EFFECT OF DIFFERENT PLACEMENT METHODS ON VOIDS FORMATION IN CLASS II CAVITY RESTORED WITH BULK-FILL RESIN COMPOSITE

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Operative Dentistry
Department of Operative Dentistry
FACULTY OF DENTISTRY
Chulalongkorn University
Academic Year 2021

ผลของวิธีการบูรณะที่แตกต่างกันต่อการเกิดช่องว่าง
ในโพรงฟันชนิดคลาสทูที่บูรณะด้วยเรซินคอมโพสิตชนิดบูรณะทั้งก้อน

น.ส.ปรินทร สิโยพุทธวงศ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาทันตกรรมหัตถการ ภาควิชาทันตกรรมหัตถการ
คณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2564

Thesis Title	EFFECT OF DIFFERENT PLACEMENT METHODS ON VOIDS FORMATIONIN CLASS II CAVITY RESTORED WITH BULK-FILL RESIN COMPOSITE
By	Miss Parinthorn Siyoputhawong
Field of Study	Operative Dentistry
Thesis Advisor	Associate Professor Chaiwat Maneenut, D.D.S., M.D.Sc., Ph.D.

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ปรินทร สิโยพุทธวงศ์ : ผลของวิธีการบูรณะที่แตกต่างกันต่อการเกิดช่องว่างในโพรงฟันชนิดคลาสทูที่บูรณะด้วยเรซินคอมโพสิตชนิดบูรณะทั้งก้อน. (EFFECT OF DIFFERENT PLACEMENT METHODS ON VOIDS FORMATIONIN CLASS II CAVITY RESTORED WITH BULK-FILL RESIN COMPOSITE) อ.ที่ปรึกษาหลัก : รศ. ทพ. ดร.ชัยวัฒน์ มณีนุษย์

การศึกษานี้มีวัตถุประสงค์เพื่อประเมินการเกิดช่องว่างโดยใช้เครื่องไมโครคอมพิวเตดโทโมกราฟฟีในโพรงฟันชนิดคลาสทูสองด้านที่บูรณะด้วยเรซินคอมโพสิตชนิดบูรณะทั้งก้อนด้วยวิธีการบูรณะที่แตกต่างกัน เตรียมโพรงฟันชนิดคลาสทูในฟันกรามน้อยบนซี่ที่หนึ่ง 40 ซี่ แบ่งฟันเป็น 4 กลุ่ม ได้แก่ กลุ่มที่ 1 ใส่วัสดุแบบหลอดครั้งเดียวโดยใช้เครื่องมือ กลุ่มที่ 2 ใส่วัสดุแบบหลอดสองครั้งโดยใช้เครื่องมือ กลุ่มที่ 3 ใส่วัสดุแบบแคปซูลครั้งเดียวโดยใช้เครื่องฉีด กลุ่มที่ 4 ใส่วัสดุแบบแคปซูลครั้งเดียวโดยใช้เครื่องฉีดร่วมกับโซนิคแฮนด์พีซ ประเมินร้อยละของช่องว่างในวัสดุบูรณะ วิเคราะห์ทางสถิติด้วย Welch's ANOVA และ Games-Howell post hoc ที่ระดับนัยสำคัญ 0.05 ผลการศึกษาพบว่า การใส่วัสดุแบบหลอดครั้งเดียวโดยใช้เครื่องมือ (กลุ่มที่ 1) และการใส่วัสดุแบบหลอดสองครั้งโดยใช้เครื่องมือ (กลุ่มที่ 2) มีร้อยละของช่องว่างมากกว่าการใส่วัสดุแบบแคปซูลครั้งเดียวโดยใช้เครื่องฉีด (กลุ่มที่ 3) และการใส่วัสดุแบบแคปซูลครั้งเดียวโดยใช้เครื่องฉีดร่วมกับโซนิคแฮนด์พีซ (กลุ่มที่ 4) อย่างมีนัยสำคัญ และไม่พบความแตกต่างอย่างมีนัยสำคัญระหว่างกลุ่มที่ใส่วัสดุแบบหลอดโดยใช้เครื่องมือ (กลุ่มที่ 1 และ กลุ่มที่ 2) และระหว่างกลุ่มที่ใส่วัสดุแบบแคปซูลโดยใช้เครื่องฉีด (กลุ่มที่ 3 และ กลุ่มที่ 4) สรุปผลการศึกษาว่าวิธีการบูรณะที่แตกต่างกันส่งผลต่อการเกิดช่องว่างในโพรงฟันชนิดคลาสทูสองด้านที่บูรณะด้วยเรซินคอมโพสิตชนิดบูรณะทั้งก้อน การใส่วัสดุแบบหลอดโดยใช้เครื่องมือเกิดช่องว่างมากกว่าการใส่วัสดุแบบแคปซูลโดยใช้เครื่องฉีด

สาขาวิชา	ทันตกรรมหัตถการ	ลายมือชื่อนิสิต
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การศึกษา		.....

6175826232 : MAJOR OPERATIVE DENTISTRY

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

Parinthorn Siyoputhawong : EFFECT OF DIFFERENT PLACEMENT METHODS ON VOIDS FORMATIONIN CLASS II CAVITY RESTORED WITH BULK-FILL RESIN COMPOSITE. Advisor: Assoc. Prof. Chaiwat Maneenut, D.D.S., M.D.Sc., Ph.D.

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

Field of Study:	Operative Dentistry	Student's Signature .....
Academic Year:	2021	Advisor's Signature .....

ACKNOWLEDGEMENTS

The author gratefully acknowledges her advisor, Associate Professor Chaiwat Maneenut, Ph.D. who offered guidance and support throughout this research. The author is grateful to Assistant Professor Soranan Chantarangsu, Ph.D. for statistic consulting. Also, thanks to the staff of the Dental Material Research and Development Center and Oral Biology Research Center, Faculty of Dentistry, Chulalongkorn University for their hospitality and valuable service.

Parinthorn Siyoputhawong

TABLE OF CONTENTS

Page

LIST OF TABLES

Page

LIST OF FIGURES

Page

CHAPTER I INTRODUCTION

Rationale and Significance of the Problem

Resin composite has been widely used to restore both anterior and posterior teeth due to esthetic concerns and gradually phased down of dental amalgam using. It can attach to the tooth via bonding systems, supports occlusal forces and provides natural tooth color. However, restoring teeth with resin composite usually found voids (1-5), both within resin composite itself and at the interfaces between cavity walls and resin composite, which are results of air trapping within the material during manufacturing (2), air trapping between layers of resin composite or air trapping at the interfaces between cavity walls and resin composite upon restoring. (1) The micro-computed tomography (micro-CT) study of Jira-arnon and Maneenut (1), which evaluated 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 tooth samples. The study of 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 polymerization shrinkage stress, cavity configurations, manufacturing process, the viscosity of resin composites and placement methods. (3-10)

Void of resin composite restoration is a restoration failure factor. Voids within resin composite can reduce its mechanical properties. (4, 5, 11, 12) Voids at axio-pulpal line angles can cause restoration fractures. These voids can be seen and compromise the esthetics of the restorations. 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 margins and external surfaces also result in leakage, discoloration, surface roughness, plaque accumulation and dental caries. Furthermore, their appearance as radiolucent areas in radiographs can be misinterpreted as dental caries. Jira-arnon and Maneenut (1) together with Chaidarun and Leevailoj (2) recommended methods to reduce void formation in resin composite restorations such as using proper viscosity resin composites, using proper placement methods and using bulk-fill resin composites.

The incremental placement of conventional resin composite is applied when restoring a deep cavity to ensure adequate light transmission for complete polymerization and avoid cuspal deflection. (13, 14) Recently, bulk-fill resin composites are introduced to solve the disadvantages of conventional resin composites. Manufacturers claim that bulk-fill resin composites can be placed in a bulk of 4-5 mm (15, 16), which can simplify the treatment procedures. Bulk-fill resin composites have improved properties and provided clinical advantages such as increased depth of cure, low polymerization shrinkage stress, which provide better marginal adaptation and reduced cuspal

deflection. (17-21) Moreover, 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. (17-21)

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 cannot repeat the evaluation. (2) Recently, with the developments in imaging technology to create three-dimensional image without cutting the sample (22), micro-computed tomography is widely used to evaluate void formation of resin composite restoration in many studies. (1, 23-26) 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 with bulk-fill resin composites which using different placement methods.

Research Question

Do different placement methods affect void formation in two-surface Class II cavity restored with bulk-fill resin composite?

Research Objectives

To evaluate void formation by micro-computed tomography in two-surface Class II cavities restored with bulk-fill resin composites using different placement methods.

Hypotheses

Null Hypothesis

There was no significant difference in percentage of void formation in Class II cavity restored with bulk-fill resin composite using different placement methods.

Alternative Hypothesis

There was significant difference in percentage of void formation in Class II cavity restored with bulk-fill resin composite using different placement methods.

Scope of the Study

Experimental design: In vitro study

Study Limitations

The results of this study may not be inferred to all clinical situations.

