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Research Article

Effects of Cavity Configuration (c-factor) on Microleakage of Different Bulk Fill Resin Composites

Wakwak M A*,

***Corresponding Author: Dr. Wakwak M A**, lecturer of Operative Dentistry, Faculty of Dental Medicine, Al-Azhar University (Cairo-Boys).

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Abstract

The present study was directed to evaluate the effects of cavity configuration (c-factor) on the microleakage of Bulk Fill resin composites. ***Materials & Methods;*** *A total of 180 freshly extracted human non-carious premolar teeth were used. Three equal cavity configurations (C- factor) (60 teeth each); flat tooth surface (C1) was prepared by cutting 2mm of the occlusal surface to expose dentin, class II MOD (without axial step) (C3) were prepared with 2mm depth and 3mm width, and class V cavity (C5) with 3mm width, 2mm depth and 3mm height. Thirty teeth from each C-factor were restored. The specimens were stored for one month, three months and six months in distilled water at 37o C in an incubator. After storage time and sealing procedures and dye immersion in silver nitrate 50% wt for 12 hours. Each tooth was split longitudinally into 2 halves and inspected under a stereomicroscope to evaluate the marginal leakage of the tooth restoration interface. Finally, a randomly representative specimen from each group was investigated under a Scanning Electron Microscope (SEM) to evaluate the qualitative examination.* ***Result****; The results of this study revealed that less microleakage of All resin materials when used with the corresponding adhesive system with all C-factors, do not eliminate the microleakage. There was a significant difference between the flat tooth surface and both class II and class V. Lower leakage score at all C-factors and at three and six storage times.* ***Conclusions****; C-factor significantly affected the marginal seal.*

Keywords*; Bulk fill resin composites, c-factor, microleakage.*

Introduction

Polymerization shrinkage remains a challenge, and one of the leading causes of secondary caries around resin-based composites (RBCs), which is the primary season for the clinical replacement of RBCs (1, 2). Research has focused on improving placement techniques, materials, and composite formulation, primarily the material's polymetric matrix, to develop systems with reduced polymerization shrinkage and polymerization shrinkage stress (3). Although low-shrinking composite resins are desirable, noteworthy that several factors determine the shrinkage stress of a restoration. These include cavity geometry, the type of material, and application technique (4). An incremental layering technique remains the gold standard to restore cavity preparation exceeding 2 mm, due to several reasons besides minimizing gap formation and polymerization stress, such as achieving adequate bonding of composite to tooth tissue and ensuring complete polymerization of RBC (5–9).

The latest generations of flowable composites, i.e., bulk-fill flowable composites, have higher filler content and claim to have improved mechanical properties, making them preferred for larger posterior restorations (10). Furthermore, the filling procedures are simplified and expedited by flowable composites that can be placed in bulk up to 4-mm thickness, without negatively affecting the polymerization shrinkage, cavity adaptation, or the degree of conversion (11–14). Two recent studies have examined bulk-fill flowable RBCs' mechanical and physical properties. Czasch and Ilie (14) compared two bulk-fill flowable RBCs, Venus Bulk Fill (Heraeus Kulzer), and SureFil SDR Flow, (DENTSPLY Caulk, Milford, DE, USA) and found that SDR had better mechanical properties despite a lower degree of conversion than Venus Bulk Fill. Besides, they found that a polymerization time of 20 s for 4-mm bulk placed increments of either material seems to be sufficient.

Another study conducted by Moorthy et al. (15) compared conventional RBC with two bulk-fill flowable RBCs, SDR (DENTSPLY Caulk) and X-tra base (VOCO GmbH, Cuxhaven, Germany), and found that the bulk-fill flowable composite groups had significantly less cuspal deflection than conventional RBC, with no difference in cervical microleakage among the groups. These two studies use a 4-mm filling technique, which goes against the convention of using incremental layering for cavity preparations exceeding 2 mm. This contemporary bulk-fill flowable RBC and its new technique have few independent studies to validate it and need further evaluation (16). Microleakage measurement provides an assessment of the marginal adaptation by evaluating dye penetration between the tested material and the tooth structure (17, 18). The longevity of a composite restoration is mainly affected by the microleakage; thus, it is essential to evaluate it (19, 20). This study aimed to evaluate the marginal microleakage, through evaluating dye penetration, of the bulk-fill flowable RBCs in comparison with the conventional RBC (nanohybrid), utilizing the incremental and bulk-filling technique.

