

Original Article

Effect of Different Placement Methods on Voids Formation in Class II Cavity Restored with Bulk-fill Resin Composite

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Abstract

The aim of this study was to evaluate void formation by micro-computed tomography in two-surface Class II cavities restored using four different placement methods with three bulk-fill resin composites. Standardized Class II cavities were prepared in forty intact human maxillary first premolar teeth. The teeth were randomly divided into four groups and restored using (n=10): 1) one bulk placement with a hand instrument; 2) two-bulk placement with a hand instrument; 3) one bulk placement with an injectable dispenser; 4) one bulk placement with an injectable dispenser and a sonic-activated handpiece. Percentage of void formation in the entire restoration was evaluated. One-way ANOVA and Games-Howell post hoc analyses were performed with a significance level of 0.05. One bulk placement with a hand instrument (Group 1) and two-bulk placement with a hand instrument (Group 2) had a significantly higher percentage of void formation than a one-bulk placement with an injectable dispenser (Group 3) and one-bulk placement with an injectable dispenser and sonic-activated handpiece (Group 4). There was no significant difference in the percentage of void formation between the hand instrument placement groups (Groups 1 and 2) and also between the injectable dispenser groups (Groups 3 and 4). In conclusion, different placement methods affected void formation in two-surface Class II cavity restored with bulk-fill resin composite. Placement with a hand instrument had a significantly higher void formation than placement with an injectable dispenser.

Keywords: Bulk-fill resin composite, Class II cavity, Micro-computed tomography, Void

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Introduction

Resin composite has been widely used to restore both anterior and posterior teeth due to esthetic concerns and gradually phased down of dental amalgam used. It can be attached to the tooth via bonding systems, supports

occlusal forces and provides natural tooth color. However, restoring teeth with resin composite usually created voids,¹⁻⁵ both within the resin composite itself and at the interfaces between cavity walls and the resin composite,

which are results of air trapped within the material during manufacturing,² air trapped between layers of resin composite or air trapped at the interfaces between cavity walls and the resin composite upon restoring.¹ The micro-computed tomography (micro-CT) study by Jira-arnon and Maneenut,¹ which evaluated the void formation in slot Class II cavities of extracted human maxillary first premolar teeth restored with bulk-fill resin composites using different placement methods, found voids in all the tooth samples. The study by Chaidarun and Leevailoj,² which investigated and compared the number of voids in small and large Class II cavities of artificial mandibular second premolar teeth restored with bulk-fill resin composite or conventional nanohybrid resin composite, found voids within the tooth samples. There are multiple factors related to void formation in resin composite restorations such as adhesive agents, polymerization shrinkage and stress, cavity configurations, the manufacturing process, the viscosity of the resin composites and placement methods.³⁻¹⁰

A void of the resin composite restoration is a restoration failure factor. Voids within the resin composite can reduce its mechanical properties.^{4,5,11} Voids at the axio-pulpal line angles can cause restoration fractures. Voids at cavity-resin composite interfaces can reduce bond strength and result in movements of fluid or bacteria through the interfaces. These can cause dental caries and post-operative sensitivity. Voids along the restoration margins and the external surfaces also result in microleakage, discoloration, surface roughness, plaque accumulation and dental caries. These voids can be seen and can compromise the esthetics of the restoration. Furthermore, their appearance as radiolucent areas in radiograph can be misinterpreted as dental caries. Jira-arnon and Maneenut¹ together with Chaidarun and Leevailoj² recommended methods to reduce void formation in resin composite restorations such as using proper viscosity resin composites, proper placement methods and bulk-fill resin composites.

The incremental placement of conventional resin composites are applied when restoring a deep cavity to ensure adequate light transmission for complete poly-

merization and to avoid cuspal deflection.^{12,13} Recently, bulk-fill resin composites are introduced to solve the disadvantages of conventional resin composites. They are claimed by manufacturers for placing in a bulk of 4-5 mm,^{14,15} which can simplify the treatment procedures. Their properties were improved and provided clinical advantages such as increased depth of cure, low polymerization shrinkage and stress, which provide better marginal adaptation and reduced cuspal deflection.¹⁶⁻²⁰ Their handling properties are similar to conventional resin composites. However, restoring cavity more than 4 mm depth with bulk-fill resin composites still requires incremental placement to avoid insufficient polymerization, which can degrade resin composites, create negative effect on physical properties and adverse biological reactions.¹⁶⁻²⁰

