Original Article

Evaluation of Voids in Class II Restorations Restored with Bulk-fill and Conventional Nanohybrid Resin Composite

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Abstract

Objectives: The aim of the study was to evaluate the influence of four resin composites on voids in small and large Class II cavities. Furthermore, the thickness of the first increment of the restorations was studied. Methods: Eighty artificial lower second premolars were divided into two preparation designs with 40 standardized Class II cavities in each, and then restored with four resin composites (three bulk-fill types: SonicFill 2, Filtek Bulk Fill (capsule), Filtek Bulk Fill (syringe) and a conventional nanohybrid resin composite: Premise). Restorations were sectioned for microscopic evaluation and a Kruskal-Wallis analysis was performed to evaluate the number of voids and percent void area. The thickness of the first increment was measured and analyzed. **Results:** There were significant differences in the number of voids and percent void area among the 4 groups in small cavities. SonicFill 2 and Filtek Bulk Fill (capsule) placed with the injection technique showing reduced voids. In contrast, no significant differences were detected among the 4 groups in large cavities. Most of the first increment thicknesses of the restorations in both cavity preparations were thicker than recommended. **Conclusions:** Voids were reduced when the injectable resin composites were applied in small Class II cavity preparations, and the best results were achieved using SonicFill 2.

Keywords: Bulk-fill resin composite, Class II cavity, Conventional resin composite, Increment, Void

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Introduction

The depth of cure for conventional resin composite is recommended at 2-mm. Based on this limitation, restoring a deep cavity can be a time-consuming task because the incremental technique must be applied to ensure adequate light transmission for complete polymerization.[1] Moreover, this technique may increase the risk of moisture contamination, air trapping and marginal gap formation.[2,3]

The newly-developed, bulk-fill type resin composites are becoming widely used to overcome the various disadvantages of conventional resin composites. Manufacturers claim that bulk-fill materials can be placed in bulk of 4 mm or even 5 mm. As a result, these materials can reduce time consumption and simplify the procedure of placement.[4] Bulk-fill resin composites have some improved properties that provide clinical advantages such as particularly increased depth of cure, reduced cuspal deflection, low polymerization shrinkage and stress, which provide better marginal adaptation. Furthermore, their handling properties are comparable to regular hybrid composites.[5-9] However, applying bulk-fill composite into a deep cavity with more than 4 mm depth requires the use of the incremental technique to prevent an insufficient polymerization, which may result in the degradation of the resin composite, thus having a negative effect on physical properties and adverse biological reactions.[10]

The adequate polymerization and proper depth of cure require sufficient light intensity, adequate wavelength, proper curing time and correct energy density in order to activate the photoinitiator within resin composite materials.[11,12] The depth of cure is dependent on the resin composite's translucency. Bulk-fill composites are more translucent for the curing light than conventional composites, because bulk-fill composites have a bigger filler size with reduced amount of filler particles.[6] Increasing the curing time increases the degree of conversion and microhardness in deeper composite layers.[9]

Direct composite restoration appears to be a very sensitive technique. Undesirable characteristics such as porosities or voids, marginal leakage, white line, improper contact and contour, are some of the causes of post-operative sensitivity and secondary caries.[13,14]

The presence of porosities or voids within composite material may originate as a result of the manufacture process or handling technique.[15,16] Many studies consider the presence of porosities and voids to affect the quality of restorations. Voids at the axiopulpal line angles could result in stress fractures of restorations.[17] Voids along the margin and the external surface also result in microleakage, surface roughness and lead to discoloration. Moreover, marginal voids can reduce the adhesion area between bonding agent and resin, resulting in decreased gap-reducing efficacy of dentin-bonding agents and mechanical strength of restorations. Finally, voids can appear as translucent areas on radiographs and may be misinterpreted as secondary caries.[13,18-20]

From previous studies, voids are commonly found along the junction between the resin composite layers when the incremental technique is applied.[16,17] In a study by Samet and others,[21] round and well-defined voids were also regularly found in samples of non-manipulated materials extruded from the original syringes. Ovoid and elongated voids were found only on interlayer areas. These were considered to be gaps created during placement.