Two hypotheses were investigated: (a) the nanohybrid RBC Filtek™ Supreme Ultra Universal Restorative will exhibit less marginal leakage than two bulk-fill flowable RBCs, Filtek™ Bulk Fill Flowable Restorative and SureFil® SDR® flow and (b) the nanohybrid RBC when restored in 2 mm increments will exhibit less marginal leakage than 4-mm bulk. The hyposis of this study was directed to study the effects of cavity configuration that may affect the microleakage of different bulk-fill resin composites.

Materials & Methods

All the materials compositions are listed according to the manufacturer's profile.

Product name	Category	Composition	Manufacturer and Batch number
Filtek™ Bulk Fill A2	Bulk fill micro-hybrid resin composite	Bis-GMA, UDMA, Bis-EMA, procrylate resins Ytterbium trifluoride, zirconia, silica (64.5wt%, 42.5vol%)	3M ESPE Dental Product St. Paul, MN,USA (3MESPE,website www.3mespe.com) (N540884)
SureFil® SDR® flow Posterior Bulk Fill Flowable,	Flowable Bulk fill Restorative	Modified UDMA, ethoxylated ethoxylated Bisphenol A dimethacrylate, and TEGDMA, resins. The filler is a combination of Bariumalumino-fluoro-borosilicate glass and strontium alumino-fluoro-silicate glass	DENTSPLY Caulk
G-aenial (One step)	self etch adhesive	4-Methacryloxyethyltrimllitate anhydride 5-10% , acetone 30-40%, water 15-20% , Dimethacrylat 15-20% , phosphoric acid ester monomer 15-20% , silicon dioxide 1-5% , photoinitiator	GC, Tokyo Japan (12101121) Website www.gc-dental.com

HEMA: 2-hydroxyethyl-methacrylate. **BIS-GMA: bisphenol-a-diglycidyl-ether-dimethacrylate.

***TEGDMA: tri-ethylene-glycol-dimethacrylate. +UDMA: Urethane dimethacrylate.

Table (1) resin composite and their adhesive:

Methods

A total of 180 freshly extracted human non-carious premolar teeth were cleaned with pumice and rubber cup mounted on a low-speed rotary hand-piece with water coolant. Teeth were rinsed with water and stored in distilled water in an incubator at 37O C. **C1 factor (C1);** (one bonded surface) A standardized flat tooth surface were prepared in 60 teeth (30 for Silorane group and 30 for Kalore group) using carbide burs**(**1**)** in high-speed handpiece with profuse water-coolant by creating a depth cut grooves of 2mm at the occlusal surface of a premolar. A graduated periodontal probe was used to confirm the depth. These grooves were united together to create a flat tooth surface (the bur was replaced after 3 preparations). **C3 factor (C3)**; (3 bonded surfaces) A standardized Class II MOD cavity without any axial step prepared in 60 teeth (30 for Silorane group and 30 for Kalore group) by using carbide burs**(**2**)** in high-speed handpiece with profuse water-coolant. Bucco-lingual width occlusally (2mm) in the middle 1/3 rd of the cusp tip of the teeth. The buccal and lingual walls were approximately parallel. The cavity depth was 2 mm. Burs were discarded after three preparations to maintain cutting efficiency and using graduated periodontal probes to confirm the dimensions.**C5 factor (C5)**; (5 bonded surface) Standardized class V cavities were prepared on the buccal surface of 60 teeth (30 for Silorane group and 30 for Kalore group). The outline of each preparation was prepared by using a window matrix give class V shape. The dimensions of class V cavities were 2 mm mesiodistally, 2 mm depth and 2 mm occluso-gingivally with the gingival margin at least 1.0 mm above the CEJ. The preparation was done by using carbide burs**(**3**)**in a high-speed handpiece with profuse water-coolant were used to carry out all preparations. A new bur was used for every three cavity preparations to maintain cutting efficiency and using graduated periodontal probes to confirm the dimensions.

Application of resin composite

Application of adhesive system according to the manufacturer's instructions, After that application, the restorative material of all groups was applied by incremental technique and light-cured for 40 sec according to the manufacturer's instructions, A3 shade color was used for each restorative material, and resin composite was packed by using Teflon applicator into the prepared cavity as the following;

Flat tooth surface (C1); 1mm increment of resin composite was applied on all the tooth surfaces and light-cured for 20 sec and another layer of 1mm was applied and cured for 20 sec.