Several methods were used to evaluate void formation in resin composite restoration. A simple method is sectioning the sample, staining and observing under a microscope. However, it can evaluate only the sectioned plane and is destructive, which has to cut the samples and the evaluation cannot be repeated.² Recently, with the developments in imaging technology to create a three-dimensional image without cutting the sample,²¹ micro-computed tomography is widely used to evaluate the void formation of resin composite restoration in many studies.^{1,22-25} However, there was still insufficient information of void formation in large and different Class II cavity designs. Thus, this study was conducted to evaluate void formation by micro-computed tomography in two-surface Class II cavities restored using four different placement methods with three bulk-fill resin composites

Materials and Methods

Specimen preparations

Forty extracted human maxillary first premolar teeth without any dental caries, restoration and cracks were collected, cleaned and immersed in 0.1% thymol solution (approved by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn

University, HREC-DCU 2020-044). The teeth were simply randomized and divided into four groups with ten teeth per group. Occlusal surface of the tooth was polished into a paralleled plane to reach the deepest level of pits or fissures by a polishing machine (NANO 2000, PACE technologies, USA). Proximal surface of the tooth was polished into a perpendicular plane to the polished occlusal surface by the polishing machine. The gingival margin of the polished proximal surface was 4 mm lower than the polished occlusal surface.

Each polished tooth was embedded in clear acrylic resin at 2 mm beneath the cemento-enamel junction level. A two-surface Class II cavity was prepared on the polished occlusal and proximal surfaces with high-speed diamond cylinder bur (Intensiv, Switzerland) using computer numerical control (CNC) specimen former (Former A-11, IMT, Thailand). The axio-pulpal line angle was rounded with a gingival margin trimmer (Hu-Friedy, USA). Dimensions of the cavity were set as follows:

- The occlusal cavity was 2 mm occluso-gingival depth, 3 mm mesio-distal width and 3 mm bucco-lingual width.
- The proximal cavity was 2 mm pulpo-gingival depth, 1.5 mm mesio-distal width and 3 mm bucco-lingual width.

Dimensions of the prepared cavity were confirmed by a digital vernier caliper (Mitutoyo, Japan).

A metal Tofflemire matrix system was applied to the prepared cavity. Matrix band was adapted and covered all cavity margins. The top margin of the band was at 1 mm above the occlusal cavity margin. The cavity was etched with 37.5% phosphoric acid (Gel Etchant, Kerr, USA) for 15 seconds, rinsed thoroughly with distilled water for 15 seconds and gently air blown for three seconds to achieve moist dentin. The OptiBond™ FL (Kerr, USA) adhesive system was applied in the cavity following the manufacturer's instructions. The OptiBond FL Primer was applied with a light scrubbing motion for 15 seconds and gently air blown for five seconds until the cavity had a slightly shiny appearance. The OptiBond FL Adhesive was applied uniformly to create a thin coating. The adhesive was

light cured with Demi™ Plus light curing unit (Kerr, USA) with light intensity 1,100-1,330 mW/cm² for 20 seconds.

Silicone index preparation

The volume of the prepared cavity in each tooth was approximately 27 mm³. Since no void was needed in the bulk of material that was pushed out from the syringe, a self-cured silicone index (Silagum Putty, DMG, Germany) was prepared to control the volume and void of syringe-type resin composite which was placed into the cavity with a hand instrument (group 1 and group 2).¹

A light cured square-shaped resin composite block (4 x 2 x 3.5 mm³), which has slightly more volume than the volume of the prepared cavity, was prepared by the computer numerical control specimen former. The resin composite block was placed on the freshly mixed silicone and pressed into the silicone with a glass slab. When the silicone was completely set, the resin composite block was taken out.

Restoring procedures

Group 1: One bulk placement with hand instrument with syringe-type Filtek™ One Bulk Fill Restorative (3M ESPE, USA)

The resin composite was pushed out of the syringe and placed into the silicone index with a CVIPC carver (Hu-Friedy, USA). All amount of resin composite (volume of approximately 27 mm³) was taken out of the index and put into the prepared cavity with the carver. It was adapted with a flat-ended plugger (Hu-Friedy, USA) in the occluso-gingival direction for 15 times with a pressure of approximately 100 grams each time (the operator was well practiced to press with the same force, using a push-pull force gauge). The excess resin composite was removed with the carver in the bucco-lingual direction for five times. The tip of the light guide was placed at 2 mm from the top of the cavity (the cusp height was compensated to simulate clinical situations) and light cured for 40 seconds. The matrix band was removed and light was applied on the buccal and lingual surfaces of the proximal cavity for 20 seconds each.