Basic Assumptions

1. All procedures in this study were done and evaluated by one operator.
2. The operator was well trained to use the materials and equipment in this study.
3. All the materials and equipment used in this study were strictly followed the instructions of the manufacturers.
4. Voids in this study were voids within resin composite, voids between the bulks of resin composite and voids at the interfaces between cavity walls and resin composite. These voids appeared as radiolucent areas in each cross-sectional image when using micro-computed tomography analysis.

Expected Benefit of the Study

To provide more information about placement methods which can reduce void formation in Class II cavity restored with bulk-fill resin composite.

Keywords

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

Conceptual Framework

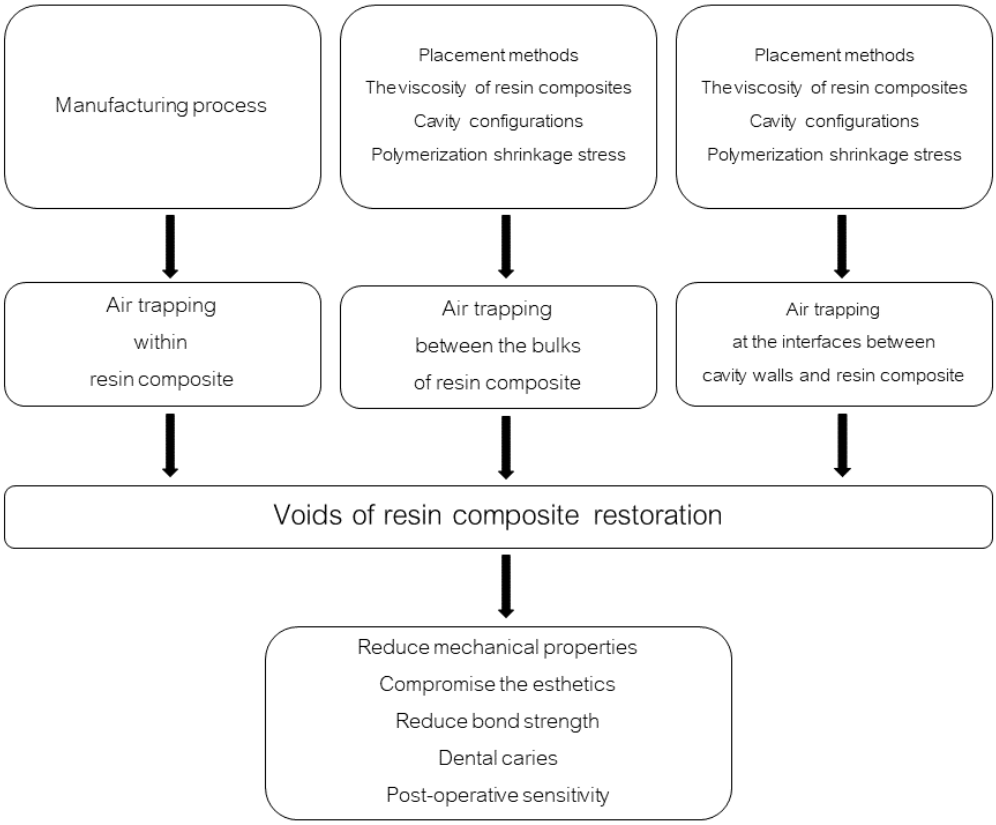


Figure 1 Conceptual framework

CHAPTER II REVIEW OF LITERATURES

Voids of resin composite restoration

Voids of resin composite restoration are results of air trapping within resin composite, air trapping between layers of resin composite or air trapping at the interfaces between cavity walls and resin composite. Voids appear as round and well-defined within resin composite or ovoid and elongated at the interfaces between cavity walls and resin composite and are sometimes called gaps. (7)

Voids of resin composite restoration can be classified into three groups by diameter length (3) as follows;

- Small voids: diameter length not more than 50 micrometers
- Medium voids: diameter length more than 50 micrometers but not more than 150 micrometers
- Large voids: diameter more than 150 micrometers

Large voids have the most pronounced effects on restorations. Restorations with large voids have low mechanical properties. (4, 5, 11)

Restoring teeth with resin composite usually found voids (1-5), both within resin composite itself and at the interfaces between cavity walls and resin composite, which are results of air trapping within the material during manufacturing (2), air trapping between layers of resin composite or air trapping at the interfaces between cavity walls

and resin composite upon restoring. (1) The micro-computed tomography study of Jira-arnon and Maneenut (1), which evaluated 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 tooth samples. The study of 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.

Factors related to voids of resin composite restoration

There are multiple factors related to void formation in resin composite restorations such as polymerization shrinkage stress, cavity configurations, manufacturing process, the viscosity of resin composites and placement methods.

1. **Polymerization shrinkage stress**

When resin composites are polymerized, the shrinkage stress occur at the interfaces between cavity walls and resin composite. The polymerization shrinkage stress can result in tooth deformation, cuspal deflection, voids between tooth and resin composite, marginal leakage, and decreasing in adaptation. (13, 14, 27)

2. **Cavity configurations**

Cavity preparation with round internal line angles can improve more adaptation of resin composite to the cavity. The study of Chaidarun and Leevailoj found voids in the axio-pulpal line angle areas due to the inability to adapt the resin composites to the cavities. (2) Feilzer and others introduced the configuration factor, which was the ratio of bonded area per unbonded area. The low configuration factor indicates that there are many unbonded areas. These areas allow resin composite to change its shape and relieve the stress. Thus, the polymerization shrinkage stress decreases. (28)

3. Manufacturing process

The study of Chaidarun and Leevailoj found voids in samples of non-manipulated resin composite extruded from the original syringe. Voids within resin composite may originate as a result of the manufacturing process. (2)

4. The viscosity of resin composites

Resin composites with proper viscosity can easily place into the cavity, provide good adaptation and do not stick to the instruments during carving. The study of Opdam and others found that high viscosity resin composite has less adaptation than low viscosity resin composite. (4, 5) Moreover, the study of Soares and others found that bulk-fill flowable resin composites demonstrate a reduced incidence of voids and have improved adaptation to the cavity walls. (29) However, the study of Balthazard and others, which evaluated void by high-resolution tomography, found that low viscosity resin composite has percentage of void and void volume more than high viscosity resin composite. (30)

5. Placement methods

There were recommendations to use an incremental technique when restoring cavities with conventional resin composites. This placement method provides complete polymerization of the resin composites and can reduce polymerization shrinkage stress. The configuration factor in the cavity decreases and reduces cuspal deflection. Moreover, the incremental technique provides better internal adaptation than restoring conventional resin composite in one bulk. (14, 27) However, the study of Soares and others found that incremental placement of conventional resin composites demonstrate a higher incidence of voids between the increments. (29)

Effects of voids of resin composite restoration

Void of resin composite restoration is a restoration failure factor. Voids within resin composite can reduce its mechanical properties. (4, 5, 11, 12) Voids at axio-pulpal line angles can cause restoration fractures. These voids can be seen and compromise the esthetics of the restorations. 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 margins and external surfaces also result in leakage, discoloration, surface roughness, plaque accumulation and dental caries. Furthermore, their appearance as radiolucent areas in radiographs can be misinterpreted as dental caries.

How to reduce voids of resin composite restoration

There are many recommendations to reduce void formation in resin composite restorations such as using proper viscosity resin composites, using proper placement methods and using bulk-fill resin composites.

1. **Using proper viscosity resin composites**

The placement of flowable resin composite improved adaptation in the gingival floor of proximal cavities. (6) Moreover, the ultrasonic 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 was 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 vibration stopped, this bulk-fill resin composite became higher viscosity. (16) The low viscosity during placement resin composite reduced incidence of voids within the bulk of material. (31) Bulk-fill flowable resin composites have improved adaptation to the cavity walls. (29)

2. Using proper placement methods

The study of Jira-arnon and Maneenut, which evaluated void formation in slot Class II cavities of extracted human maxillary first premolar teeth restored with different placement methods of bulk-fill resin composites using micro-computed tomography, found that placement resin composite from a syringe with hand instrument created more voids than from a capsule with injectable dispenser. Moreover, this study also found that incremental placement created voids between layers of resin composite. (1)

Standardized slot Class II cavities were prepared in forty extracted human premolars, which were divided into four groups.