Class II (C3); the first 2mm increment of resin composite was applied to the buccal wall of MOD cavity obliquely from the pulpal floor to the outer occlusal margins and light-cured for 40 seconds. The second increment of 2mm was applied to the lingual wall obliquely from the pulpal floor to the occlusal margin and light-cured for 40 sec. The remaining of the cavity was filled with 1 mm increment up to the occlusal margin and cured for 40 seconds.

Class V (C5); the first increment of 1mm of resin composite was applied diagonally to the occlusal wall of class V cavity and light-cured for 20 seconds. Then, the second layer of 1mm was applied diagonally to the cervical wall and light-cured for 20 seconds. The remaining of the cavity was filled with 1mm and light-cured for 20 seconds.

After restorative procedures, the teeth were stored in water at 37°C in an incubator with 100% humidity at different storage times (one month, three months and six months) until they were tested. The specimens were immersed in an aqueous solution of 50wt% ammoniacal silver nitrate (pH 9.5) for 24 h, followed by 8h in a photo-developing solution. Teeth were sectioned longitudinally.

Microleakage measurement using dye penetration technique

For Stereomicroscope and Scanning Electron Microscope (SEM) examination a special treatment for each specimen proceeded firstly;

The specimens were immersed in an aqueous solution of 50wt% ammoniacal silver nitrate (pH 9.5) for 24 h, followed by 8h in a photo-developing solution, to permit the reduction of di-ammine silver ions to metallic silver grains. The specimens were removed from the photo-developing solution and washed in running water for 2min. Then the specimens were dehydrated in ascending concentrations of ethanol as follows: 25% for 20 min, 50% for 20 min, 75% for 20 min, 95% for 30 min, and 100% for 60 min.

Sectioning of specimens

Teeth were sectioned longitudinally in a buccolingual direction through the middle of the restoration for class V and flat dentin specimens by using a fine diamond disc at low speed with water coolant. While for class II MOD specimens the sectioning was in mesio-distall direction through the middle of the restoration. The degree of dye penetration was assessed by using a modified scoring system according to the following;

Score 0 = No dye penetration

Score I = Dye penetration along the enamel wall only.

Score 2= Dye penetration along with enamel and extend up to1mm in the dentinal wall.

Score 3= Dye penetration along with enamel and extend 2mm in the dentinal wall for flat tooth surface and class II, while extending along the entire length of the cervical floor of class V.

Score 4= Dye penetration up to the dentin bridge more than 2mm in the dentinal wall for flat dentin and class II, while extending along the entire length of the cervical floor and one-half of the axial wall of class V.

Results

The mean leakage score and standard deviation values of the collected data were calculated for each group. Statistical analysis for the mean of each group was done using the Kruskal–Wallis test followed by the Mann–Whitney U test to compare between the different variables. The significance level was set at ($P \leq 0.05$). Statistical analysis was performed with software IBM® SPSS® Statistics version 20.

Effect of Configuration factor regardless of the effects of the other variables

Statistically; there was a significant difference between Silorane and Kalore resin composite in all C-factor. Where in flat dentin (C1) groups the mean leakage value (0.53±0.07) for Silorane resin composite was higher than the mean leakage value (0.36±0.05) for Kalore resin composite where p-value=(0.001). While in Class II (C3) groups and Class V (C5) groups the mean leakage value (1.52±0.7) and (1.95±0.7) respectively for Silorane resin composite was lower than the mean leakage value (1.74±0.9) and (2.12±0.1) respectively for Kalore resin composite where p-value=(0.001).

Group / Time	C1 (Flat dentin) Mean ± SD	C3 (Class II) Mean ± SD	C5 (ClassV) Mean ± SD
S	0.53±0.07	1.52±0.7	1.95±0.7
K	0.36±0.05	1.74±0.9	2.12±0.1
P-value	0.001[A]	0.001[A]	0.001[A]

A: significant ($p<0.05$)

Table (2): The mean, standard deviation (SD) and p-values of the effect of C-factor for restorative material regardless of the other variables.