Group 2: Two-bulk placement with hand instrument with syringe-type Filtek™ One Bulk Fill Restorative (3M ESPE, USA)^{26,27} (Fig. 1)

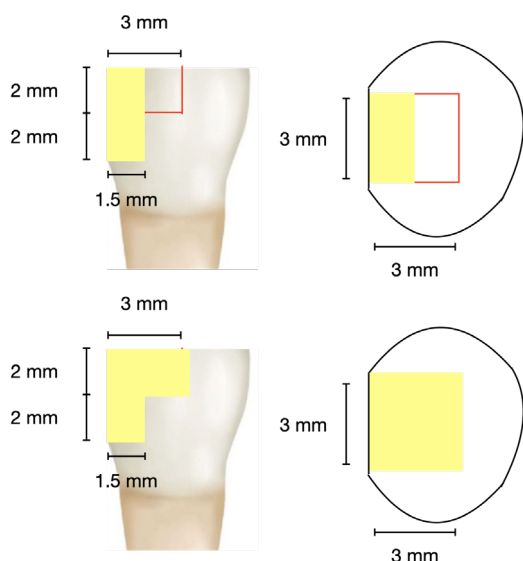


Figure 1 Two-bulk placement with hand instrument of Group 2

The placement was modified from the centripetal technique in which the proximal part against the matrix band was created first and the remaining occlusal cavity was filled up later.^{26,27} The resin composite was pushed out of the syringe and placed into the silicone index with the CVIPC carver. Two-thirds of the resin composite (volume of approximately 18 mm³) was taken out of the index and put it into the proximal cavity with the carver and adapted with the flat-ended plugger in the occluso-gingival direction for five times and in the mesio-distal direction for five times using the same force. The top level of the resin composite was at the same level of the occlusal margin. The rest of the resin composite (volume of approximately 9 mm³) was put into the occlusal cavity with the carver and adapted with the flat-ended plugger in the occluso-gingival direction for five times. The excess resin composite was removed with the carver in the bucco-lingual direction for five times. The tip of the light guide was placed at 2 mm from the top of the cavity (compensated cusp height to simulate clinical situations) and light cured for 40 seconds. The matrix band was removed and light was applied on the buccal and lingual surfaces of the proximal cavity for 20 seconds each.

Group 3: One bulk placement with injectable dispenser with capsule-type Filtek™ One Bulk Fill Restorative (3M ESPE, USA)

The Filtek™ One Bulk Fill Restorative capsule was put into the Filtek™ Restoratives Dispenser. The tip of the capsule was placed 0.5 mm above the gingival wall. The resin composite was dispensed and the capsule tip was moved upward and kept inside the bulk of the resin composite during dispensing until the resin composite reached the occlusal surface. The excess resin composite was removed with the carver in the bucco-lingual direction for five times. The tip of the light guide was placed at 2 mm from the top of the cavity (compensated cusp height to simulate clinical situations) and light cured for 40 seconds. The matrix band was removed and light was applied at buccal and lingual surfaces of the proximal cavity for 20 seconds each.

Group 4: One bulk placement with injectable dispenser and sonic-activated handpiece with SonicFill™ 2 (Kerr, USA)

The SonicFill™ 2 capsule was put into the SonicFill™ Handpiece. The dispensing rate of the handpiece was set at level 3. The tip of the capsule was placed 0.5 mm above the gingival wall. The handpiece was activated by fully depressing the foot pedal and the capsule tip was moved upward and kept inside the resin composite while the handpiece was activated. The handpiece was turned off when the resin composite reached the occlusal surface. The excess resin composite was removed with the carver in a bucco-lingual direction for five times. The tip of the light guide was placed 2 mm from the top of the cavity (the cusp height was compensated to simulate clinical situations) and the light cured for 40 seconds. The matrix band was removed and light was applied at buccal and lingual surfaces of the proximal cavity for 20 seconds each.

All restored teeth were kept in an incubator (Contherm 1200, Contherm, New Zealand) with a relative humidity of 100 % at 37°C for 24 hours.

