Pamir T, Türkün M. Factors affecting microleakage of a packable resin composite: An *in vitro* study. Oper Dent 2005;30:338-45.
42. Narayana V, Ashwathanarayana S, Nadig G, Rudraswamy S, Doggalli N, Vijai S, *et al*. Assessment of microleakage in class II cavities having gingival wall in cementum using three different posterior composites. J Int Oral Health 2014;6:35-41.
43. Kleverlaan CJ, Feilzer AJ. Polymerization shrinkage and contraction stress of dental resin composites. Dent Mater 2005;21:1150-7.