

The Effect of Two Bulk Fill Resin Composites on Microleakage in Endodontically Treated Teeth

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Abstract: *Purpose:* To evaluate the effect of two bulk fill resin composites on microleakage in endodontically treated Class II restorations.

Materials and Methods: Twenty-four non-carious molars were selected and randomly divided into three groups (n = 8). The Class II cavity preparations were made with the cervical margin 1 mm below the cementum-enamel junction, and endodontic treatment was performed using a resin-based sealer and gutta-percha points. In Group 1 (Control), resin composite (G-aenial Posterior; GC Corp., Tokyo, Japan) was applied to the interproximal wall, and then restorative material was applied incrementally. In Group 2, resin composite was applied to the interproximal wall, followed by a 4-mm-layer of a bulk fill flowable composite (x-tra base; Voco, GmbH, Cuxhaven, Germany) and the remaining occlusal part of the cavity was filled with resin composite. In Group 3, resin composite was applied to the interproximal wall, followed by a 4mm layer of a bulk fill fiber-reinforced composite (everX Posterior; GC Corp., Tokyo, Japan), and the remaining occlusal part of the cavity was filled with a resin composite. The restorations were then subjected to 500 thermal cycles, each with a dwell time of 20 seconds at 5 and 55 °C. The adaptation at the cervical margin was evaluated by dye penetration, and one tooth was used to evaluate the restorative material interface using SEM. The data were statistically analyzed using the Kruskal Wallis test (p < 0.05).

Results: No significant difference in dye penetration was found between the control and the experimental groups. Microleakage was significantly higher on enamel margins compared with the dentin margins for all of the groups.

Conclusion: The use of bulk fill restorative materials under resin composites does not affect the sealing ability of restorations.

Keywords: Short fiber composite, Leakage, Resin based material.

INTRODUCTION

Endodontic treatment is generally performed on teeth significantly affected by caries, multiple repeat restorations and/or fractures [1]. Kirkevang *et al.* evaluated the relationship between the quality of endodontic and coronal restorations and periapical status, demonstrating the significance of coronal restoration quality in the incidence of apical periodontitis as well as the significance of root canal treatment quality [2]. Endodontically treated teeth can be restored with either indirect or direct restorations. With direct resin composite restorations, polymerization shrinkage and shrinkage stress can cause gap formation and microleakage, which can result in secondary caries, post-operative sensitivity, and clinical failure of the restoration. New resin composites and adhesive materials have been developed to improve marginal adaptation, reduce polymerization shrinkage

and shrinkage stress and work effectively on enamel, dentin and cement in Class II direct composite restorations [3,4].

In addition to improvements in the restorative materials, new restoration application techniques have also been designed to reduce marginal leakage. In deep Class II mesio-occlusaldistal (MOD) restorations, the use of resin composites can decrease the curing light intensity depending on the depth of the material [5]. The intensity of light at a given depth and for a given irradiance period is a critical factor in determining the degree of monomer conversion and is significantly associated with the mechanical properties, biocompatibility, color stability and thus the clinical success of a restoration [5-7]. Consequently, it is important to achieve sufficient irradiance on the bottom surface of each of the incremental layers used to build up the restoration [5]. To ensure the ease of use, current improvements in resin composites by manufacturers have resulted in bulk fill flowable composite bases that are marketed for use beneath

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conventional resin-based composite materials, with a reported depth of cure in excess of 4 mm [8-11].

Recently, a short fiber-reinforced composite material (everX Posterior, GC Corp., Tokyo, Japan) was introduced for use with the bulk filling technique [12]. This restorative material is intended to be used as a base-filling material in high stress-bearing areas, especially in large cavities of vital and non-vital posterior teeth [12]. The restoration base should be a maximum of 4 mm thick ("cavity lining") for Class I and II composite restorations and must be covered with a wear-resistant, polishable restorative composite, such as GC G-aenial Posterior or GC Kalore. The composite layer should be 1-2 mm on the occlusal surface [13]. EverX Posterior consists of a combination of a resin matrix, randomly orientated E-glass fibers and inorganic particulate fillers [5]. The resin matrix contains bis-GMA, TEGDMA and PMMA, forming a matrix referred to as a semi-interpenetrating polymer network (semi-IPN), which provides good bonding properties and improves the toughness of the polymer matrix [14,15].