Analysis of voids formation using micro-computed tomography

All teeth were removed from the resin blocks and the root, buccal surface and lingual surface was cut 1-2 mm away from the margins of the cavity with a high-speed diamond cylinder bur. The prepared samples were placed in a 10 mm diameter holder and stabilized with sponges. The holder was put into a micro-computed tomography machine (μ CT 35, Scanco Medical, Switzerland). The machine was set to 70 kV, 100 μ A, voxel size 6 μ m and filtered the radiation with aluminum 0.5 mm thickness.¹ The samples were scanned and sets of approximately 500 images per one restoration were recorded. The operator set regions of interest covering the entire restoration. The percentages of volume of void per volume of the entire restoration were calculated using a micro-computed tomography evaluation program.

Statistical Analysis

SPSS Statistics 26 software (IBM, USA) was used to analyze the data. A significance level of 0.05 was set. The Shapiro-Wilk test was performed to test normality. The one-way ANOVA and Games-Howell post hoc analyses were performed to analyze the percentage of voids.

Results

The mean percentage of the volume of the void per volume of the entire restoration is presented in Table 1. Group 2, two-bulk placement with a hand instrument was the highest, followed by Group 1, one bulk placement with a hand instrument and Group 4, one bulk placement with an injectable dispenser and a sonic-activated handpiece. Group 3, one bulk placement with an injectable dispenser was the lowest.

Table 1 Mean percentage of volume of void per volume of the entire restoration and standard deviation. The same superscript letter means no statistically significant difference

Group	Mean (SD)
1: One bulk placement with hand instrument	0.66 (0.39) ^a
2: Two-bulk placement with hand instrument	1.08 (0.38) ^a
3: One bulk placement with injectable dispenser	0.10 (0.09) ^b
4: One bulk placement with injectable dispenser and sonic-activated handpiece	0.14 (0.11) ^b

One bulk placement with a hand instrument (Group 1) and two-bulk placement with a hand instrument (Group 2) had significantly higher percentage of void formation than one bulk placement with an injectable dispenser (Group 3) and one bulk placement with an injectable dispenser and a sonic-activated handpiece (Group 4). There was no significant difference in the percentage of void formation between the hand instrument placement groups (Groups

1 and 2) and also between the injectable dispenser groups (Groups 3 and 4).

Voids at the cavity walls, line angles and within the bulk of resin composites were found in all groups (Fig. 2, 3, 4 and 5). Voids located between the bulks of resin composite were found in only Group 2, two-bulk placement with a hand instrument (Fig. 3).

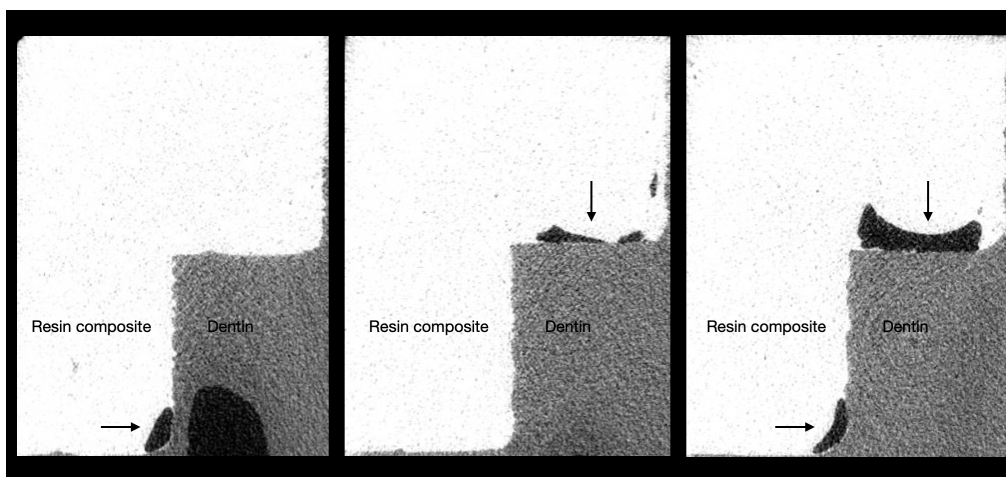


Figure 2 Representative cross-sectional images of Group 1, one bulk placement with a hand instrument. Voids are indicated by arrows