Voids can be classified into 3 groups by diameter length: small void (≤50 μm), medium void (>50 - ≤150 μm) and large void (>150 μm), according to the study of Medlock and others.[22] Large voids have the most pronounced effect on restorations, and probably also lead to lower fatigue resistance, wear resistance, and gross microleakage.[13,19,23,24] Another study found that

internal voids were correlated with marginal microleakage in class II composite restorations. Since material voids are equally important to gap space, and both are depended on the manipulation of the material.[20] Besides, cavity depth, width and volume do correlate with the amount of voids and gap spaces, but only for the high viscous composite material.[25]

At present, few studies exist focusing on voids in Class II restorations restored with bulk-fill resin composites and it has not been proven that it can be achieved in either small or large cavities. Moreover, there is a lack of available research about the increment thickness that is created during placement. The thickness that exceeds the limited depth of cure can cause negative effects on the restorations.

Thus, the objective of this study was to investigate and compare the number of voids in small and large Class II cavities restored with bulk-fill composite or conventional nanohybrid resin composite. Furthermore, the thickness of the first increment of the restoration was studied. The null hypotheses to be tested were that there would be no differences in presence of voids of 1) small Class II cavities, 2) large Class II cavities placed with different resin composites.

Materials and Methods

Specimen preparation

Eighty artificial lower second premolars (Nissin Dental Products INC, Kyoto, Japan) were divided into 2 groups, one group was prepared for small Class II cavity and the other one was prepared for large Class II cavity. Standardized Class II cavities were prepared at the mesial surfaces using cylinder diamond bur diameter 1 mm and 1.5 mm (Intensiv, Montagnola, Switzerland). Round internal line angles and round point angles were created to assist the adaptation of composite materials. Two preparation designs were followed:

- A small cavity was prepared, as shown in Figure 1a. The dimension was a 2-mm mesio-distal width, a 3-mm bucco-lingual width and a 5-mm occluso-gingival depth.
- A large cavity was prepared, as shown in Figure 1b. The dimension was a 4-mm mesio-distal width, a 3-mm bucco-lingual width, a 5-mm occluso-gingival depth and a 2-mm pulpal depth.

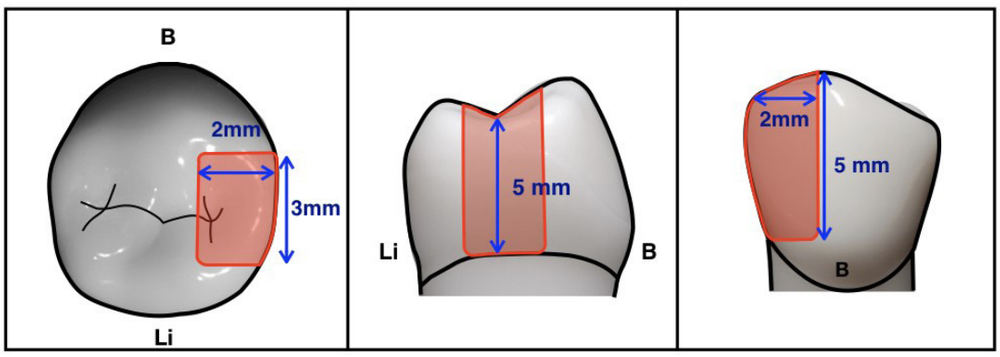

Figure 1a. *Small cavity preparation*

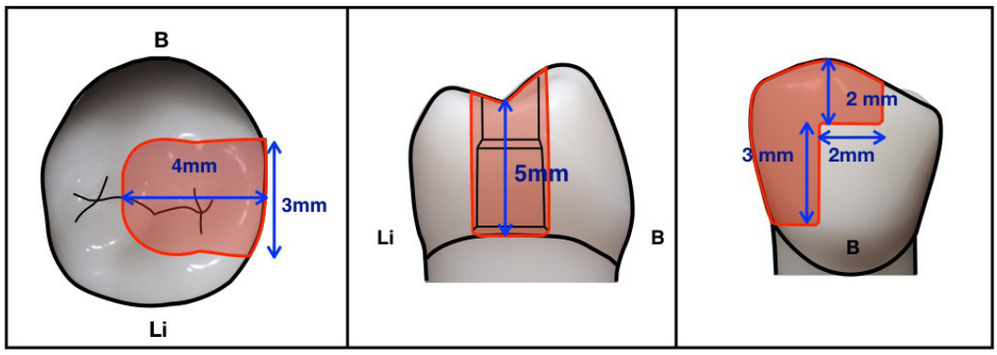

Figure 1b. *Large cavity preparation*

Application Techniques

Forty cavities in each preparation design were randomly assigned to 4 experimental groups according to the restorative materials used, with 10 specimens in each group. After that, the cavities were cleaned and air-dried. Teeth were mounted in a dentoform model (Nissin Dental Products INC, Kyoto, Japan) and a sectional matrix system (Ultradent, UT, USA) was adapted. Then, a layer of Optibond Solo Plus adhesive (Kerr, Orange, CA, USA) was applied, air-thinned and light cured for 20 seconds.