The low-viscosity, flowable composite x-tra base (Voco, GmbH, Cuxhaven, Germany) (filler content: 75% by weight) is a flowable composite with reduced shrinkage on a traditional methacrylate base. It is indicated for use in the bulk filling technique to introduce a maximum 4-mm-thick restoration base ("cavity lining") in Class I and II composite restorations. After curing, x-tra base must be covered in the region of the occlusal anatomy by another layer of a methacrylate-based hybrid composite at least 2 mm in thickness and suitable for posterior teeth, such as the nanoparticle-modified hybrid composite GrandioSO (Voco, GmbH, Cuxhaven, Germany). X-tra base can also be applied in a first thin layer as a cavity liner in Class I and II cavities [10,16].

An elastic liner between the tooth structure and composite resin may compensate for contraction stresses and prevent gap formation [17]. The performance of dentin adhesives or a low-viscosity, low-modulus intermediate resin as an elastic barrier between the dentin adhesive and resin-based restorative material has been investigated previously [18,19]. However, the use of flowable resin did not produce gap-free resin margins in Class II cavities or in bulk filled restorations [20].

The restoration of endodontically treated teeth must be designed to maximize the strength of these teeth and increase their longevity [21]. Bulk fill flowable resin-

based composite bases being marketed for use beneath conventional resin-based composite materials have also been recommended for use with endodontically treated teeth [10,13]. Therefore, the aim of this study was to evaluate the effect of two bulk fill resin composites on microleakage in endodontically treated Class II (MO) restorations of premolar teeth.

MATERIALS & METHODS

Twenty-four sound human upper premolars with fully developed apexes extracted for orthodontic reasons were selected for this study. After extraction, they were hand-scaled to remove tissue remnants and stored at 4 °C in a 0.5% aqueous chloramine T solution until further use.

Before preparing the teeth, an outline of the cavity was drawn with a lead pencil, and parallel-sided standardized MO cavities were prepared using a diamond bur (835-012-4, Diatech, Switzerland) in a high-speed hand piece under an air-water spray. The buccolingual width of the cavity was 4 ± 0.1 mm on the occlusal and gingival sides. The gingival wall was 3.5 ± 0.2 mm deep to the axial wall. The bur was replaced after every fourth cavity preparation to ensure high cutting efficacy. The facial and lingual walls of the occlusal segment were prepared in parallel. The cavosurface margins were prepared at 90°, and all of the internal angles were rounded.

After the preparations, a conservative endodontic access was performed on the pulp chamber wall. Next, all of the canals were prepared using a Pro-Taper Ni-Ti Rotary System (Dentsply Malleifer) and obturated with an AH 26 sealer (Dentsply; DeTrey, Konstanz, Germany) and gutta-percha using a lateral compaction technique. Following the endodontic treatments, the coronal root canal openings were sealed with a thin layer of conventional glass ionomer cement (Ketac Molar Easy Mix, 3M Espe, St. Paul, MN, USA), and then the teeth were randomly divided into three groups (n = 7) according to the restorative materials that were used.

Group 1 (Controls)

After drying the prepared tooth surfaces by gentle blowing with an air syringe, a single-step self-etch adhesive (G-aenial Bond, GC Corp., Tokyo, Japan) was applied to the enamel and dentin surfaces using a disposable applicator. Ten seconds after the application, the adhesive was dried thoroughly for 5 seconds with oil-free air under maximum air pressure

and light cured for 10 s with a quartz-tungsten-halogen (QTH) curing light (Optilux 501, SDS/Kerr, Danbury, CT, USA) according to the manufacturer's instructions. After adhesive polymerization, a metal matrix band (Adapt SuperCap Matrices, Kerr, Bioggio, Switzerland) was placed around the tooth. A thin layer of a resin composite (G-aenial Posterior GC Corp., Tokyo, Japan) was applied toward the metallic matrix contacting the cavosurface of the proximal box up to one third of the occlusal-cervical extension. The other two layers were applied over the previous increment contacting the cavosurface margin of the proximal box and forming the marginal ridge. Using the centripetal technique, the mesial wall (approximately 1 mm thick) of the restoration was completed, and the cavity was turned into a class I thereafter. Then, three increments of resin composite were applied horizontally. Each increment was light-cured for 20 s.

Group 2

G-aenial Bond was applied to the enamel and dentin surfaces according to the manufacturer's instructions. After the matrix application, the mesial wall of the cavity was created with G-aenial Posterior as previously described. The bulk fill flowable composite x-tra base (Voco GmbH, Cuxhaven Germany) was applied at a 4-mm thickness horizontal to the resulting class I cavity and cured for 20 s. After the flowable composite application, the remaining cavity was restored with resin composite.