Group 1: One bulk placement with Filtek™ Bulk Fill Posterior syringe

Group 2: Incremental placement with Filtek™ Bulk Fill Posterior syringe

Group 3: One bulk placement with Filtek™ Bulk Fill Posterior capsule

Group 4: One bulk placement with SonicFill™ capsule

Three-dimensional images from micro-computed tomography found voids in all tooth samples. Group 2, incremental placement with Filtek™ Bulk Fill Posterior syringe, found voids in the middle of the restorations. (Figure 2)

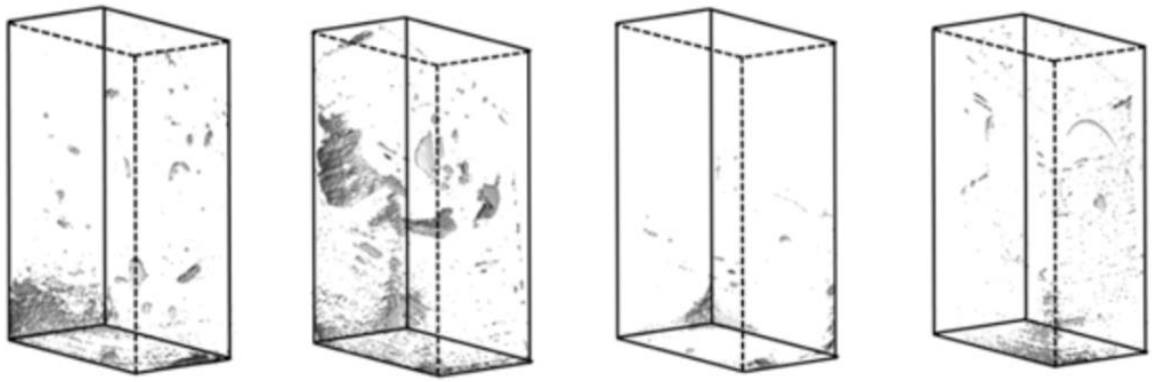


Figure 2 Three-dimensional images of voids (1)

Group 1: One bulk placement with Filtek™ Bulk Fill Posterior syringe found voids at cavity walls and line angles. (Figure 3)

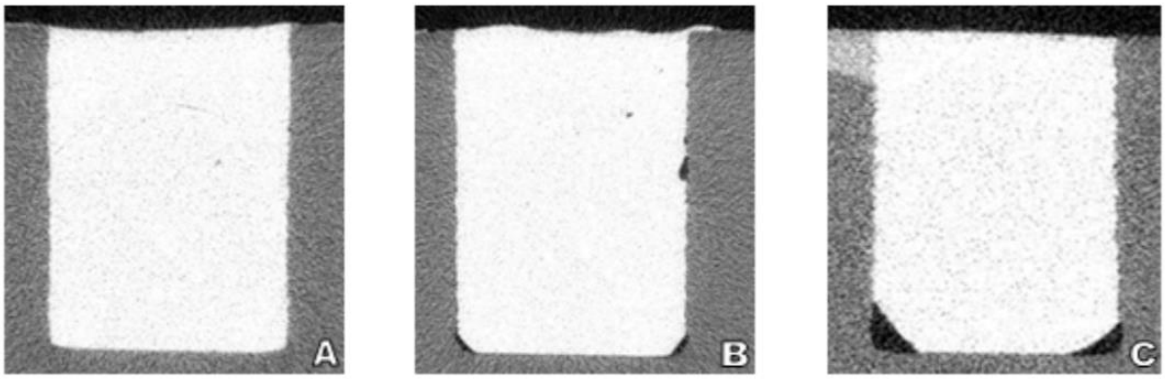


Figure 3 Cross-sectional images of group 1 (1)

Group 2: Incremental placement with Filtek™ Bulk Fill Posterior syringe found voids at cavity walls, line angles, and in the middle of the restorations (Figure 4)

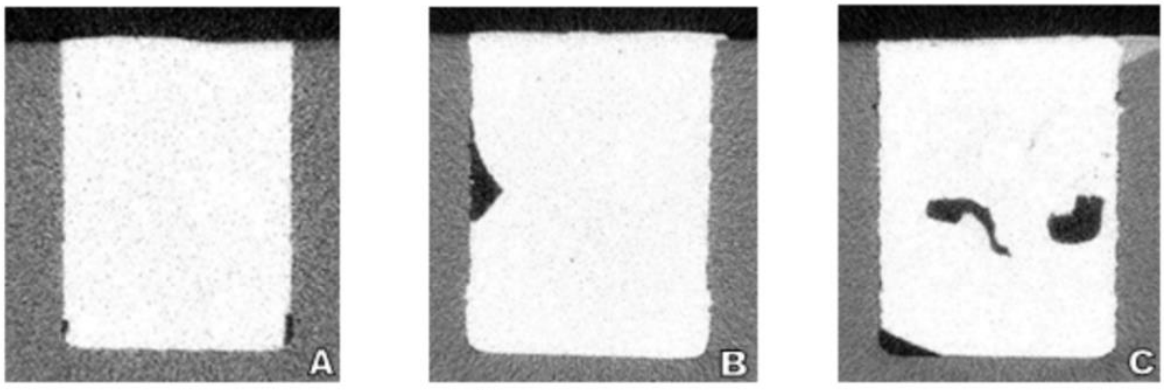


Figure 4 Cross-sectional images of group 2 (1)

Group 3: One bulk placement with Filtek™ Bulk Fill Posterior capsule found voids at cavity walls and line angles (Figure 5)

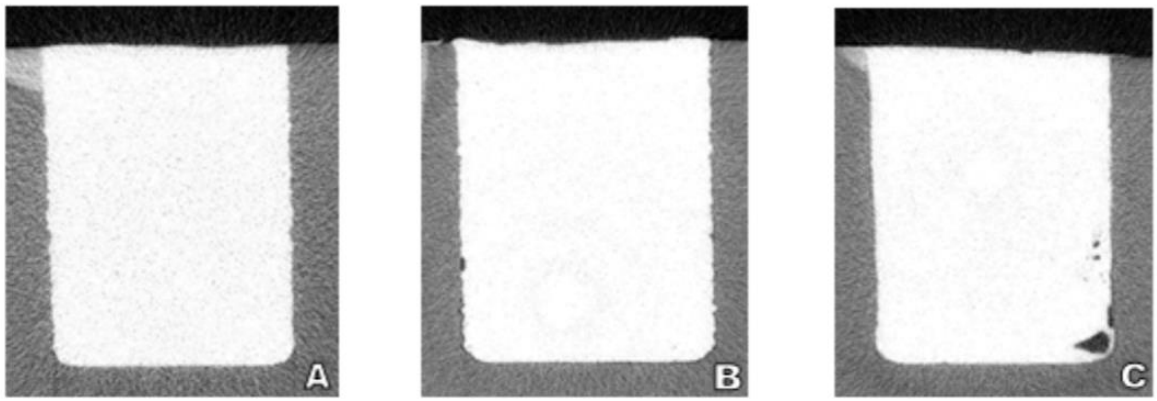


Figure 5 Cross-sectional images of group 3 (1)

Group 4: One bulk placement with SonicFill™ capsule found voids at cavity walls and line angles. (Figure 6)

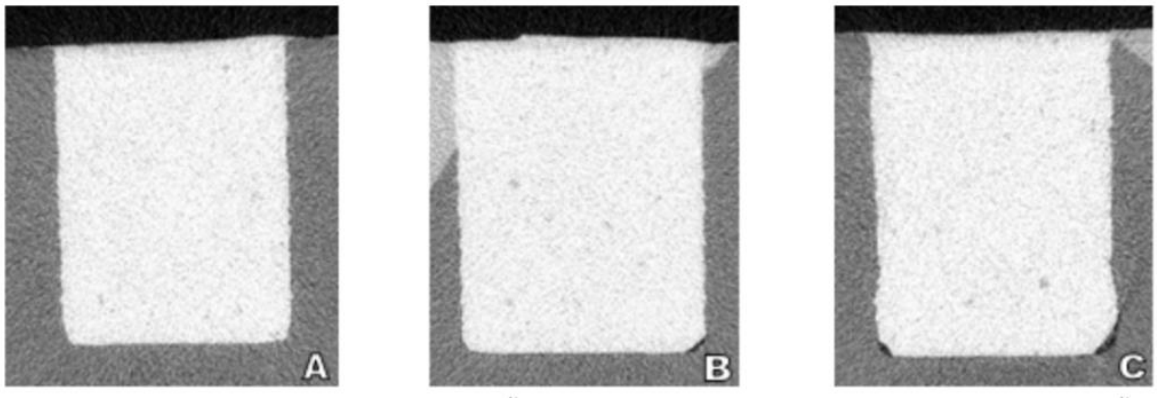


Figure 6 Cross-sectional images of group 4 (1)

Percentage and standard deviation of voids was presented in Table 1. Group 2, incremental placement with Filtek™ Bulk Fill Posterior syringe, had significantly higher percentage of voids than other groups. There was no significant difference in percentage of voids between group 1, one bulk placement with Filtek™ Bulk Fill Posterior syringe, group 3, one bulk placement with Filtek™ Bulk Fill Posterior capsule and group 4, one bulk placement with SonicFill™ capsule.