One operator with 4 years' experience in dental practice performed the restorations. A periodontal probe (12 UNC color-code probe, Hu-Friedy, Chicago, IL, USA) had been used to measure the depth of each cavity before the procedure was started. The first increment and subsequent increment used different shades to provide contrast in increment color for the measurement of the first increment thickness. A lighter shade was used for the first increment with a darker shade for subsequent increment. Three bulk-fill resin composites were used, including SonicFill 2, Filtek Bulk Fill Posterior Restorative (capsule), Filtek Bulk Fill Posterior Restorative (syringe) and a conventional nanohybrid resin composite: Premise. Table 1 summarizes the restorative materials used in this study. All materials were used according to the manufacturers' instructions, which are illustrated in Table 2.

Table 1 *Restorative materials used*

Material	Manufacturer	Type	Shade*	Lot No.
OptiBond Solo Plus	Kerr (Orange, CA, USA)	Single-component dental adhesive	-	5991290
SonicFill 2	Kerr (Orange, CA, USA)	Bulk-fill composite (Thick-consistency)	B1 A3	5469501 5928183
Filtek Bulk Fill Posterior Restorative (Capsule)	3M ESPE (St.Paul, MN, USA)	Bulk-fill composite (Thick-consistency)	A1 C2	N748348 N713397
Filtek Bulk Fill Posterior Restorative (Syringe)	3M ESPE (St.Paul, MN, USA)	Bulk-fill composite (Thick-consistency)	A1 C2	N690323 N711565
Premise	Kerr (Orange, CA, USA)	Conventional composite (Thick-consistency)	A1 A4	5983207 5939846

- ** A lighter shade for the first increment and a darker shade for subsequent increment*

Table 2 *Material applications according to the manufacturers' instructions*

Material	Application method
OptiBond Solo Plus	1. Apply adhesive for 15 seconds, using a light brushing motion. 2. Air thin for 3 seconds. 3. Light cure for 20 seconds.
SonicFill 2	1. Insert Unidose capsule into SonicFill Handpiece. 2. Place the tip 1.5 mm above the deepest portion of the cavity. 3. Activate SonicFill Handpiece by fully depressing foot pedal. 4. Fill entire cavity with 4-mm bulk, keep the tip inside the material at all times while the handpiece is activated. 5. Press and sculpt using hand instruments. 6. Light cure for 10 seconds (Additional curing from buccal and lingual aspect after removing the matrix).
Filtek Bulk Fill Posterior Restorative (Capsule)	1. Insert capsule into Restorative Dispenser. 2. Place the tip close to the deepest portion of the cavity. 3. Start dispensing. 4. Fill entire cavity with 4-mm bulk, keep the tip inside the material at all time while dispensing. 5. Press and sculpt using hand instruments. 6. Light cure for 10 seconds (Additional curing from buccal and lingual aspect after removing the matrix).
Filtek Bulk Fill Posterior Restorative (Syringe)	1. Extrude material out on pad. 2. Place a 4-mm bulk into the cavity. 3. Press and sculpt using hand instruments. 4. Light cure for 10 seconds (Additional curing from buccal and lingual aspect after removing the matrix).
Premise	1. Extrude material out on pad. 2. Place a 2-mm increment into the cavity. 3. Press and sculpt using hand instruments. 4. Light cure for 20 seconds (Additional curing from buccal and lingual aspect after removing the matrix).

This study design resulted in 4 restorative groups for each preparation design:

Group 1: SonicFill 2

The first 4-mm bulk of composite (shade B1) was dispended into the cavity using a SonicFill handpiece at a setting speed of 3. After the first increment was injected and pressed with a plugger (5A XTS, Hu-Friedy, Chicago, IL, USA), the composite was cured with a Demi Plus (Kerr, Orange, CA, USA) according to the recommendation. Then, the following increment of composite (shade A3) was dispended to fill the cavity using the same application method and sculpted with a carver (IPC Interproximal Carver, Hu-Friedy, Chicago, IL, USA).

