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ORIGINAL ARTICLE

Comparing nanoleakage between class II bulkfill and incremental composite restorations using snowplow technique

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Nanoleakage

Abstract *Purpose:* To compare the nanoleakage between bulkfill and incremental-fill resin composites in class II slot preparations for primary and permanent teeth restored by the snowplow technique.

Materials and Methods: Class II slots were prepared in 32 M (16 exfoliated/extracted primary and 16 permanent molars). Optibond All-InOne self-etching adhesive was applied and cured. A flowable composite, Premise, was then injected into the gingival seat without curing using the snowplow technique. Cavities were restored using Sonicfill/bulkfill or microhybrid Herculite composites. Energy dispersive X-ray spectrometry was used to assess nanoleakage as silver deposition percentages along the axial and cervical walls. Multivariate analysis of variance was used to assess the effect

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of tooth type (primary and permanent teeth) and placement technique (bulkfill and incremental techniques) on nanoleakage at the axial and cervical walls.

Results: Bulkfill restorations had significantly greater nanoleakage than incremental restorations at the cervical walls in primary and permanent molars (mean = 1.21 vs 0.49 in primary molars and 0.76 vs 0.24 in permanent molars). Equivalent results were observed at the axial walls of the restorations (mean = 0.66 vs 0.14 in primary molars and 0.28 vs 0.08 in permanent molars, with a P value of < 0.001).

Conclusions: Less nanoleakage was observed in class II slot/snowplow resin–composite restorations using the incremental technique compared to bulkfill in both dentitions. However, greater nanoleakage was detected on the cervical walls when compared with the axial walls.

1. Introduction

Despite technological advancements in restorative techniques, the proper restoration of posterior teeth remains a challenging problem. The procedure requires conservative tooth preparation, and materials with minimum technique sensitivity (Bohaty et al., 2013). Marginal integrity is a factor that impacts the clinical performance of the posterior composite restorations (Ástvaldsdóttir et al., 2015). Microleakage due to polymerization shrinkage causes post-operative sensitivity, marginal staining, recurrent caries, pulpitis, and restoration failure (Mantri and Mantri, 2013).

Attempts have been made to reduce polymerization shrinkage by placing resin composites in small increments, modifying the cavity designs, applying a flowable liner and changing the matrix composition, and filler contents (Radhika et al., 2010, Veloso et al., 2019). One attempt is the snowplow technique which involves the placement of a thin layer of uncured flowable composite on the gingival margin of the proximal box, and the injection of composite paste in bulk over the flowable composite. This technique is supposed to push the flowable composite toward the cavity walls allowing a homogeneous restoration (Clark, 2010).

The snowplow technique remains controversial. Some studies have reported that co-curing the flowable liner with the composite restoration did not improve the marginal seal (Bore Gowda et al., 2015; Boruziniat et al., 2016), while other studies found no impact or decrease of microleakage when each type of composite was cured separately (Panahandeh et al., 2015; Pedram et al., 2018). Boruziniat et al. *meta*-analysis (2016), on the lab performance of direct composite restorations using the snowplow technique, indicated that the flowable composite has no effect on the microleakage of class II composite restorations. These findings were also confirmed in their clinical study (Borouziniat et al., 2019).

The placement of resin composite using the incremental layering technique aims to reduce the polymerization shrinkage. However, its main disadvantage is the possibility of void incorporation between composite layers (Veloso et al., 2019).

The bulkfill technique is another composite placement method involving placing and curing composites in one 4–5 mm-thick bulk (Veloso et al., 2019). Previous in-vitro and in-vivo studies have reported low polymerization shrinkage (El-Damanhoury and Platt, 2014), good marginal adaptation (Orłowski et al., 2015), and reduced working time (Chesterman et al., 2017) for bulkfill restorations. SonicFill is a bulkfill composite placement system for posterior restorations; it has the characteristics of both low-viscosity flowable composites and high-viscosity composites. It has a high filler content and special modifiers that can be activated by a sonic energy handpiece to temporarily reduce material viscosity, which allows its rapid flow. Once the sonic energy stops, the composite returns to a high-viscosity state for proper contouring (Chesterman et al., 2017).