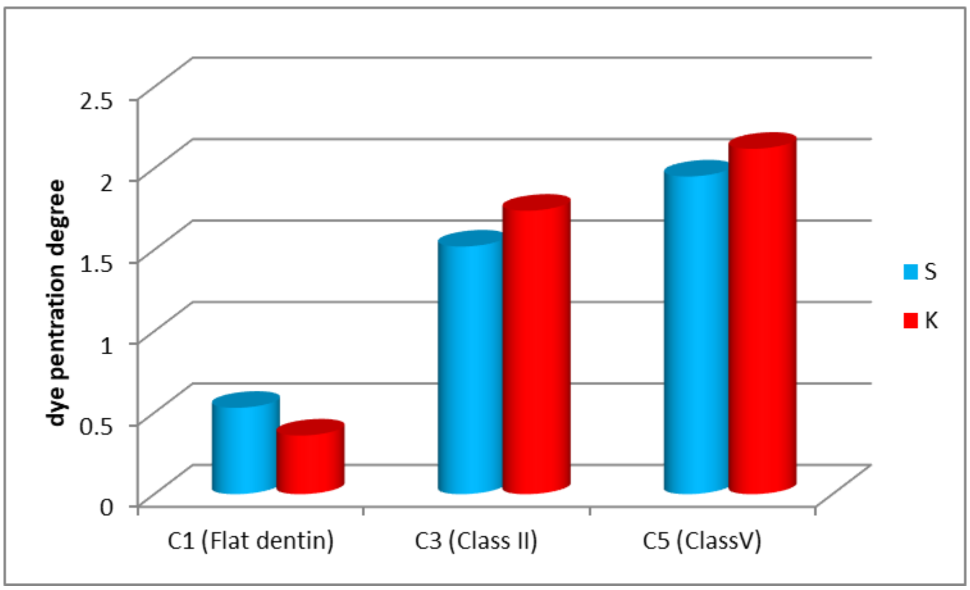


Figure 1: Bar chart representing of the effect of C-factor for restorative material regardless the other variables

Effect of storage time

Statistically; There was no significant difference between the mean leakage value (0.90±0.09) of Silorane at one month and the mean leakage value (0.92±0.09) of Kalore at one month where p-value (0.2). Also no significant difference between the mean leakage value (1.38±0.8) of Silorane at three months and the mean leakage value (1.39±0.9) of Kalore at three months where p-value (0.4).

While a statistically significant difference was found between the mean leakage value (1.70±0.6) of Silorane at six months and the mean leakage value (1.83±0.6) of Kalore at six months where p-value (0.04).

Group Time	S (Mean ± SD)	K (Mean ± SD)	P-value
T1 (1month)	0.90±0.09	0.92±0.09	0.2[a]
T3 (3months)	1.38±0.8	1.39±0.9	0.4[b]
T6 (6months)	1.70±0.6	1.83±0.6	0.04[B]

B; significant (p<0.05) a, b; non-significant (p>0.05)

Table (3): The mean, standard deviation (SD) values and P-value for the effect of storage time on restorative materials:

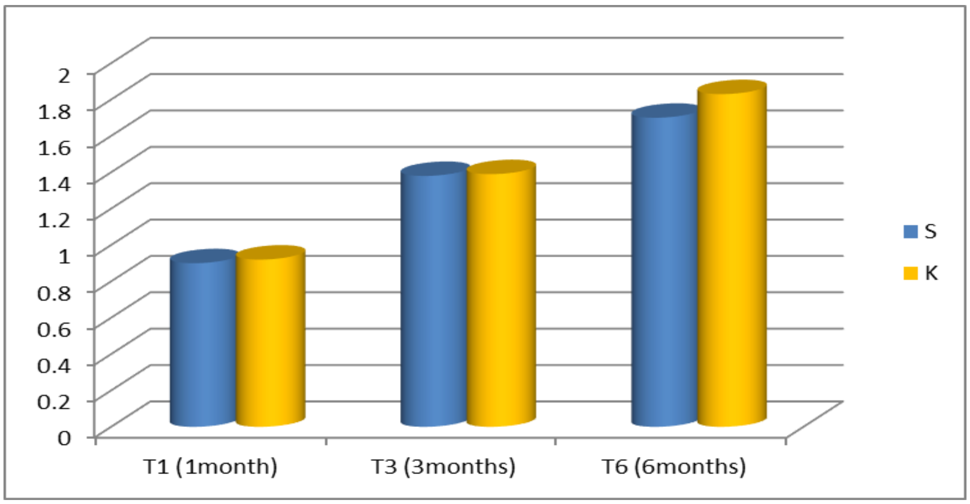
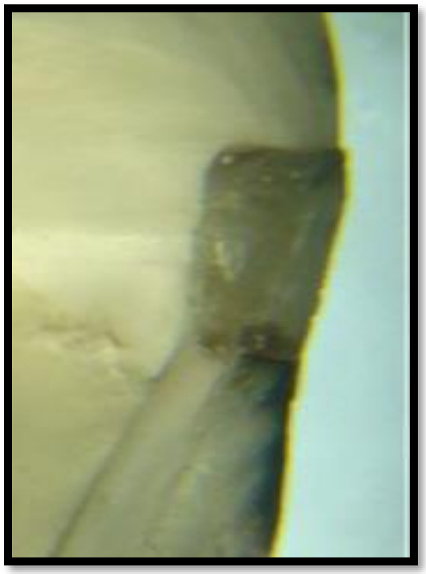