Group 2: Filtek Bulk Fill Posterior Restorative (capsule)

The first 4-mm bulk of composite (shade A1) was injected into the cavity using a dispenser gun. After the first increment was injected and pressed with a plugger, the composite was cured. Then, the following increment of composite (shade C2) was injected to fill the cavity using the same application method and sculpted with a carver.

Group 3: Filtek Bulk Fill Posterior Restorative (syringe)

The first 4-mm bulk of composite (shade A1) was smeared into the cavity with a plugger and a carver, followed by light cure. Then, the following increment of composite (shade C2) was placed to fill the cavity using the same application method and sculpted with a carver.

Group 4: Premise

The first 2-mm bulk of composite (shade A1) was smeared into the cavity with a plugger and a carver, followed by light cure. Then, the following increment of composite (shade A4) was placed to fill the cavity using the same application method and sculpted with a carver.

Microscopic Evaluation

The restorations were finished with fine grit diamond burs (Intensiv, Montagnola, Switzerland) and stored for 24 hours. The teeth were embedded in epoxy resin blocks and sectioned vertically in a mesio-distal plane with a low-speed cutting machine (ISOMET 1000, Buehler, USA), resulting in two sections of each specimen to be inspected. Then, the sections were polished using a polishing machine (NANO 2000T, PACE technologies, USA) with varying grits of abrasive paper (Grit sizes: 800, 1000 and 1200). After the sections were cleaned for 1 minute with ultrasonic cleaning (BRANSONIC 5210, Germany), they were immersed in Methylene Blue solution for 5 minutes to improve the visibility of voids, then rinsed with water and air-dried.

One examiner evaluated the specimens under a stereomicroscope with 20X magnification (ML 9300 MEIJI TECHNO, Saitama, Japan) and photographed the specimens with a digital camera (AxioCam MRc 5, Carl Zeiss, Germany). Each section was measured for number of voids, void diameter, total view area, total void area and thickness of the first increment with analysis software (ImagePro-plus, Media Cybernetics, USA). Then, the percent area of void was calculated. Only large void that was larger than 150 µm in diameter was counted and evaluated.

Statistical Analysis

The nonparametric Kruskal-Wallis test was performed to analyze the number of voids and percent void area among the 4 material groups of each cavity preparation, followed by multiple pairwise comparisons. A significance level of 0.05 was used for all analyses. The data for thickness measurement was analyzed using descriptive statistics. All tests were performed with SPSS 20.0 software (Chicago, IL, USA).

Results

As a control procedure, 4 resin composites were evaluated for porosities that were larger than 150 µm in diameter. All resin composites were cut from the syringe tips and unidose capsule tips, light-cured and sectioned for microscopic evaluation. The results were shown to be free of large porosities (Figure 2).

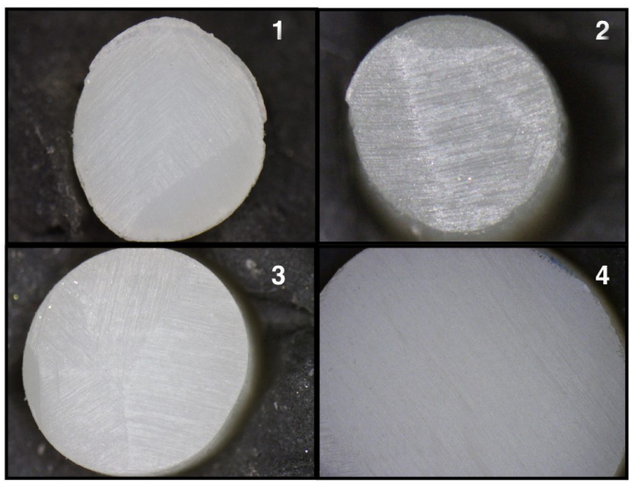

Figure 2 *Cured composite samples from manufacturer batch (1.SonicFill 2, 2.Filtek Bulk Fill (capsule), 3.Filtek Bulk Fill (syringe), 4. Premise)*

A total of 160 sections were available for evaluation, which were comprised of 80 sections for small cavity preparation and 80 sections for large cavity preparation. The number of voids for the 4 material groups in small cavities are presented in Table 3. There was a statistically significant difference ($p<0.05$) in the number of voids among the 4 groups. The results were in ascending order as follows: SonicFill 2, Filtek Bulk Fill (capsule), Filtek Bulk Fill (syringe) and Premise. The pairwise comparisons between groups showed no significant differences ($p>0.05$) between SonicFill 2 and Filtek Bulk Fill (capsule), or between Filtek Bulk Fill (capsule) and Filtek Bulk Fill (syringe). The number of voids for the 4 material groups in large cavities are presented in Table 3. The evaluation showed no significant difference ($p>0.05$) in the number of voids among the 4 groups.