Sano et al. (1995) described a test to assess leakage using silver nitrate to detect nanometer porosities within the hybrid layer of the dentin–resin interface. Nanoleakage assessment provides reliable information on the marginal seal of the restoration (Pioch et al., 2001). Several studies have assessed the microleakage of bulkfill composites (Swapna et al., 2015). However, only few studies have assessed nanoleakage in class II restorations, particularly when restored using the snowplow technique. In addition, studies addressing the incremental application of resin composites using the snowplow technique are scarce (Ferracane and Lawson, 2021; Sampaio et al., 2020). This technique may enhance the marginal adaptation of class II slot resin–composite restorations. Therefore, this study aimed to compare the nanoleakage between bulkfill and incremental-fill resin composites in snowplow class II slot restorations for primary and permanent teeth.

2. Materials and methods

This study was approved by the Ethical Committee, Faculty of Dentistry, Alexandria University. The sample included 32 human molars (16 primary and 16 permanent molars) free of cracks, fractures, restorations, or structural defects. Exfoliated/extracted primary teeth and permanent third molars were collected from the outpatient clinics of the Faculty of Dentistry, Alexandria University, Egypt.

The sample size was estimated assuming a 5 % alpha error and 80 % study power. To ensure that the study was adequately powered, the post hoc power was calculated based on the mean nanoleakage values, and the reported power was 97.4 %. According to El-Keredy et al. (2020), the mean (SD) silver weight penetration percentages when the bulkfill and incremental composite techniques were used were 1.06 (0.43) and 0.67 (0.31), respectively. Based on a comparison of means, the sample size was calculated (Power and Sample Size Calculators, 2020) to be 15 per group, which was increased to 16 to consider any lab errors. The total sample size needed for stratification by tooth type was 32.

2.1. Cavity preparations

The teeth were polished with a slurry of pumice and water to remove debris and blood stains and stored in distilled water at room temperature. Cavity preparations were performed on sound proximal surfaces using carbide burs no. 330 (SS White Burs, New Jersey) for primary molars and no. 245 (Brasseler USA Dental Instrumentation, GA, USA) for permanent molars with a high-speed, water-cooled handpiece. Bur no. 330 is a smaller version of bur no. 245. It has the same tip-diameter but is half the length of bur no. 245. Both burs were selected to match the tooth size of each dentition. Burs were replaced every-five preparations.

Class II slots with occlusal dovetail and circumferential short bevel (0.5 mm) were prepared on the proximal surfaces following the guidelines for composite restorations (Nowak et al., 2019; Ritter, 2017) to simulate the clinical cavity designs. Primary teeth were prepared by a pediatric dentist, whereas permanent teeth were completed by a restorative dentist. For primary molars, i) an occlusal lock was prepared (1.5 mm), ii) the proximal box of each preparation was a dovetail, with its walls converging occlusally, and iii) the gingival floor (4 mm-wide and 1 mm-deep) was placed 1 mm above the cementoenamel junction. For permanent molars, i) the proximal box measured 5 mm width buccolingually and 1.5 mm depth at the gingival floor, and ii) the gingival floor was 1 mm above the cementoenamel junction.

The prepared molars were placed in a plastic mold (Typodont) using a softened pink wax, with molars adjacent to each other to simulate clinical conditions. Samples of each dentition (16 primary and 16 permanent teeth) were randomly divided into two equal groups according to the restoration techniques. The teeth in one quadrant were restored using the bulkfill technique (test group), and the other quadrant was restored with the incremental technique (control group), considering that the prepared surface was facing an intact adjacent tooth surface.