Group 3

G-aenial Bond was applied to the enamel and dentin surfaces according to the manufacturer's instructions. After the matrix application, the mesial wall of the cavity was created with G-aenial Posterior as previously described for Group 1. The bulk fill fiber-reinforced composite everX Posterior (GC Corp., Tokyo, Japan) was applied at a 4-mm thickness horizontal to the resulting class I cavity and cured for 20 s. After the fiber-reinforced composite application, the remaining cavity was restored with resin composite.

The restorations were polished using a one-step finishing/polishing system (One Gloss, Shofu Inc., Kyoto, Japan). The restorations were stored in distilled water at 37°C for 24 h and then thermocycled 500 times between 5 and 55 °C with a dwell time of 30 s. After thermocycling, the apices of all of the teeth were sealed with amalgam (YDA Amalgam Alloy Capsules, Hangzhou Yinya New Materials Co. Ltd., Hangzhou, China), and 2 coats of nail polish were applied to within

approximately 1 mm of the tooth/composite interface. Next, the specimens were immersed in a 0.5% aqueous solution of methylene blue at room temperature for 24 h. After removal from the solution, any surface-adhered dye was carefully rinsed away with tap water.

On each restoration, two mesio-distal cuts were prepared longitudinally with a diamond saw mounted in a cutting machine (Isomet, Buehler; Lake Bluff, Illinois, USA). These preparations yielded four evaluation surfaces (28 evaluation surfaces per group) for each restoration. The sections were observed under a stereomicroscope (Olympus SZ61, Olympus Corporation, Tokyo, Japan) at 40× magnification, and microleakage at the occlusal and gingival walls in each section was evaluated by two independent operators according to the following scoring system:

Scores for cervical margins were:

0 = no penetration;

1 = leakage extending within first 1/2 of the cavity wall;

2 = leakage extending beyond 1/2, but not as far as the cervical cavity floor;

3 = leakage extending beyond the cervical cavity Wall and reaching the cavity floor.

For enamel margins, the scores were:

0= no penetration;

1 = leakage extending within first¹/₂ of the enamel wall;

2 = leakage extending beyond 1/2, but not as far as the dentin-enamel junction;

3 = leakage extending beyond the enamel-dentin junction. [22]

For each group one tooth was used for SEM observation of the resin-dentin interface. Preparation for SEM was as follows: The specimens were sectioned vertically in a mesio-distal plane through the center of the restoration and were polished with 600, 800 and 1200 grid silicon carbide abrasive papers under running water and then for high polishing they were treated with 1µ, 0.3µ and 0.05 µ alumina powder using polishing cloths. The specimens were immersed into 10% phosphoric acid solution for 15 seconds and then they were rinsed with water for 15 seconds and

Table 1: Data of distribution, the mean values and standard deviations of enamel and dentin microleakage for each group and pairwise comparisons. Capital letters are the comparison of the groups within the enamel and dentin margins ($p>0.05$). Within a row, values having different lower case exhibited statistically significant difference ($p<0.05$); comparison of the same groups between enamel and dentin

Adhesive system	Groups	Enamel leakage scores								Dentin leakage scores						
		n	0	1	2	3	Mean	SD	*	0	1	2	3	Mean	SD	*
G-aenial Bond	G1	28	0	5	8	15	2.36	.78	Aa	6	9	6	7	1.5	1.11	Ab
	G2	28	1	3	13	11	2.21	.77	Aa	8	5	6	9	1.57	1.23	Ab
	G3	28	0	0	17	11	2.39	.49	Aa	3	13	8	4	1.46	.88	Ab

dried for 10 seconds. Afterwards, specimens were treated with 10% sodium hypochlorite for 30 seconds, rinsed thoroughly with water and fixed in glutaraldehyde solution (pH 7.4) for two hours. Then they were dehydrated through ascending series of ethanol (25% to 100%) and dried at room temperature for 24 hours. Following the drying procedure, the samples were sputter-coated with gold (Emitech K-550X sputter coater; Emitech, Ashford, UK), operating at 20kV under SEM (JEOL JCM-5000 NeoScope™, JEOL, Tokyo, Japan) with various magnifications.

Statistical analysis was carried out using the Kruskal-Wallis test to determine statistically significant differences in leakage at the occlusal and gingival margins separately among groups for each dentin adhesive, and between the three dentin adhesives for the same groups. An intergroup comparison of occlusal versus gingival margin locations was completed using the Wilcoxon signed-rank test. All the statistical tests were performed at a $p<0.05$ level of significance.