Table 3 *The number of voids for small and large cavity preparation*

Group	Small Cavity Number of Voids Median (Q1,Q3)	Large Cavity Number of Voids Median (Q1,Q3)
SonicFill 2	2.00 (0.25,2.00) [a,b]	3.50 (2.00,4.00) [A]
Filtek Bulk Fill (capsule)	2.00 (0.25,2.75) [b,c]	3.00 (2.00,3.75) [A]
Filtek Bulk Fill (syringe)	2.50 (1.25,4.75) [c]	3.50 (2.00,5.00) [A]
Premise	4.00 (3.00,6.75) [d]	4.00 (3.00,6.00) [A]

-Void composed of > 150 µm in diameter

-Kruskal-Wallis test: The results with the same superscript letters are not statistically different (at p<0.05)

The percent void area for the 4 material groups in small cavities are summarized in Table 4. The results showed that there was a statistically significant difference ($p<0.05$) in the percent void area among the 4 groups. The results were in ascending order as follows: SonicFill 2, Filtek Bulk Fill (capsule), Premise and Filtek Bulk Fill (syringe). For the between groups comparisons, there was a significant difference ($p<0.05$) in the percent void area between SonicFill 2 and Filtek Bulk Fill (syringe), SonicFill 2 and Premise, and Filtek Bulk Fill (capsule) and Premise. On the other hand, the evaluation showed no significant difference ($p>0.05$) in the percent of void area among the 4 groups in large cavities. The percent void area of the 4 material groups are presented in Table 4.

Table 4 *The percent void area of small and large cavity preparation*

Group	Small Cavity Percent Void Area (%) Median (Q1,Q3)	Large Cavity Percent Void Area (%) Median (Q1,Q3)
SonicFill 2	0.19 (0.02,0.57) [a]	0.53 (0.40,0.96) [A]
Filtek Bulk Fill (capsule)	0.21 (0.02,0.53) [a, b]	0.49 (0.23,0.70) [A]
Filtek Bulk Fill (syringe)	0.50 (0.19,1.53) [b, c]	0.48 (0.17,0.84) [A]
Premise	0.90 (0.44,1.19) [c]	0.69 (0.30,0.90) [A]

-Void composed of > 150 µm in diameter

-Kruskal-Wallis test: The results with the same superscript letters are not statistically different (at p<0.05)

In this study, the first increments were measured for thickness, specifically for thickness greater than recommended for the first increment. From the results of thickness greater than recommended, the descriptive statistics of the 4 material groups in small cavities are shown in Table 5. Filtek Bulk Fill (syringe) showed the lowest of 65 % for the first increments that were thicker than the recommended thickness. For the overall result of small cavity preparations, 86.3 % of the first increments were thicker than the recommended thickness. The results of the 4 material groups in large cavities are shown in Table 5. Filtek Bulk Fill (capsule) showed the lowest of 75 % for the first increments that were thicker than the recommended thickness. For the overall result of large cavity preparations, 91.30 % of the first increments were thicker than the recommended thickness.

Table 5 *The number and percent of the first increment thicker than the recommended thickness for small and large cavity preparation*

Group	Number of Restorations (Incorrect / Correct)		Percentage of Restorations (Incorrect / Correct)	
	Small Cavity	Large Cavity	Small Cavity	Large Cavity
SonicFill 2	19/1	20/0	95/5	100/0
Filtek Bulk Fill (capsule)	19/1	15/5	95/5	75/25
Filtek Bulk Fill (syringe)	13/7	19/1	65/35	95/5
Premise	18/2	19/1	90/10	95/5
Total of Percent Incorrect Restoration			86.3 %	91.3 %

- Incorrect: The first increment thickness is thicker than manufacturer's recommendation.