Table 1 Percentage and standard deviation of voids (1)

Group	Mean (SD)
1: One bulk placement with Filtek™ Bulk Fill Posterior syringe	0.487252 (0.481677) [b]
2: Incremental placement with Filtek™ Bulk Fill Posterior syringe	1.615359 (1.1136211) [a]
3: One bulk placement with Filtek™ Bulk Fill Posterior capsule	0.329878 (0.2375264) [b]
4: One bulk placement with SonicFill™ capsule	0.208143 (0.1971202) [b]

The same superscript letter means no statistically significant difference

3. Using bulk-fill resin composites

The incremental placement of conventional resin composite is applied when restoring a deep cavity to ensure adequate light transmission for complete polymerization and avoid cuspal deflection. (13, 14) Recently, bulk-fill resin composites are introduced to solve the disadvantages of conventional resin composites. Manufacturers claim that bulk-fill resin composites can be placed in a bulk of 4-5 mm (15, 16), which can simplify the treatment procedures. Bulk-fill resin composites have improved properties and provided clinical advantages such as increased depth of cure, low polymerization shrinkage stress, which provide better marginal adaptation and reduced cuspal deflection. (17-21) Moreover, 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. (17-21)

Evaluation of voids of resin composite restoration

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 cannot repeat the evaluation. (2) Recently, with the developments in imaging technology to create three-dimensional image without cutting the sample (22), micro-computed tomography is widely used to evaluate void formation of resin composite restoration in many studies. (1, 23-26)

Voids appeared as radiolucent areas in each cross-sectional image when using micro-computed tomography analysis. Micro-computed tomography was widely used in dentistry to analyze voids of restorations. The study of Kim and Park and Han and Park evaluated the internal adaptation of resin composite restorations in the regions of interest by choosing some cross-sectional images in the same interval. (24, 25) The study of Jira-arnon and Maneenut evaluated all void formation in slot Class II cavities restored with different placement methods of bulk-fill resin composites and reported a significant difference in percentage of voids. (1)

X-ray radiography provides a two-dimensional image while teeth have three-dimensional structures. The development of a tomography imaging technique, which has the movement of light source and detector, provides images focusing on one plane and other planes in low contrast. For high contrast images, the data of the light intensity

transmitted from the sample in different views were calculated using a computer to create three-dimensional imaging and were called computed tomography. (22)

Computed tomography provides images with volume elements or voxels as one mm^3, while micro-computed tomography provides images with voxels 5-50 μm^3 or 1,000,000 times smaller than computed tomography. These smaller voxels provide high-resolution and three-dimensional imaging. (22)

Micro-computed tomography consists of a micro-focus X-ray tube, collimator which creates fan or cone radiation, specimen holder, and phosphor-detector/charge-coupled device camera. (Figure 7) (32)

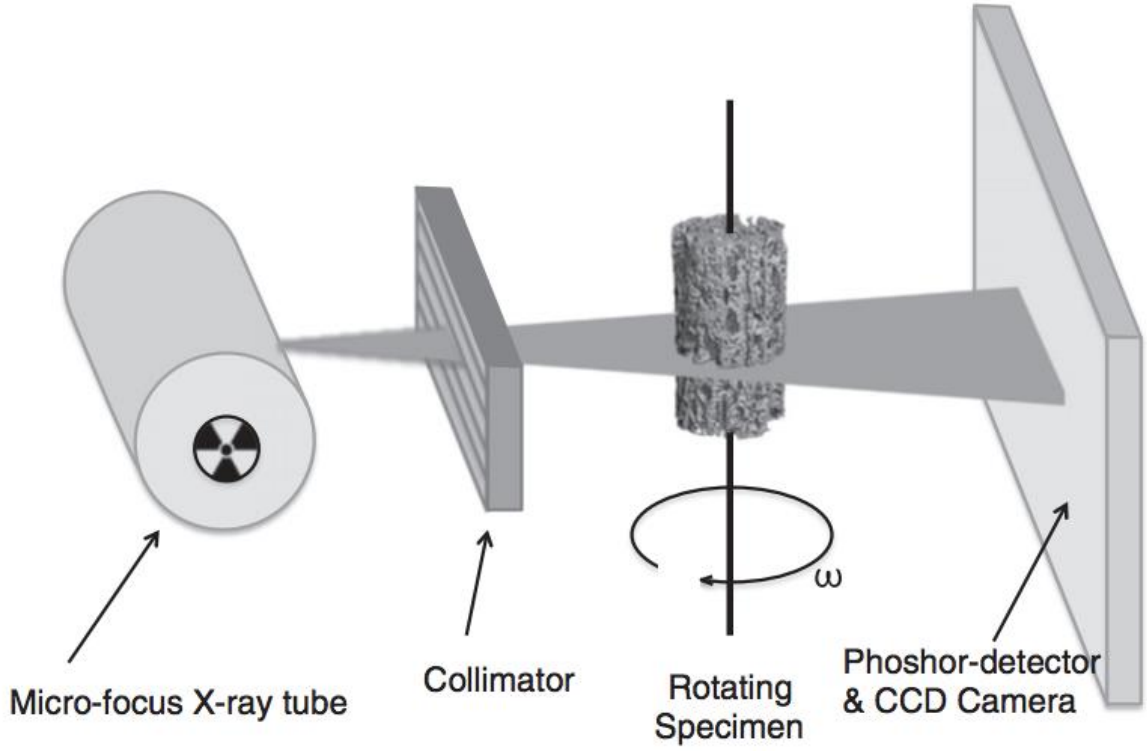


Figure 7 Micro-computed tomography (32)

CHAPTER III MATERIALS AND METHODS

Research Design

Experimental design: In vitro study (approved by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University, HREC-DCU 2020-044).

Sample Size Description

The sample size was calculated by G*Power 3.1 (F-test family for one-way ANOVA) with an alpha of 0.05 and power of 0.8 using data from the previous study of Jira-arnon and Maneenut (1) on voids of bulk-fill resin composite restoration in Class II cavity. The total samples were 40 samples for 4 groups, 10 samples for each group as shown in Figure 8.

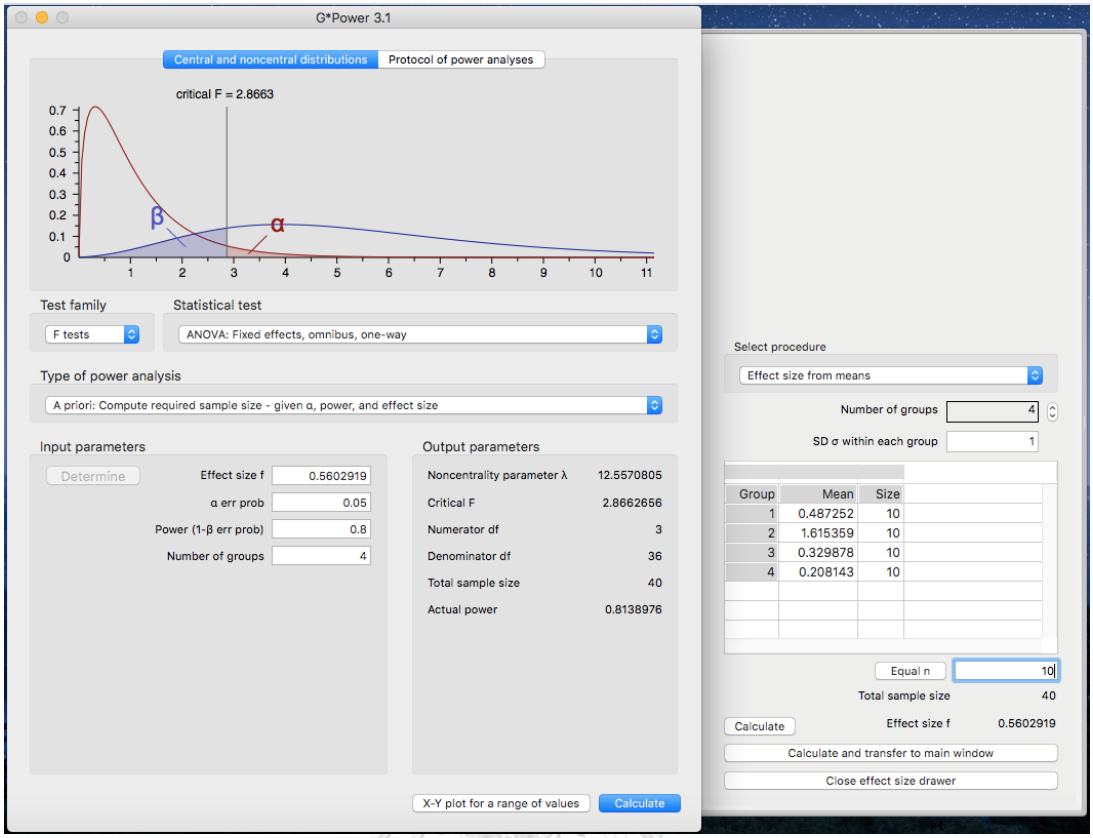


*Figure 8 Sample size calculated by G*Power 3.1*

Materials

1. Syringe-type Filtek™ One Bulk Fill Restorative (3M ESPE, USA)
2. Capsule-type Filtek™ One Bulk Fill Restorative (3M ESPE, USA)
3. SonicFill™ 2 (Kerr, USA)
4. OptiBond™ FL (Kerr, USA)
5. Gel Etchant (Kerr, USA)
6. Distilled water (Oral Biology Research Center, Faculty of Dentistry, Chulalongkorn University)
7. 0.1% Thymol solution (M dent, Thailand)
8. Clear acrylic resin
9. Polyvinyl siloxane impression material (Silagum Putty, DMG, Germany)