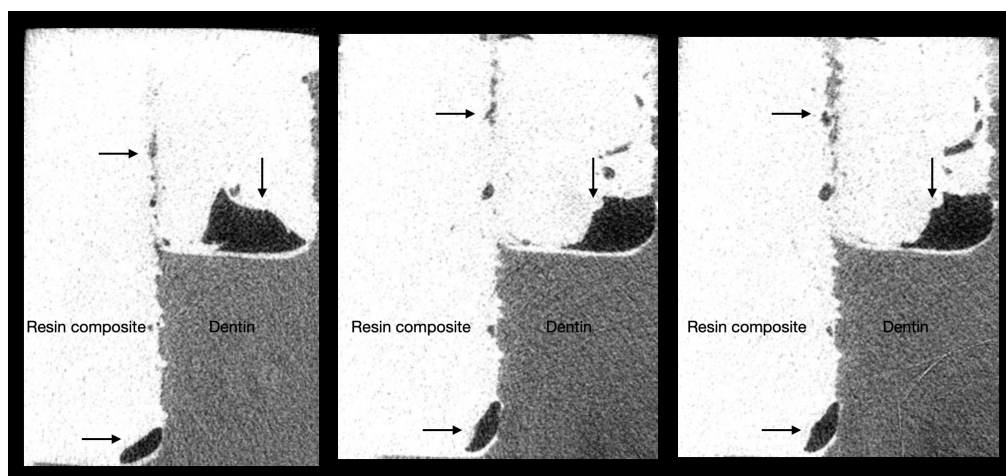


Figure 3 Representative cross-sectional images of Group 2, two-bulk placement with hand instruments. Voids are indicated by arrows

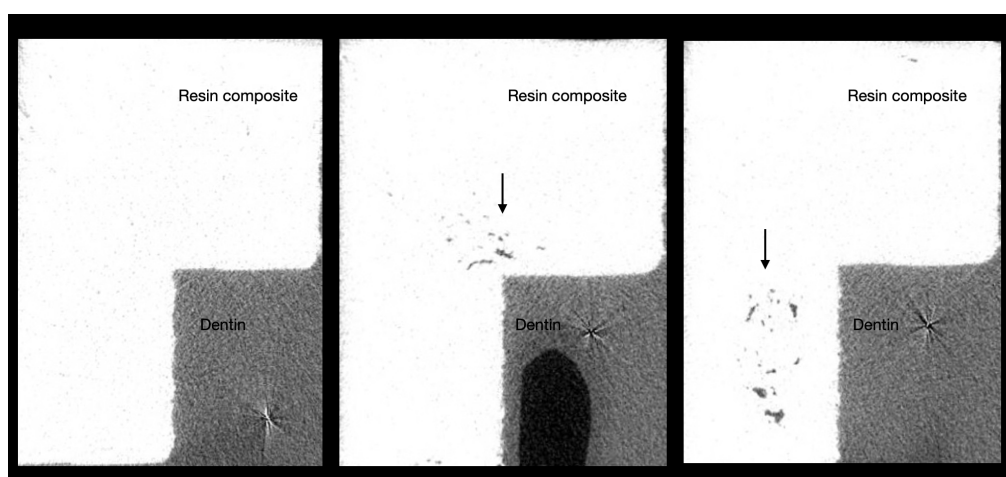


Figure 4 Representative cross-sectional images of Group 3, one bulk placement with an injectable dispenser. Voids are indicated by arrows