RESULTS

The distribution data, mean values and standard deviations for the enamel and dentin microleakage for each group as well as pairwise comparisons are shown in Table 1.

For the enamel and dentin margins, there were no significant differences among the tested groups. In contrast, a significant difference between the enamel and dentin microleakage was observed in all three groups (Figure 1).

The SEM images of the interfaces treated with G-Aenial Bond for the three groups are shown in Figures 2-4. In Group 1, the adhesive layer (AL) was uniform; however, there were gap formations between the AL and the enamel (Figure 2a). Figure 2b shows that the hybrid layer (HL) was very thin, although the AL was uniform and thick. In addition, a uniform contact was observed between the AL and the composite, although

voids in the AL and resin tags were clearly visible. In Group 2, there was a gap between the AL and enamel (Figure 3a). In the dentin margins, the AL, HL and resin tag formation were visible, although there was a breakdown in the AL. In Group 3, gap formation occurred in the enamel margin (Figure 4a), as was observed for the other groups. In Figure 4b, a non-uniform HL and AL were observed with gap formations noted between these 2 layers.

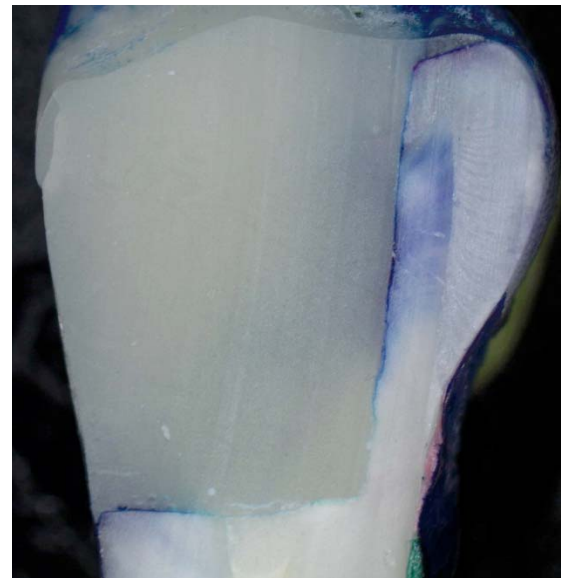


Figure 1: Typical dye leakage; enamel score 3, cervical score 1.

DISCUSSION

Different restorative materials and techniques are used for the coronal restoration of endodontically treated teeth. A coronal restoration after endodontic treatment can prevent the movement of bacteria and their products and also reinforce the residual tooth structure. Therefore, the long-term prognosis of endodontically treated teeth depends on the quality of the final restoration [23-26]. In endodontically treated teeth, the volume of the restoration is larger and more resin increments are required to fill the cavity preparation. Therefore, endodontic treatment causes

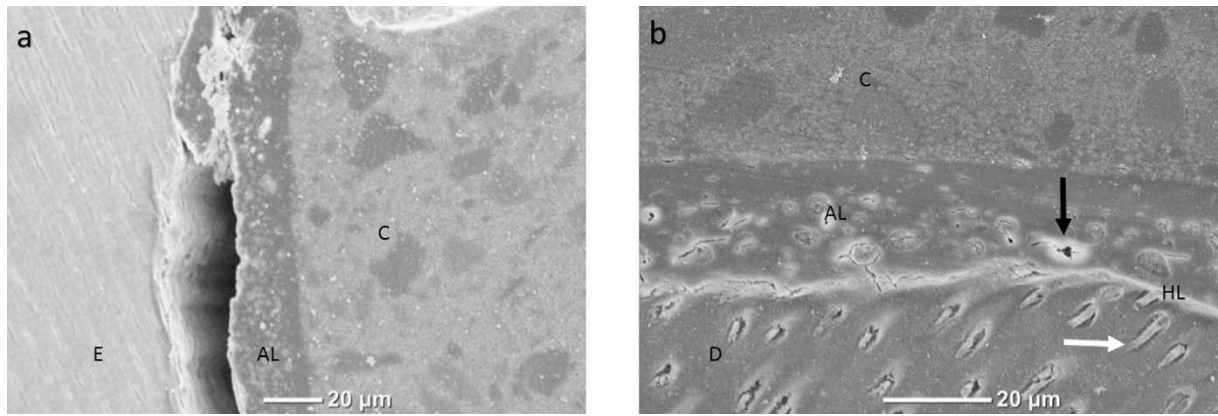


Figure 2: (a) SEM image enamel-G-Aenial Bond -resin composite interface in Group 1. (C-Composite, AL-Adhesive Layer, E-Enamel); (b) SEM image of dentin- G-Aenial Bond interface in Group 1. (black arrow-Voids, C-Composite, D-Dentin, AL-Adhesive Layer, HL-Hybrid Layer).