2.2. Restorative procedures

The prepared cavities were restored using the snowplow technique (Cohn, 2013). Matrix *T*-bands (PulpDent Corporation, Watertown, USA) for primary molars and matrix Tofflemire (Tangshan Zhengtong Exhibition Co., Hebei, PRC) for permanent molars were secured in place using plastic wedges. Two successive coats of OptiBond™ All-In-One self-etch adhesive (Kerr Corporation, Orange, USA) were applied to the cavity walls, air-thinned for 5 s, and light-cured for 20 s. This self-etching adhesive was used due to its compatibility with the flowable composite premise. A 1 mm-thick layer of flowable composite (Premise™, Kerr Corporation, Orange, USA) was applied over the gingival seat without curing (Hilton and Quinn, 2001). In the test group (8 primary and 8 permanent molars), cavities were restored using the Kerr SonicFill™ composite (Kerr Company, KerrHawe SA, Switzerland) delivered in one-bulk through a specially designed sonic-energy handpiece. A light-curing protocol was followed by initial curing for 10 s from both the buccal and lingual sides. The occlusal surface was then cured for 20 s, and both the buccal and lingual sides were cured for 10 s after band removal using a Quartz-tungsten halogen light (Degulux 570 mW/cm^2 Degussa Hüls, Hanau, Germany) with built-in radiometers. In the control group, cavities were restored using the incremental fill technique with the microhybrid composite Herculite XRV™ (Kerr Corporation, Orange, USA), which was applied in oblique layering. For each increment, curing was performed similarly to the bulkfill. After band removal, the final curing was done for 10 s in both the buccal and lingual directions. Co-curing of the flowable liner was performed using both bulkfill and incremental techniques. All materials were applied according to the manufacturer's instructions. Restorations were finished and polished, and the samples were stored for aging in distilled water at room temperature for 3 months.

2.3. Nanoleakage test

Specimens were coded and sealed using epoxy resin, except for the restoration and 1 mm around its margins. The sealed areas were coated with nail varnish, the specimens were submerged in distilled water for 10 min for rehydration, and immersed in 50 % freshly prepared silver nitrate solution (Cennabras Industria e Comércio Ltda, Guarulhos, São Paulo, Brazil) for 24 h in the dark, washed under running water for 5 min, and kept for 8 h in a photo-developer solution (Kodak, Rochester, NY, USA) under fluorescent light to allow the conversion of silver ions into metallic silver (Medina et al., 2014). The specimens were then flushed under running water for 5 min to remove the remnants of the photo-developer and sectioned mesiodistally using a high-speed disk underwater coolant.

For nanoleakage assessment, a blinded assessor for the allocation of the sample was conducted. All specimens were coated with gold in a sputter-coating unit (JFC 1100 E) and observed by scanning electron microscopy (SEM) at 20 kV (model Jeol JSM-5300-JSM, Tokyo, Japan) by a blinded expert examiner from the dental biomaterials department. Intra-examiner reliability was evaluated with a Kappa of 0.83.

Specimens were then evaluated using energy-dispersive analytical X-ray spectrometry (EDAX) (Model 6583 INCA Penta FETX3, OXFORD Instruments, England). The amount of silver grain deposition at a nanoscale level was displayed by silver (Ag) uptake peaks (wt.%) along the cervical and axial tooth/restoration interfaces (Labib et al., 2016) and measured at 2,000 × magnification.

2.4. Statistical analysis

Normality was checked for all variables. Means, standard deviations, and ranges were calculated. The T-test was used for the comparison of silver weight deposition (w%) between the two groups. Multivariate analysis of variance (MANOVA) was used to assess the effect of tooth type and placement technique on nanoleakage along the cervical and axial cavity walls. The significance level was set at 5 %. SPSS was used for the statistical analysis.

3. Results

Table 1 shows that bulkfill restorations have significantly greater nanoleakage than incremental restorations at the cervical walls in primary and permanent molars (mean = 1.21 vs 0.49 in primary molars and 0.76 vs 0.24 in permanent molars).

Equivalent results are observed at the axial walls of the restorations (mean = 0.66 vs 0.14 in primary molars and 0.28 vs 0.08 in permanent molars). Collectively, nanoleakage is greater with bulkfill than with the incremental technique, in primary teeth than in permanent teeth, and at the cervical wall than at the axial wall.

Figs. 1 and 2 display the nanoleakage pattern of the bulkfill and incremental composites/dentin interface and the percentages of silver grain deposition along the cervical and axial walls of the primary and permanent molars.

Table 2 presents the association of tooth type and technique of placement with silver deposition (w%). Incremental fill has significantly lower nanoleakage than bulkfill at both the cervical and axial walls. Nanoleakage in permanent molars is significantly lower than in primary molars at the cervical and axial walls.