Equipment

1. Micro-computed tomography (μCT 35, Scanco Medical, Switzerland)
2. Polishing machine (NANO 2000, PACE technologies, USA)
3. Computer numerical control (CNC) specimen former (Former A-11, IMT, Thailand)
4. Digital vernier caliper (Mitutoyo, Japan)
5. Incubator (Contherm 1200, Contherm, New Zealand)
6. LED light-curing system (Demi™ Plus, Kerr, USA)
7. Filtek™ Restoratives Dispenser (3M ESPE, USA)
8. SonicFill™ Handpiece (Kerr, USA)
9. High-speed diamond cylinder burs (Intensiv, Switzerland)
10. Tofflemire matrix retainer
11. Metal matrix bands
12. Flat-ended plugger (1/2 Black Plugger, Hu-Friedy, USA)
13. Resin composite carver (IPC Interproximal Carver, Hu-Friedy, USA)
14. Gingival margin trimmer (Hu-Friedy, USA)
15. Glass slab
16. Triple syringe

Methods

Specimen Preparations

1. Forty extracted human maxillary first premolar teeth without dental caries, restoration and crack were collected, cleaned and immersed in 0.1 % thymol solution.
2. The teeth were simply randomized and divided into four groups with ten teeth per group.
3. Occlusal surface of the tooth was polished into a paralleled plane until it reached the deepest level of pits or fissures by a polishing machine (NANO 2000, PACE technologies, USA). (Figure 9)

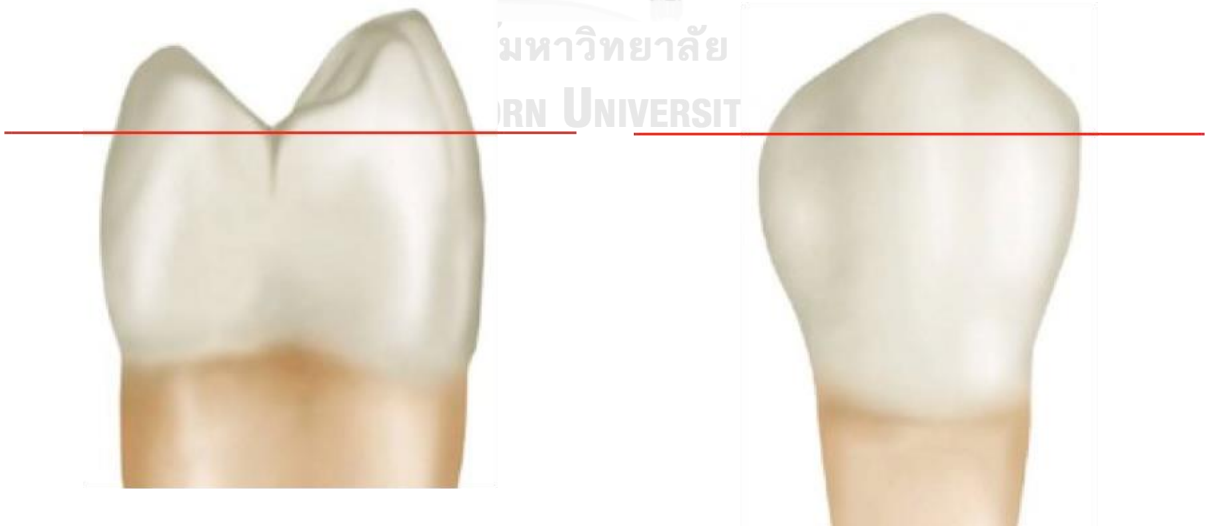


Figure 9 Polishing of occlusal surface

4. 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. (Figure 10)

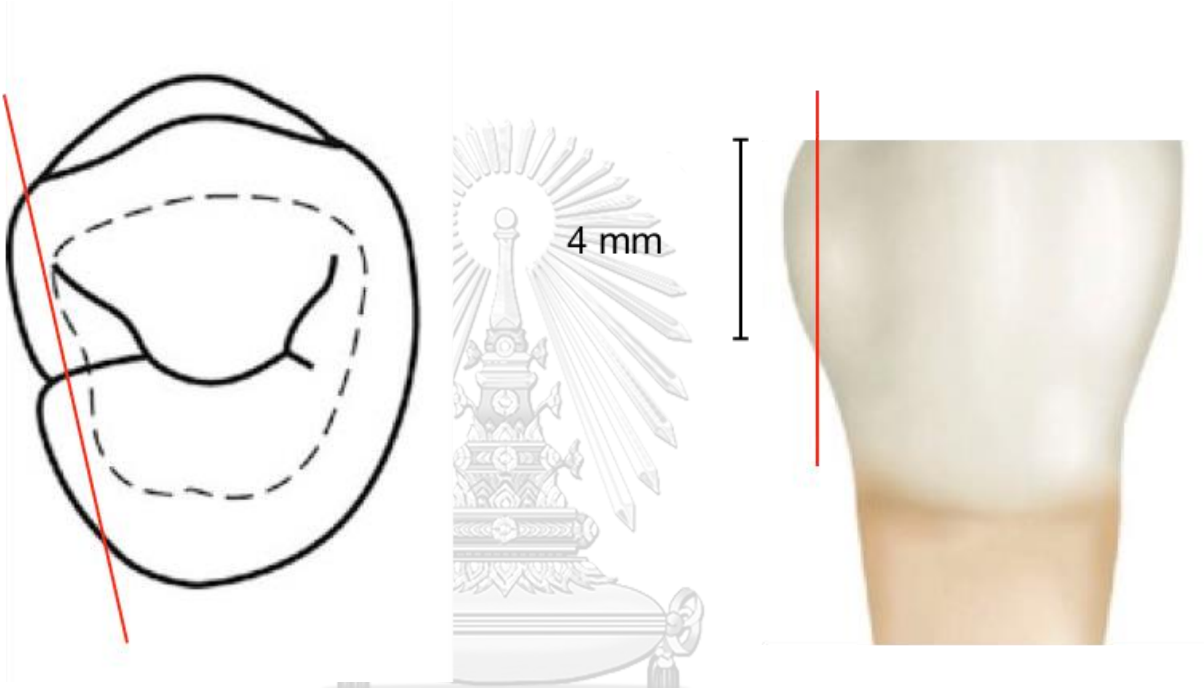


Figure 10 Polishing of proximal surface

5. Each polished tooth was embedded in clear acrylic resin at 2 mm beneath the cementoenamel junction level and 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). 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. (Figure 11)

The proximal cavity was 2 mm pulpo-gingival depth, 1.5 mm mesio-distal width and 3 mm bucco-lingual width. (Figure 12)

Dimensions of the prepared cavity (Figure 13) were confirmed by a digital vernier caliper (Mitutoyo, Japan).