Figure (2): Bar chart representing the effect of storage time on restorative materials.

Photograph of the restorative materials under the stereomicroscope:



Figure(3); photograph under the stereomicroscope of a sectioned tooth with Silorane resin composite of C-factor 5 after one month storage showing score (2).

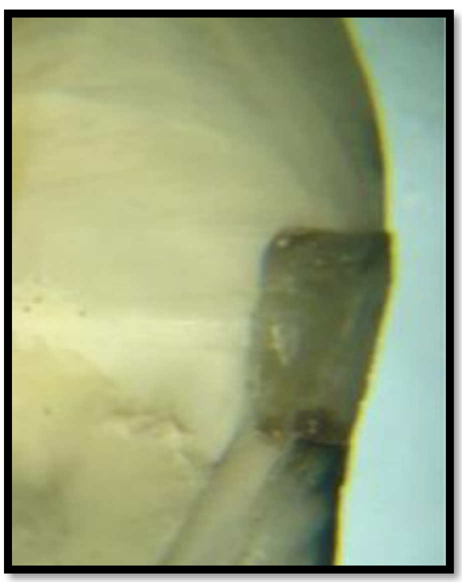


Figure (4); photograph under the stereomicroscope of a sectioned tooth with Siloran resin composite of C-factor 5 after three months storage showing score (2).

Scanning Electron Microscope observations

Scanning Electron Microscope (SEM) was used to determine the marginal gap as it provides high resolution electron micrographs and it can provide a more accurate picture of the marginal leakage

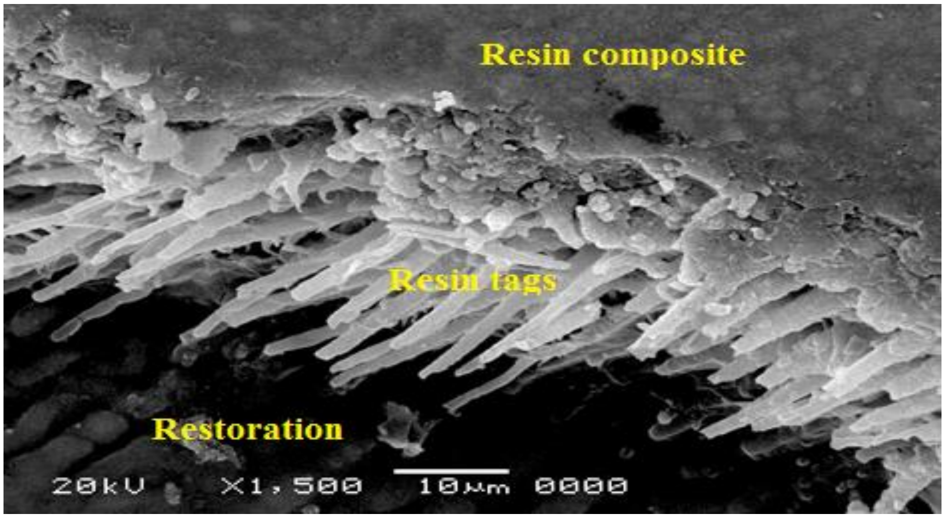


Figure (5): Scanning electron photomicrograph for the resin dentin interface (at 1500X) of Silorane at 6 months storage showing gap at the interface.