4. Discussion

This research objective aimed to evaluate the effectiveness of the snowplow method in promoting adequate marginal adaptation in class II slot cavity resin restorations. The results of this study showed that nanoleakage was greater in the bulkfill compared with the incremental technique and in the primary teeth compared with the permanent teeth. In addition, in both restoration techniques, nanoleakage was greater at the cervical wall than at the axial wall.

In the literature, studies evaluating nanoleakage using the snowplow technique are scarce. Therefore, the results of the present study were compared with those evaluating microleakage. The current findings indicating low nanoleakage values are consistent with the findings of Borouziniat et al. (2019). They reported that the application of flowable composite as a liner with the snowplow technique can enhance the adaptation of the resin–composite restoration and recommended this technique when the gingival floor is difficult to access. However, Panahandeh et al. (2015) found that co-curing the flowable with the hybrid composite can decrease the microleakage in class II composite restorations compared to the groups where the composite was cured separately. Furthermore, El-Naga et al. (2015) found a better sealing ability of the flowable composite in terms of nanoleakage when compared with the one-step self-etching system using hybrid composite. In contrast, Nematollah et al. (2017) found that the snowplow technique increases microleakage relative to other techniques used for class V cavity restorations.

Nanoleakage values in the present study were lower than those reported by Al-Agha et al. (2015) and Labib et al. (2016). This variation in values may be due to differences in cavity configuration, adhesive materials, and tests used for leakage evaluation. In addition, the low values of nanoleakage in this study may be attributed to the additional curing time of SonicFill as recommended by the manufacturer.

The present study reported greater nanoleakage values with the bulkfill than with the incremental technique in both primary and permanent teeth. This finding may be explained by the high filler content in the bulkfill system and the great depth of polymerization that impairs the light transmission and curing processes. Moreover, placing the composite in increments may reduce the configuration factor (C-factor) and polymerization shrinkage, allowing additional stress relief (Kim et al., 2015).

The literature is inconsistent regarding the shrinkage and marginal seal of bulkfill compared with incrementally placed composites. Consistent with the current findings, El Keredy et al. (2020) reported significantly higher nanoleakage with bulkfill than with incremental resin composite application. Agarwal et al. (2015) suggested that the viscosity of bulkfill may affect the marginal adaptation of resin in class II restorations. However, other studies have not reported any significant differences in leakage between bulkfill and incremental techniques (Kochotwuttinont et al., 2017; Mosharrafian et al., 2017). A recent systematic review has also reported comparable clinical performance of bulkfill and incremental-fill resin composite restorations in permanent molars. However, only 10 articles have been evaluated (Veloso et al., 2019). These controversial findings may be due to differences in properties of materials used, curing and restoration methods, and/or the tests used for leakage assessment.

In the present study, the cervical walls exhibited greater nanoleakage than the axial walls in the permanent and primary teeth. Similar findings were observed by de Mattos Pimenta

Table 1 Comparison of mean nanoleakage values between bulkfill and incremental resin composites in primary and permanent molars.

			Bulkfill*	Incremental**	T-test P-value
Primary molars	Cervical wall	Mean (SD)	1.21 (0.34)	0.49 (0.10)	< 0.001***
		Min–Max	1.00–2.00	0.40–0.60	
	Axial wall	Mean (SD)	0.66 (0.18)	0.14 (0.07)	< 0.001***
		Min–Max	0.40–1.00	0.00–0.20	
Permanent molars	Cervical wall	Mean (SD)	0.76 (0.11)	0.24 (0.05)	< 0.001*
		Min–Max	0.60–0.90	0.20–0.30	
	Axial wall	Mean (SD)	0.28 (0.10)	0.08 (0.09)	0.001*
		Min–Max	0.10–0.40	0.00–0.20	

SD: Standard Deviation, Min: Minimum, Max: Maximum.
* Test group.
** Control group.
*** Statistically significant.