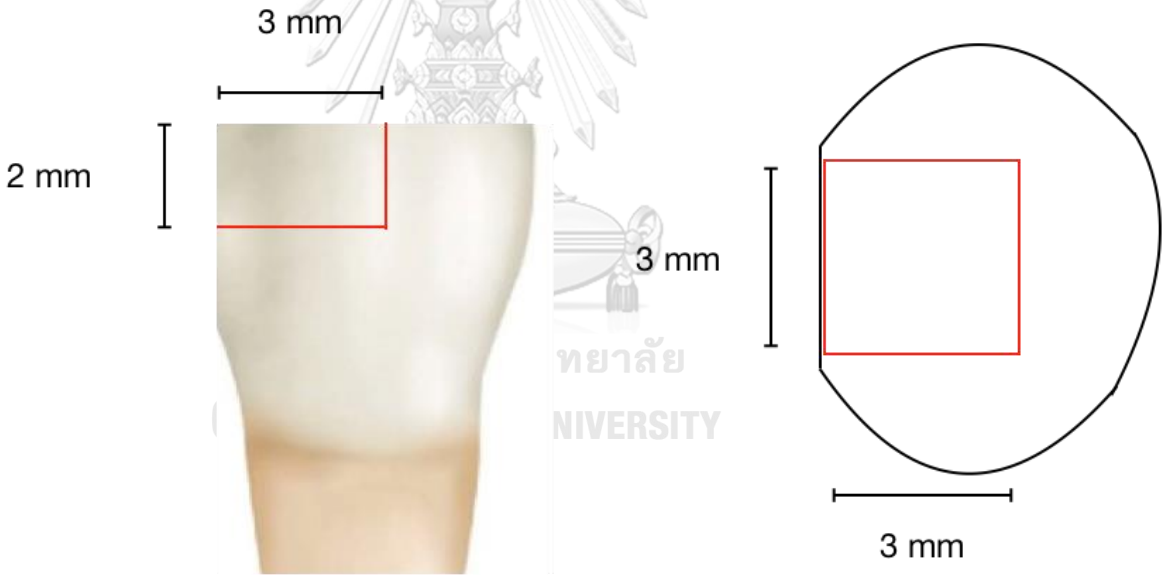


Figure 11 Occlusal cavity preparation

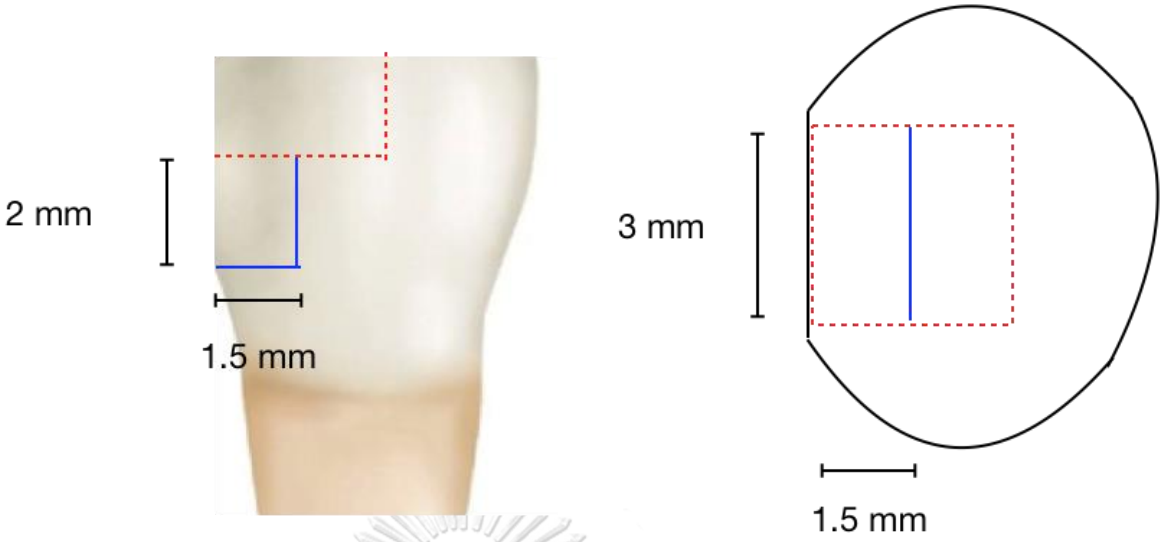


Figure 12 Proximal cavity preparation

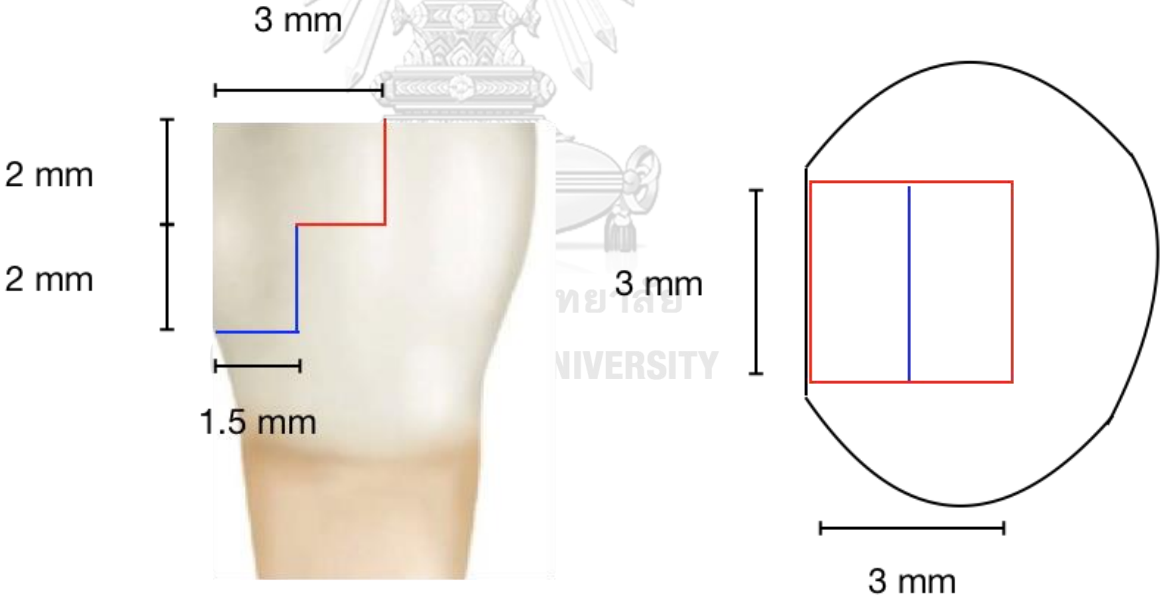


Figure 13 Prepared Class II cavity

6. A metal Tofflemire matrix system was applied to the prepared cavity. Matrix band was adapted and covered all cavity margins. Top margin of the band was at 1 mm above the occlusal cavity margin.

7. 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 blew for 3 seconds to achieve moist dentin. OptiBond™ FL (Kerr, USA) adhesive system was applied in the cavity following the manufacturer's instruction. OptiBond™ FL Primer was applied with a light scrubbing motion for 15 seconds and gently air blew for 5 seconds until the cavity had a slightly shiny appearance. OptiBond™ FL Adhesive was applied uniformly to create a thin coating. The adhesive was light cured with Demi™ Plus (Kerr, USA) with light intensity 1,100-1,330 mW/cm^2 for 20 seconds.

Silicone Index Preparations

The volume of the prepared cavity in each tooth was approximately 27 mm^3. Since no void was needed in the bulk of material that was pushed out from the syringe, 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 hand instrument (group 1 and group 2). (1)

A light cured square-shaped resin composite block (4 x 2 x 3.5 mm^3), which was 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, took the resin composite block out.

Restoring Procedures

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

Push the resin composite out of the syringe and put into the silicone index with a CVIPC carver (Hu-Friedy, USA). Took all resin composite (volume of approximately 27 mm^3) out of the index and put it into the prepared cavity with the carver. Adapted it with a flat-ended plugger (Hu-Friedy, USA) in occluso-gingival direction for 15 times with a pressure of approximately 100 grams per time (the operator was well practiced to press with the same force, using a push-pull force gauge). Removed resin composite excess with the carver in bucco-lingual direction for 5 times. Placed the tip of the light guide at 2 mm from the top of the cavity (compensated cusp height to simulate clinical situations) and light cured for 40 seconds. Removed the matrix band and light was applied at 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) (33, 34) (Figure 14, 15)

The placement was modified from the centripetal technique which proximal part against matrix band was created first and remaining occlusal cavity was filled up later. (33, 34) Push the resin composite out of the syringe and put into the silicone index with the CVIPC carver. Took two-thirds of resin composite (volume of approximately 18 mm^3) out of the index and put it into the proximal cavity with the carver and adapted it with the flat-ended plugger in occluso-gingival direction for 5 times and in mesio-distal direction for 5 times using the same force. The top level of the resin composite was at the same level of the occlusal margin. Put the rest of the resin composite (volume of approximately 9 mm^3) into the occlusal cavity with the carver and adapted it with the flat-ended plugger in occluso-gingival direction for 5 times. Removed resin composite excess with the carver in bucco-lingual direction for 5 times. Placed the tip of the light guide at 2 mm from the top of the cavity (compensated cusp height to simulate clinical situations) and light cured for 40 seconds. Removed the matrix band and light was applied at buccal and lingual surfaces of the proximal cavity for 20 seconds each.