- Correct: The first increment thickness is equal or less than manufacturer's recommendation.

Discussion

From the evaluation of 4 resin composite sections that were cut from the syringe tips and unidose capsule tips, it was shown that the materials were free of large porosities. However, a few microporosities (<150 µm in diameter) were found in the materials. This result is in accordance with previous studies.[16,24,26]

Voids have been evaluated and measured with different techniques, sectioning the sample and observing under microscope is the most basic destructive method.[13,19,26,27] In this study, only voids that were larger than 150 µm in diameter were evaluated. The presence of these voids within the restorations could be due to the application technique. The restorations were sectioned vertically in a mesio-distal direction. In this way, voids could be found if they appeared along the section line. In fact, the restorations could have more voids than the reported results.

Voids are located in the same frequency within all materials, but gaps are more frequently located within high viscous composites, both at the bottom and at the side cavity walls.[25] In this study, voids could be found scattered in all parts of the section and varied from round to irregular shapes. These voids could be found along the junction between increment layers, along the position of the axiopulpal line angle, angle and margin (Figures 3 and 4), which may result from an inability to adequately adapt the resin composite. Moreover, the external surface was another area where voids could be found (Figure 5). The presence of these voids may cause drawbacks within a restoration.

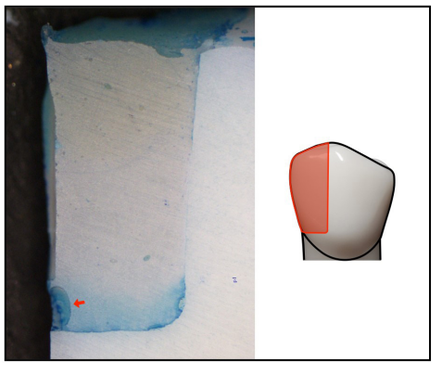

Figure 3 *Voids along the interface layer and void at the angle (Large cavity preparation)*

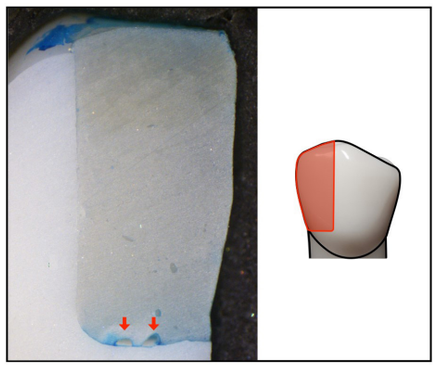

Figure 4 *Voids along the gingival margin (Small cavity preparation)*

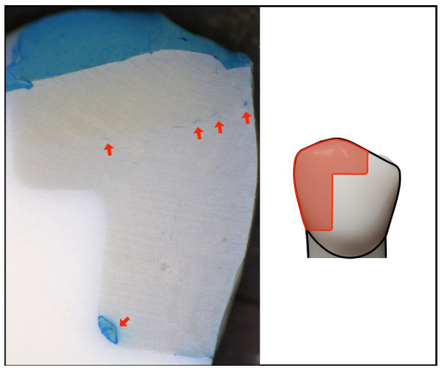

Figure 5 *Void at the external surface (Small cavity preparation)*

In this study, resin composites were categorized into 2 specific characteristics of application method, which were injectable and packable resin composite. SonicFill 2 and Filtek Bulk Fill (capsule) are injectable type, while Premise and Filtek Bulk Fill (syringe) are packable type. This study found that the 4 groups of resin composite had differences in the number of voids and percent void area. The injectable resin composites, which included SonicFill 2 and Filtek Bulk Fill (capsule), showed a lower number of voids and lower percent void area than the other 2 packable resin composites, which included Premise and Filtek Bulk Fill (syringe). Hence the first null hypothesis was rejected. These findings are consistent with previous studies.[13,19] From previous study concerning mode of application, it is known that the injection technique can decrease voids and eliminate large voids.[19] Furthermore, it has been shown that the reapplication of resin composite after being placed into the cavity with a hand instrument can increase voids between the material and the cavity wall, if the material sticks to the hand instrument or syringe tip and is pulled away from the cavity. Likewise, the same problem may occur when the matrix band is unstable. This situation may be related more to packable resin composites.[18]