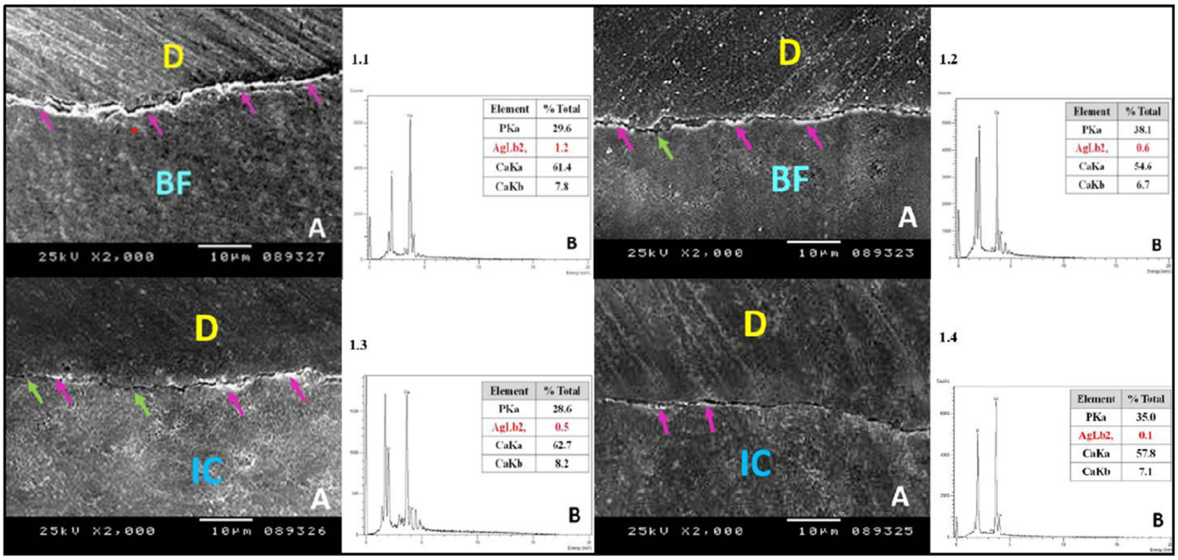

Fig. 1 Scanning electron microscopy image (A) and corresponding energy dispersive analytical X-ray spectrometry spectrum (B) representing silver depositions (Ag %) along bulkfill (BF) and incremental (IC) composites/dentin (D) interface at the cervical (1.1&1.3) and axial (1.2&1.4) walls of primary molars showing the following: (1.1) Nanoleakage pattern of BF as a thin continuous line of silver depositions (pink arrows). (1.2) An irregular interrupted line of silver depositions in BF (pink arrows), with few spots free of silver (green arrow). (1.3)Nanoleakage pattern of IC as few scattered spots of silver depositions (pink arrows), with areas free of silver (green arrows). (1.4)Apparent absence of silver depositions with few silver spots (pink arrows) in the IC.