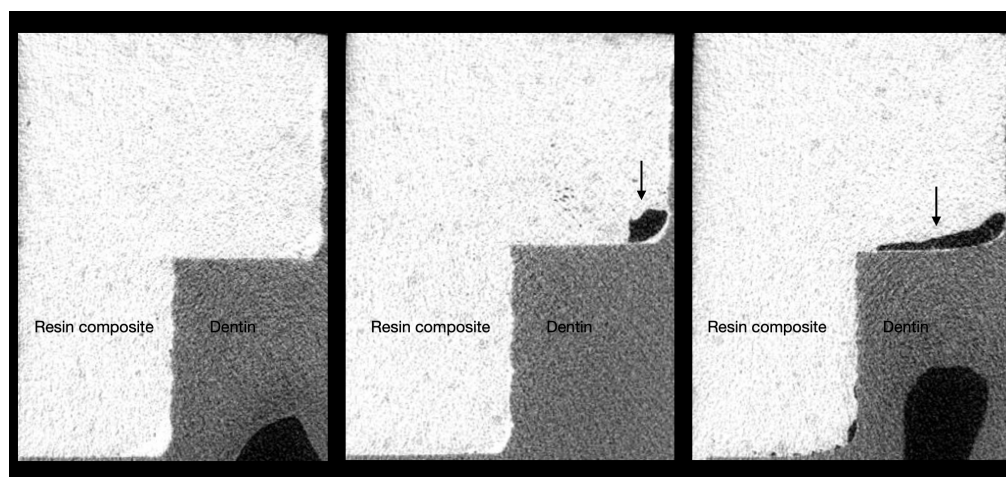


Figure 5 Representative cross-sectional images of Group 4, one bulk placement with an injectable dispenser and sonic-activated handpiece. Voids are indicated by arrows

Discussion

Voids in this study were voids within the resin composite, voids between the bulks of the resin composite and voids at the interfaces between cavity walls and the resin composite. These voids appeared as radiolucent areas in each cross-sectional image when using micro-computed tomography analysis. The effect of cavity size and volume were discarded by using computer numerical control specimen former to standardize the cavity. The silicone index was prepared to control the volume of the syringe-type resin composite which was placed with a hand instrument.¹ Putting a closely adapted amount of resin composite to the cavity volume could reduce the chance of void formation compared to putting much more which would have to be taken out or putting much less which would add in the material.

The results of this study found voids in all the tooth samples. Although the line angle was round, voids could occur at the line angles of the cavity. It also occurred at the interfaces between cavity walls and resin composite more than within the bulk of resin composites (Fig. 2, 3, 4 and 5). Voids at both occlusal and proximal line angles infer that more line angles means more possibilities of voids. The percentage of void formation was about 1 % and less. It was higher when placed with a hand instrument than placed with an injectable dispenser. The results

corresponded to the study by Jira-arnon and Maneenut,¹ which found that placement of syringe-type resin composite into slot Class II cavity with a hand instrument created more void formation than dispensed from a capsule. This study extended the Class II cavity into two surfaces and the placement method of two bulks was different from the previous study. The placement of Group 2 in two-bulk with a hand instrument (Fig. 1) was modified from the studies of Bichacho²⁶ and Hassan and others.²⁷ This placement method provided an uninterrupted proximal surface. A smooth proximal surface was clinically desirable because it could be easily cleaned and could have less plaque accumulation. However, there were interfaces of resin composite at the occlusal cavity (Fig. 3) in which voids could be formed more than in one bulk placement (Fig. 2). Voids at the interfaces in the occlusal cavity could affect the restorations more than voids within the bulk of resin composites in terms of leakage, weakness and staining. The interface of the bulks of resin composite in this study was a vertical line in the occlusal cavity instead of a horizontal line in the proximal cavity. This means that voids could be formed wherever the interface was.

The study by Aggarwal and others found that the placement of flowable resin composite improved adaptation in the gingival floor of proximal cavities.⁶ More-

over, the study by Schmidlin and others found that the ultrasound application improved marginal adaptation in Class II cavities.⁹ An example of bulk-fill resin composite that used sonic energy to reduce the viscosity of resin composite for a short time and did not reduce filler by volume is SonicFill™ 2. The company claimed that SonicFill™ 2 had low viscosity to flow and had high viscosity to shape. The flowable properties could increase adaptation to the cavities. When the handpiece vibration stopped, this bulk-fill resin composite became higher viscosity.¹⁵ The results of this study also showed that one bulk placement with injectable dispenser and sonic-activated handpiece had voids especially at the cavity walls and line angles but significantly lower percentage of void formation than placement with hand instrument.

From the results of this study, some recommendations could be drawn to reduce void formation in Class II cavity restored with bulk-fill resin composite such as placement with an injectable dispenser or injectable dispenser and sonic-activated handpiece. During the placement, the dispensing tip should be above the deepest part of the cavity by 0.5 mm and the dispensing tip should be kept inside the resin composite during dispensing. However, in the case of using a syringe-type bulk-fill resin composite which is quite common in clinical practice, one bulk placement could reduce steps and the amount of void in the restoration.

Conclusion

With the limitations of this study, it could be concluded that different placement methods affected void formation in two-surface Class II cavity restored with bulk-fill resin composite. Placement with a hand instrument had a significantly higher void formation than placement with an injectable dispenser.

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