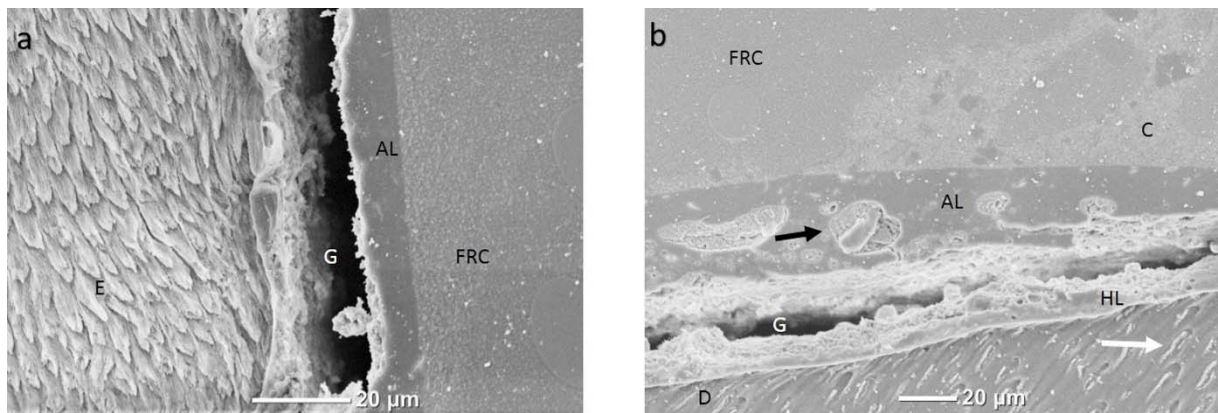


Figure 3: (a) SEM image enamel-G-Aenial Bond -resin composite interface in Group 2. (FRC-Fiber reinforced composite, AL-Adhesive Layer, E-Enamel, G-Gap formation); (b) SEM image of dentin- G-Aenial Bond interface in Group 2. (black arrow-Voids, FRC-Fiber reinforced composite, C-Composite, D-Dentin, AL-Adhesive Layer, HL-Hybrid Layer, G-Gap formation).

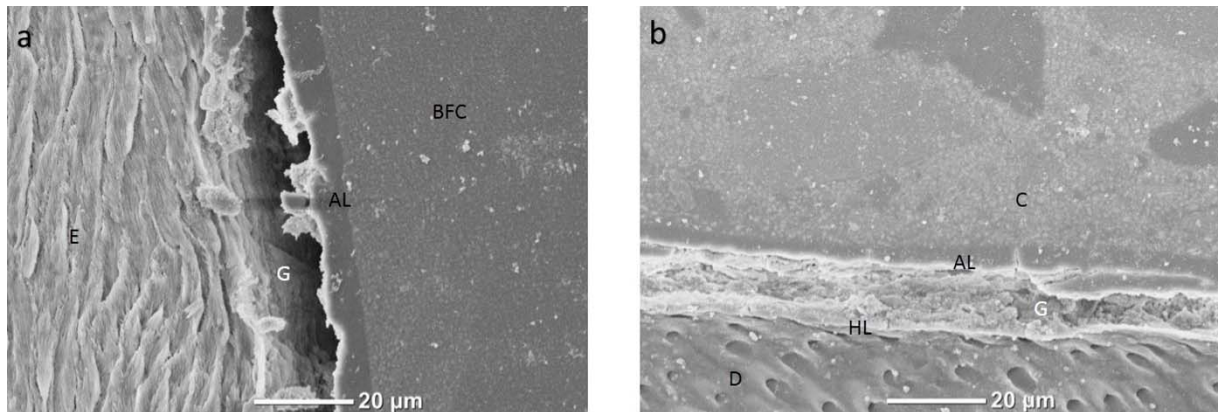


Figure 4: (a) SEM image enamel-G-Aenial Bond -resin composite interface in Group 3. (BFC-Bulk fill composite, AL-Adhesive Layer, E-Enamel, G-Gap formation); (b) SEM image of dentin- G-Aenial Bond interface in Group3. (C-Composite, D-Dentin, AL-Adhesive Layer, HL-Hybrid Layer).