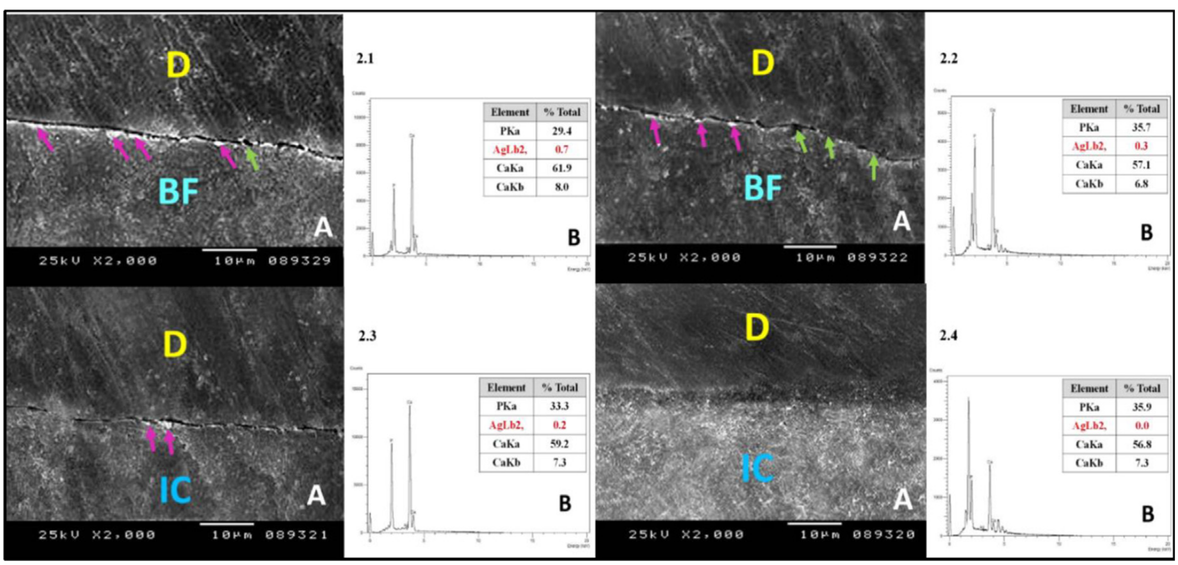

Fig. 2 Scanning electron microscopy (SEM) image (A) and corresponding energy dispersive analytical X-ray spectrometry spectrum (B) representing silver depositions (Ag %) along bulkfill (BF) and incremental (IC) composites/dentin (D) interface at the cervical (2.1&2.3) and axial (2.2&2.4) walls of permanent molars showing the following: (2.1) Nanoleakage pattern of BF composite as an apparent line of silver depositions (pink arrows), with tiny spots free of silver (green arrow). (2.2) Apparent absence of silver deposits (green arrows), with spots of silver depositions (pink arrows). (2.3) Nanoleakage pattern similar to the SEM image # (2.2). (2.4) Obvious absence of silver depositions along the resin–dentin interface.

Vidal et al. (2013) and El Keredy et al. (2020), who found that nanoleakage is significantly affected by cavity margin location and configuration, with lower marginal adaptation at the cervical walls compared with the occlusal walls. These findings may be attributed to the reduced enamel thickness cervically and weaker dentin bonding because of its high water and organic components, in addition to the histological variations found between enamel and dentin (Agarwal et al., 2015; Swapna et al., 2015). Moreover, the deepest area of the resin composite at the gingival floor, which was away from the light source, may not be adequately polymerized.

The current results show more nanoleakage in the primary teeth than in the permanent teeth. These findings agree with Mosharrafian et al. (2017) and Adi and Altinawi (2020), who

Table 2 Association of tooth type and technique of placement with silver depositions (w%) along the cervical and axial walls.

		Cervical wall		Axial wall	
		B (95 % CI)	P-value	B (95 % CI)	P-value
Placement technique	Incremental vs Bulkfill	−0.63 (−0.76, −0.49)	< 0.001*	−0.36 (−0.47, −0.26)	< 0.001*
Tooth type	Permanent vs primary	−0.35 (−0.49, −0.21)	< 0.001*	−0.23 (−0.33, −0.12)	< 0.001*
Model F		55.37		35.27	
P-value		< 0.001*		< 0.001*	
Adjusted R^2		0.78		0.69	

MANOVA was used, B: Regression Coefficient, CI: Confidence Interval.
**Control group.
***Statistically significant.
[*] Test group.

reported greater microleakage at the gingival margin in primary teeth than in permanent teeth. They attributed their findings to differences in the histology and morphology of primary teeth. Primary enamel has fewer inorganic components than permanent enamel and is thinner with a higher density of rods. Primary dentin is also less mineralized with a larger diameter and number of dentinal tubules (De Menezes Oliveira et al., 2010).

Addressing the limitations, being invitro study, different oral environmental parameters were not tested. Also, only one type of brand for the bulkfill, as well as for the microhybrid, was tested. Therefore, these results cannot be generalized.

5. Conclusion

Less nanoleakage was observed in class II slot/snowplow resin–composite restorations using the incremental technique compared with the bulkfill in both dentitions. However, greater nanoleakage was detected on the cervical walls when compared with the axial walls.

Ethics statement and consent to participate

Ethical approval was obtained from the Research Ethics Committee, Faculty of Dentistry, Alexandria University, Egypt (IRB 00,010,556 – IORG 0008839) and was performed in full accordance with the Helsinki Declaration. Informed consent was obtained from parents/guardians to use their children's extracted teeth for research purposes.

CRediT authorship contribution statement

Amel M. Ali: Methodology. **Dawlat Mostafa:** Methodology. **Amal Sakr:** . **Maha El Tantawi:** . **Hoda Abellatif:** . **Mona A. Elkateb:** .

Declaration of competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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