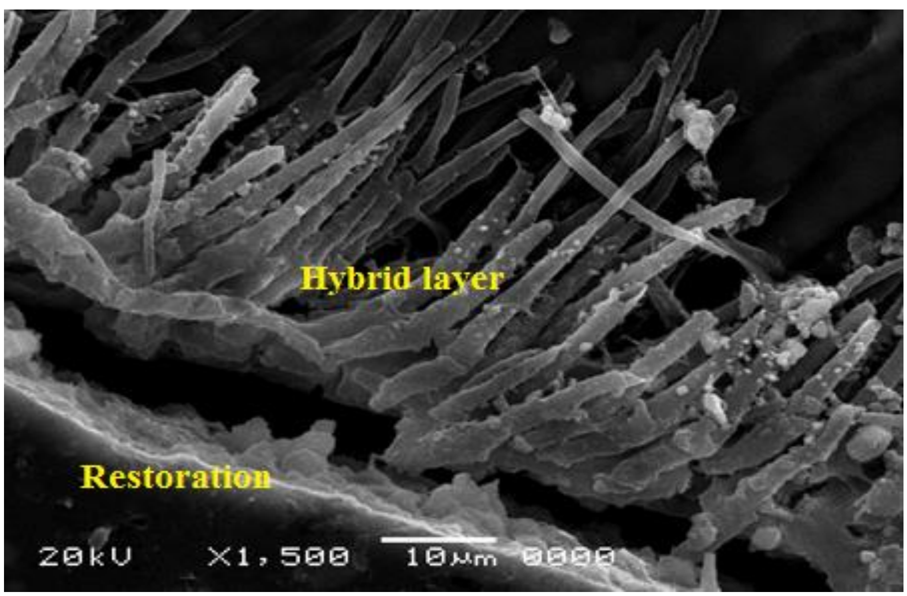


Figure (6): Scanning electron photomicrograph for the resin dentin interface (at 1500X) of Kalore at six months storage showing gap at the interface.

Discussion

In the present in vitro study, we compared the marginal microleakage (silver nitrate uptake) observed with nanohybrid RBCs in two different clinical protocols and two bulk-fill flowable composites. The first protocol used the conventional recommended incremental technique served as a control group and a 4-mm bulk of nanohybrid RBC to be comparable with the tested bulk-fill flowable RBCs, bulk-fill flowable RBC, Filtek™ Bulk Fill Flowable Restorative (3M™, ESPE™), and SureFil® SDR® flow (DENTSPLY Caulk), according to their manufacturers' recommendations. To simulate clinical conditions, extracted intact human teeth were used in this investigation. After randomization and preparation of the samples, the teeth were kept in distilled water throughout the investigation to prevent dehydration. All cavities were prepared and restored by the same experienced operator. All the samples were thermocycled for 2,000 cycles to resemble the aging of the restoration in the oral environment and then were embedded in silver nitrate to detect microleakage. Based on our results, the first null hypothesis was rejected: the nanohybrid RBC did not exhibit less marginal leakage than the two bulk-fill flowable RBCs using the incremental technique and exhibited more microleakage using the bulk-filling technique. The second null hypothesis was also rejected: the nanohybrid RBC when restored in 2-mm increments exhibited less marginal leakage than the 4-mm bulk. The results of this in vitro study revealed that the Filtek™ Bulk Fill Flowable RBC had the lowest mean value for marginal microleakage. However, the standard deviation was wide compared with the conventional nanohybrid RBC incremental technique, which had a mean value very similar to that of the Filtek™ Bulk Fill Flowable RBC with a smaller standard deviation. There was no statistically significant difference in microleakage between the two groups, which is a promising result regarding the bulk-fill flowable composite. However, it is still more predictable to use the incremental technique. (7,8)