the loss of the roof of the pulp chamber and may flex due to shrinkage stresses. All these factors may affect the marginal quality of bonded restorations in endodontically treated teeth [22]. In the present study, there were no statistically significant differences observed among the three groups with respect to

enamel or dentin. In addition, compared with the control group (Group 1), the use of new bulk fill resin-based composites (Group 2 and Group 3) with a 4 mm bulk placement did not increase marginal leakage. Therefore, it could be argued that the bulk fill resin-based composites may improve the marginal sealing

capacity of restorations in class II cavities. Consistent with these findings, it has been reported that a bulk fill resin-based composite used as a 4 mm bulk fill dentine replacement performs well with respect to marginal quality [27]. Also in support of the present study findings, Moorthy *et al.* demonstrated that class II cavities filled with a resin-based composite (GrandioSO) with an oblique increment revealed no significant difference compared with a bulk fill flowable resin-based composite (e-xtra base) with a 2mm single increment [8]. It has been reported that the placement of a flowable compomer as a liner beneath its packable counterpart results in the least amount of overall leakage compared with other material combinations when a flowable composite is used as a liner [28]. Furthermore, the C-factor may be reduced by the use of flowable materials as a liner underneath resin composites where the C-factor is the ratio of bonded to unbonded surfaces linked by the increment of composite being cured. Increments linking fewer surfaces are considered to have a reduced C-factor, leading to a reduction in polymerization stress and associated problems. Reducing the C-factor may lower the internal stresses within a restoration [29-31]. These observations may explain the findings of the present study that the levels of microleakage associated with bulk fill resin-based materials were similar to that of the control group.

In the present study, there were statistically significant differences observed between the microleakage of the occlusal and gingival margins for all three of the treatment groups; the microleakage scores for the gingival margins were significantly lower than the microleakage scores for the occlusal margins. In agreement this finding, Demirci *et al.* demonstrated that G-aenial Bond resulted in higher microleakage for enamel margins compared with dentinal margins [32]. One-bottle one-step self-etching adhesives were less effective for bonding to enamel than etch-and-rinse adhesives, showing inferior marginal quality scores [33]. In addition, based on the results of this study, it may be concluded that bulk fill resin-based materials reduce microleakage in the gingival margins of class II cavities. Consistent with these results, it has been showed that the use of a flowable resin composite or compomer may reduce microleakage at the gingival margin of a deep Class II composite restoration that extends apical to the cemento-enamel junction [29]. In the present study, bulk fill fiber-reinforced composites (Groups 2 and 3) were applied at a 4-mm thickness horizontal to the resulting class I cavity and cured for 20 s. After the fiber-reinforced composite application,

the remaining cavity was restored with resin composite. Different cavity models have been investigated using finite element analysis, leading to the conclusion that due to the lack of wall deformation in class I and small class II MO cavities, the maximum stresses are generated along the tooth restoration interface [34]. In the control group with conventionally layered resin composite restorations, the resin composites were applied using a simplified horizontal incremental technique [27]. Horizontal layering in the proximal box as described here is easier to perform than more sophisticated layering techniques [35]. However, horizontal layering has been reported to result in unfavorable configuration factors of the individual increment, being added up to the top of the proximal box resin composite modulation [27]. The fact that the bulk fill resin-based materials were also applied in a 4 mm horizontal increment in this study may have contributed to the study outcomes. In addition, a new category of flowable resin-based composites was introduced as bulk fill material and as a liner in class I and II restorations. This new material category is may allow restorative material to be applied in 4 mm thick bulks instead of using the current incremental placement technique without negatively affecting polymerization shrinkage, cavity adaptation or the degree of conversion [37]. Moreover, manufacturers state that the polymerization shrinkage of these materials is lower than the commonly used flowable and conventional resin-based composites [37], and a 4-mm-placement of these bulk fill materials decreased the volume of resin composite which covered the entire restoration. Decreased composite volume may help reduce polymerization shrinkage. Together, this information may explain the findings of the present study that bulk fill resin-based composite reduced microleakage in the gingival margins.

CONCLUSION

In the present study, two type bulk fill materials and composite control material were unable to prevent microleakage in gingival and occlusal margins of class II cavities. On the other hand there were statistically significant difference between microleakage of occlusal and gingival margins for two bulk fill materials and composite control material. Besides, microleakage scores in gingival margins were significantly higher than microleakage scores of occlusal margin for the three materials. It may be concluded that bulk fill resin based materials in the present study reduced microleakage in the gingival margins of class II cavities.

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