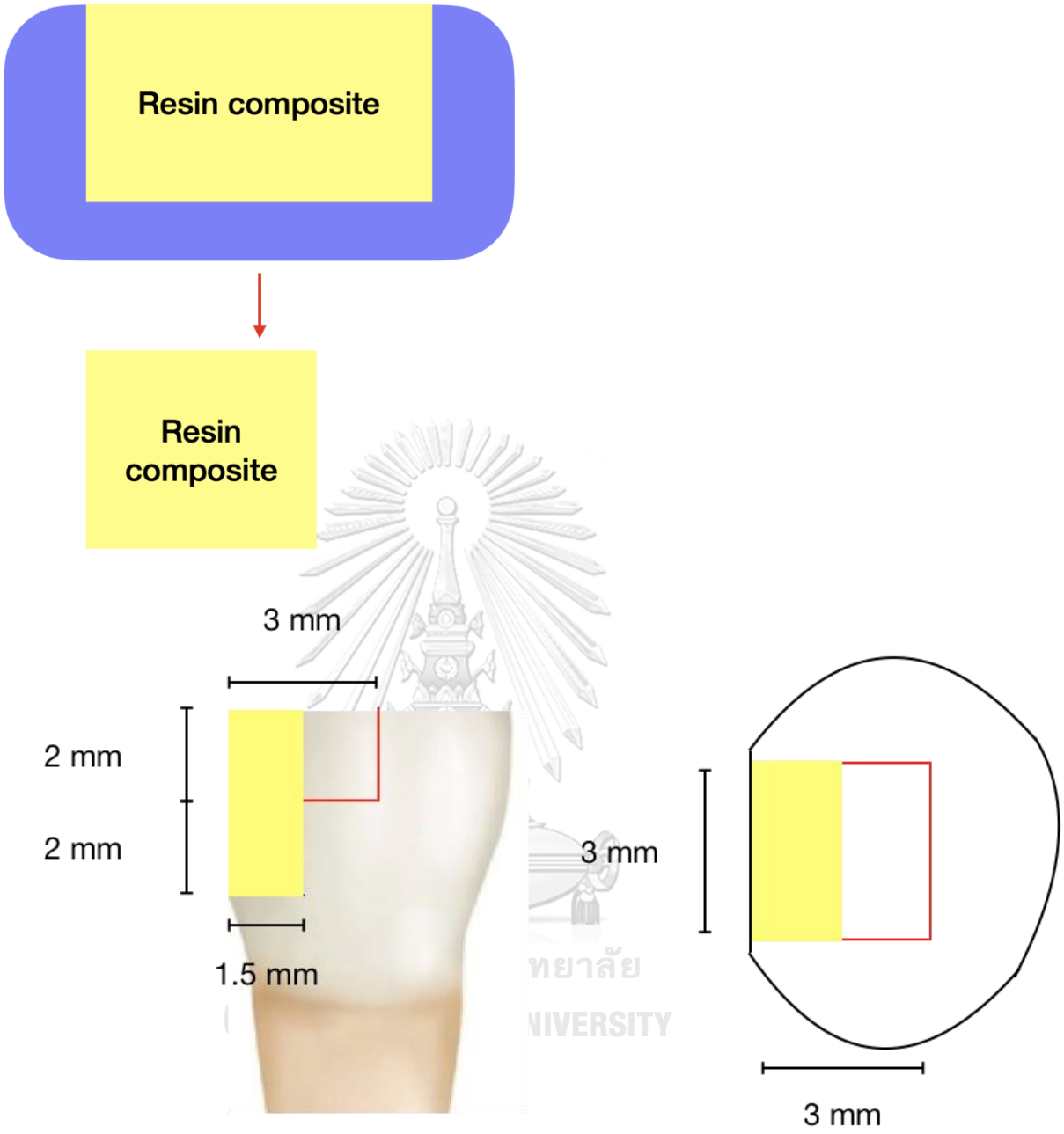


Figure 14 Restoring the first bulk of group 2

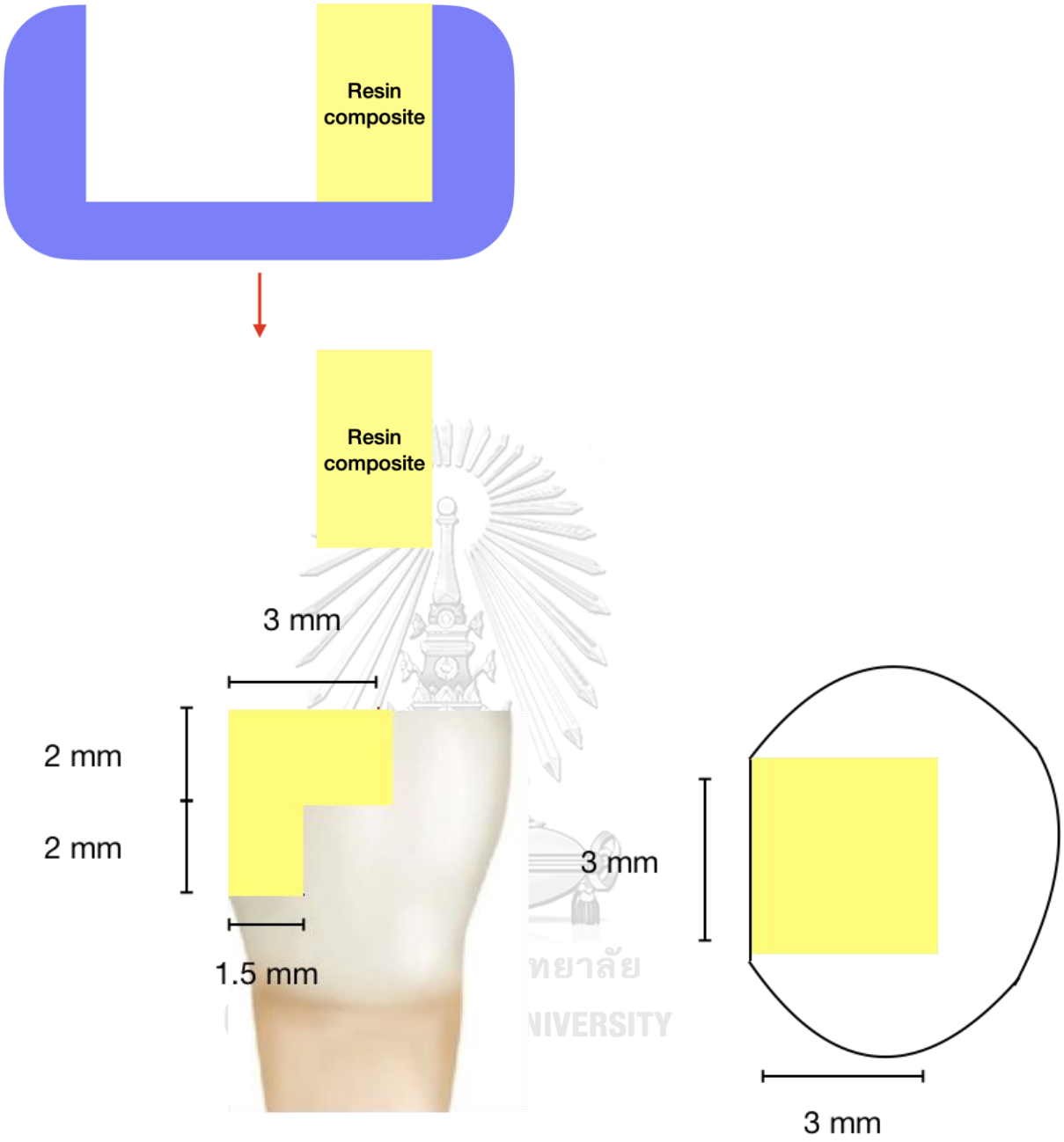
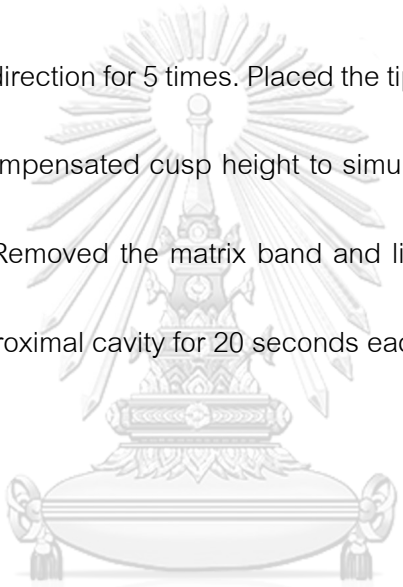


Figure 15 Restoring the second bulk of group 2

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

Put Filtek™ One Bulk Fill Restorative capsule into Filtek™ Restoratives Dispenser. Placed the tip of the capsule above the gingival wall for 0.5 mm. Dispensed the resin composite and kept the capsule tip inside the bulk of resin composite at all times until the resin composite reached the occlusal surface. Removed resin composite excess with the carver in bucco-lingual direction for 5 times. Placed the tip of the light guide at 2 mm from the top of the cavity (compensated cusp height to simulate clinical situations) and light cured for 40 seconds. Removed the matrix band 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)

Put SonicFill™ 2 capsule into SonicFill™ Handpiece. Set the dispensing rate of the handpiece at level 3. Placed the tip of the capsule above the gingival wall for 0.5 mm. Activated the handpiece by fully depressed the foot pedal and kept the capsule tip inside the resin composite at all times while the handpiece was activated. Stopped activate the handpiece when the resin composite reached the occlusal surface. Removed resin composite excess with the carver in bucco-lingual direction for 5 times. Placed the tip of the light guide at 2 mm from the top of the cavity (compensated cusp height to simulate clinical situations) and light cured for 40 seconds. Removed the matrix band 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 degrees Celsius for 24 hours.

Analysis of void formation using micro-computed tomography

All teeth were removed from the resin blocks and cut the root, buccal surface and lingual surface at 1-2 mm away from the margins of the cavity with 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 (μCT 35, Scanco Medical, Switzerland). The machine was set to 70 kV, 100 μA, voxel size 6 μm and filtered the radiation with aluminium 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 covered the entire restoration. The percentages of volume of void per volume of the entire restoration were calculated using 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. Shapiro-Wilk test was performed to test normality. Welch's ANOVA and Games-Howell post hoc analyses were performed to analyze the percentage of voids.

CHAPTER IV RESULTS

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

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

Voids in all groups were found at cavity walls, line angles and within the bulk of resin composites (Figure 16, 17, 18 and 19). Void which was between the bulks of resin composite was found in only group 2, two-bulk placement with hand instrument (Figure 17).