These findings are following those reported by Czasch and Ilie (14) and Moorthy et al. (15). Of note in the latter study, the cavity design had fairly shallow areas, which might not reflect the bulk filling properties of the material. Although the SureFil® SDR® flow showed higher microleakage than that is seen with the Filteck™ Bulk Fill Flowable RBC and the nanohybrid RBC incremental technique, the difference was not statistically significant. The difference was also not statistically significant when the nanohybrid RBC was placed in 4-mm bulk. These results were in agreement with those of Roggendorf et al. (13), who found that 4 mm of SDR® had no detrimental effect in comparison with the conventional composite in terms of microleakage. Conventional nanohybrid RBC when placed in 4-mm bulk showed the highest microleakage, as anticipated, significantly different from the Filtek™ Bulk Fill Flowable RBC and the nanohybrid RBC incremental technique. This is primarily due to the limitations of the physical properties of the material; the incremental technique is the gold standard for conventional RBC to achieve good physical properties. This result is in agreement with numerous studies (28–36), which reported that the inadequate resin polymerization adversely affects the RBC physical properties, reduces the bond strength to the tooth, and increases marginal wear and breakdown. It is noteworthy that the recommended 20-s curing time is shade-dependent. That time is applicable only for the universal shade that was used in this study for both materials and the results showed that it was sufficient. For the other shades of Filtek™ Bulk Fill Flowable, the manufacturer's recommendation was 40 s. The results of this study are in agreement with those of Czasch and Ilie (14), who stated that the polymerization time of 20 s for 4 mm is appropriate. Nevertheless, the results showed that the simplified application procedure with 4-mm bulk of bulk-fill flowable RBCs and 20 s of curing, particularly for Filtek™ Bulk Fill Flowable, did not negatively affect the polymerization shrinkage. Consequently, the marginal microleakage is of great appeal. The results of this study also revealed that the marginal microleakage in the gingival surface was statistically higher than that in the occlusal surface. This result contradicts the study conducted by Deliperi and Bardwell (3), as they found no significant difference in dye penetration between the occlusal and gingival microleakage scores for most of the comparison groups, except one that yielded more dye penetration at the occlusal surface than at the gingival. This could be due to their study design; they were examining different adhesive techniques for the conventional restorative RBC protocol in 2-mm increments. In contrast, this study examined a bulk-filling protocol. The deepest area of the composite bulk may not have been adequately polymerized. Interestingly, the difference in microleakage could not be predicted between Filtek™ Bulk Fill Flowable and SDR®, since both are from the same material type, have similar properties, and have enhanced translucency (37) that promotes light transmittance and enables adequate curing efficiency up to 4-mm bulk of composite. However, the average particle size of Filtek™ is 0.6 nm, whereas the SDR® average particle size is 4.2 nm. This difference in particle size may have contributed to hindering light penetration of the light cure and consequently polymerization. Another explanation could be the novel monomer composition (3).

Study limitations and further research the methodology used for bulk-fill flowable RBC was the application of the material in 4-mm bulk to fill the entire cavity prepared. This methodology is in contrast to that used in the clinical setting, where the manufacturer recommends the use of the 4-mm bulk as the base layer for boxes deeper than 4 mm, followed by a capping layer (open sandwich technique). This is primarily due to the difficulty in handling the flowable consistency for replicating the anatomy of the tooth, not due to material limitation. For this reason, the study design was adequate for the intended polymerization and microleakage testing of the material. In this in vitro study, the polymerization method was specified, using 90° occlusally about the tooth, 5 mm away from the tooth with continuous light curing. The use of Tofflemire matrix to prevent curing light transmission proximally was necessary for this study (i.e., evaluating the microleakage of 4-mm bulk fill of RBC). The 5-mm distance was selected to simulate the clinical setting. However, curing 90° of the occlusal surface is difficult to achieve in some of the situations where the restoration is hard to reach, and it is not the typical clinical curing method. But it was used in this study to standardize the restoration and curing method procedure for all the samples. Perhaps future studies could involve different cavity designs that enable a more relevant clinical protocol, using a clear matrix and different curing directions. In this study, we adopted a commonly used aging method to simulate the degradation of the bond over time in the oral cavity, aging by thermocycling. The efficacy of thermocycling in simulating clinical aging has been the subject of controversy among researchers (38, 39). Although it is the most frequently used method of aging for microleakage evaluation up to now, there is no consensus in the literature for a relevant regimen foraging (19). Other aging methods include water storage and thermomechanical loading. Previous studies showed a statistically significant difference between thermocycling and water storage, thermocycling being superior (40). Furthermore, thermomechanical loading is superior to thermocycling, with a statistically significant difference (41). Thermomechanical loading is recommended for use in future studies, as it is more analogous to the oral condition. Due to time and resources limitation, the evaluation of dye penetration was done in a two-dimensional view, using a single section through the center of the restoration. This might have resulted in an underestimate of the results. Future studies may employ multiple sectioning of the teeth to obtain a three-dimensional view, thus presenting more accurate results. Also, the evaluation of dye penetration was done using a stereomicroscope at 20× magnification, which was sufficient to evaluate the dye penetration. However, it would be interesting to examine the mode of failure using a scanning electron microscope in future studies. citation of composites in cavities with high C-factor. (26,27)

Conclusions

C-factor significantly affected the marginal seal.

Long term storage in the water dramatically increased microleakage.

Bulk fill type of restorative material is significantly affected the marginal adaptation.

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