No statistical differences ($p>0.05$) in the number of voids and percent void area were observed in the 4 material groups for large cavity preparation. Thus, the second null hypothesis was accepted. The explanation for this finding may be the preparation design of large cavity being more prone to increased line angles. In the same way, Ironside and Makinson[16] reported on the

occurrence of voids at the line angle and the sharp angle. The study of Opdam and others,[13] they compared the two application techniques between injection technique and packing technique in the same operator. From six operators, all operators produced better void reductions with the injection technique in small cavities, whereas not all of them produced better results in large cavities. Furthermore, a correlation of deeper or wider cavities with the presence of voids is probably a result of higher polymerization contraction in larger restorations.[25] Resin composite material achieves its thicker consistency by increasing filler size, modifying filler distribution and adding other types of fillers. Filler size and distribution have an effect on the packing stress and viscosity. Moreover, filler size was found to have an effect on the presence of voids. Resin composites with larger filler sizes could result in increased voids, and also affect the handling properties.[28,29] Thick-consistency composites tend to produce more voids and imperfect marginal adaptation than thin-consistency and medium-consistency composites, whatever the application mode used. Therefore, larger cavities filled with high viscous composite material may present a higher amount of voids and gaps.[19,25] In this study, all the resin composites used were thick-consistency composites.

Regarding the thickness of the first increment as manufacturer recommendation, the injection technique type used, the tip of SonicFill 2 capsule with 1.5 mm diameter and 2 mm diameter for the Filtek Bulk Fill (capsule) tip. The diameter of the tips was compared to the area of the gingival floor (2x3 mm^2) in both small and large cavities and found that diameter for the tips was probably fit to this area. Therefore, restoring Class II cavities with a matrix band placement by injection application, the operator may not achieve clear access to estimate the thickness of the first increment accurately during the dispensing of materials. In addition, the tips cannot be withdrawn to the same distance as the thickness of the increment while the materials are dispensing, causing the materials to overflow on the dispensing tips. The former condition resulted in inaccurate thickness of the first increment. For packing application, the plugger that was used also has a 1.5 mm diameter tip, so the operator may not achieve clear access during placement of the material at the gingival floor.

It can be assumed that the thickness of composite restoration also depends on the skills of operator. Most resin composites that were used in this study were bulk-fill composites determined to be 4 mm thick. Generally, most dentists are more accustomed to a 2-mm thick layer of conventional resin composite. However, this current study had only one operator performed the restorations. The results of this study showed that most of the first increment thicknesses of the restorations were thicker than the recommended increment thickness not only for 4-mm thick, but also 2-mm thick. Placement of the first increment is always thicker than the recommended thickness and may affect the depth of cure.

In addition, curing light also has an effect on polymerization and depth of cure of resin composite. Light-curing units with blue light emitting diode (LED) has been recognized as a promising technology for polymerization of resin-based materials because all the light emitted is within the spectrum of maximum absorption of camphorquinone at 468 nm.[12,30] In this study, Demi Plus curing unit (Kerr, Orange, CA, USA) was used. This light-curing unit has a peak wavelength of 453 nm. The Demi Plus has a new Periodic level shifting technology that shifts the output intensity from an impressive base of 1100 mW/cm^2 to a peak of 1330 mW/cm^2.[31] From the previous finding, the placement of 4-mm composite increments cannot be generally recommended for all high-viscosity bulk-fill materials under evaluation of degree of conversion and microhardness, at least at curing times ≤ 30 seconds.[9] Regarding the degree of conversion, 30 seconds curing time had positive effect on polymerization properties at least 4-mm incremental thickness of bulk-fill composites.[9,32]

For this reason, the degree of conversion and

microhardness at the bottom surface of the increment of these bulk-fill type resin composite should be studied. Furthermore, skills of operator on performing the restoration using incremental technique should be further evaluated.

Conclusion

Within the limitations of this study, it can be concluded that Class II resin composite restorations are difficult to restore free of voids. In small Class II cavities, SonicFill 2 showed the best results for the number of voids and percent void area. From the overview, SonicFill 2 and Filtek Bulk Fill (capsule), which are injectable resin composites, showed better results in the number of voids and percent void area. Nevertheless, the large cavity group showed no difference in results for voids regardless of the material used. The results of this study showed that most of the first increment thicknesses in restorations were thicker than the recommended thickness for both small and large cavities. Therefore, dentists should exercise more awareness and care when carrying out composite placement.

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