Table 2 Mean percentage of volume of void per volume of the entire restoration and standard deviation

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

The same superscript letter means no statistically significant difference

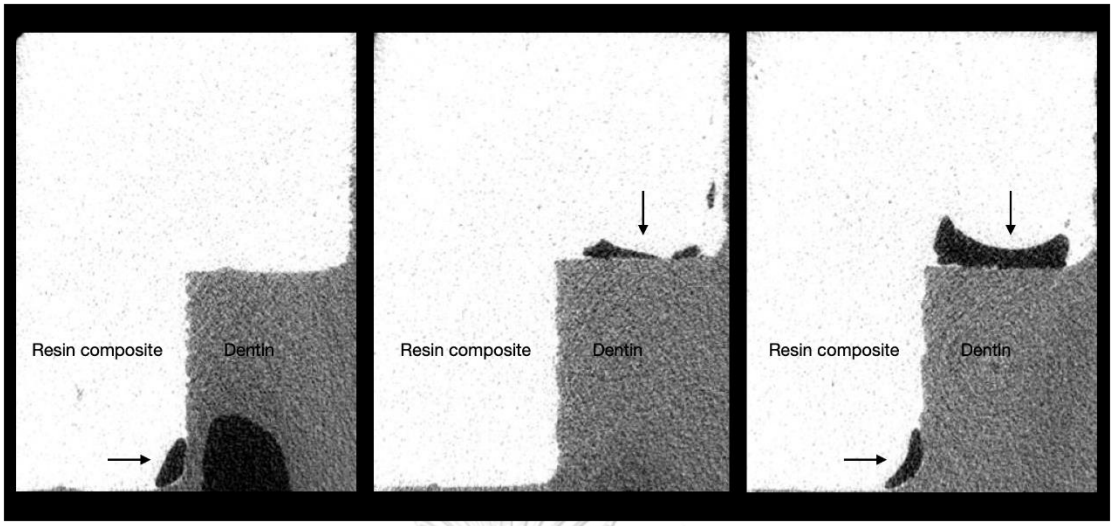


Figure 16 Representative cross-sectional images of group 1 , one bulk placement with hand instrument. Voids are indicated by arrow.

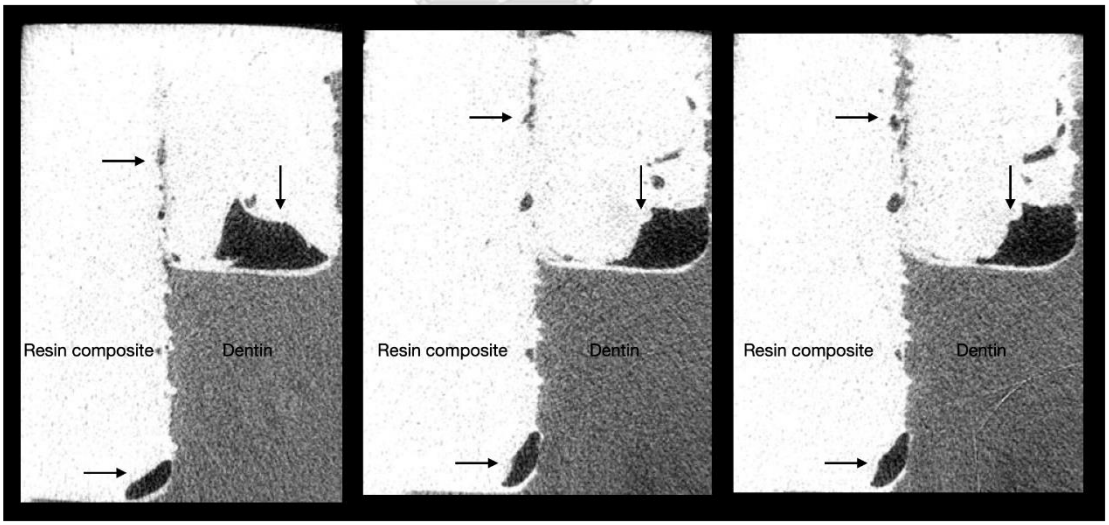


Figure 17 Representative cross-sectional images of group 2 , two-bulk placement with hand instrument. Voids are indicated by arrow.

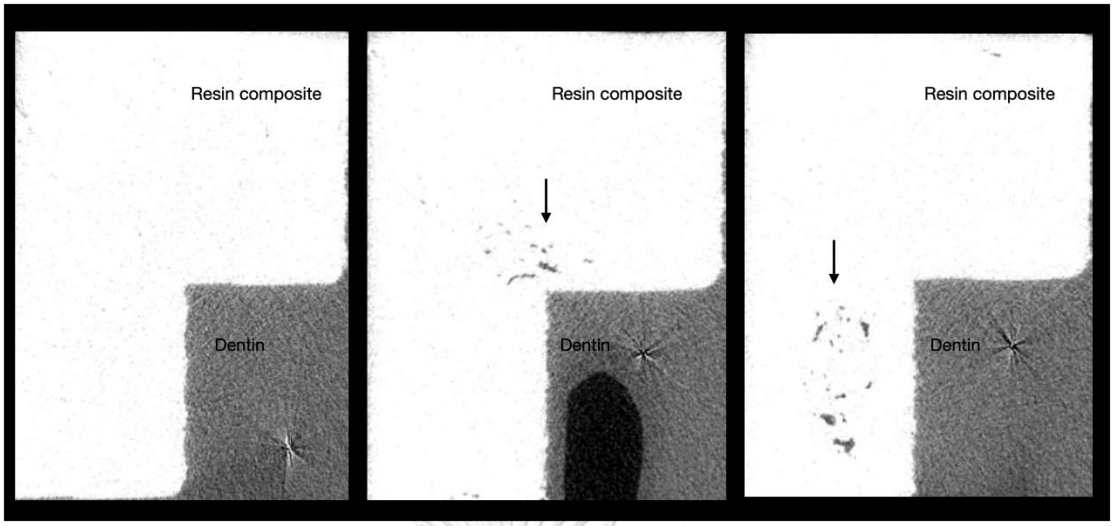


Figure 18 Representative cross-sectional images of group 3 , one bulk placement with injectable dispenser. Voids are indicated by arrow.

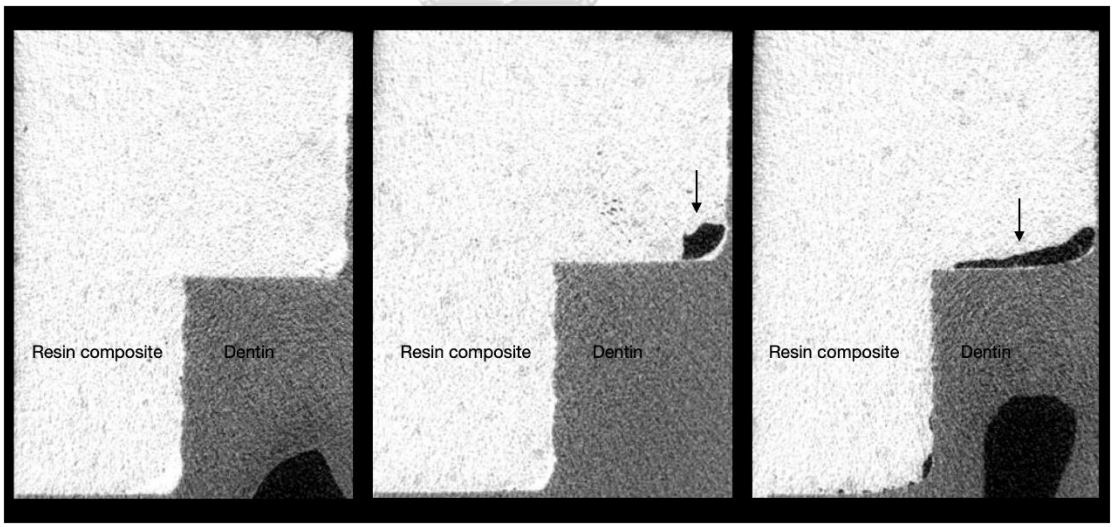


Figure 19 Representative cross-sectional images of group 4 , one bulk placement with injectable dispenser and sonic-activated handpiece. Voids are indicated by arrow.

CHAPTER V DISCUSSION

Voids in this study were voids within resin composite, voids between the bulks of resin composite and voids at the interfaces between cavity walls and resin composite. These voids appeared as radiolucent areas in each cross-sectional image when using micro-computed tomography analysis. 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 syringe-type resin composite which placed with hand instrument. (1) Put and adapted closely amount of resin composite to the cavity volume could reduce chance of void formation compare to putting much more amount which had to take out or putting much less amount which had to add in the material.

The results of this study found voids in all tooth samples. Although line angle was round, voids could occur at line angles. It was also occurred at the interfaces between cavity walls and resin composite more than within the bulk of resin composites (Figure 16, 17, 18 and 19). Voids at both occlusal and proximal line angles infer that more line angles, more possibility of voids. The percentages of void formation were about 1 % and less. It was higher when placed with hand instrument than placed with injectable dispenser. The results corresponded to the study of Jira-arnon and Maneenut (1), which found that placement syringe-type resin composite into slot Class II cavity with 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 differed from the previous study. The placement of group 2 in two-bulk with hand instrument (Figure 14 and 15) was modified from the studies of Bichacho (33) and Hassan and others. (34) This placement method provided an uninterrupted proximal surface. A smooth proximal surface was clinical desirable because it was cleaned easily and could have less plaque accumulation. However, there were interfaces of resin composite at occlusal cavity (Figure 17) which voids could be formed more than in one bulk placement (Figure 16). 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 was a vertical line in the occlusal cavity instead of horizontal line in the proximal cavity. It means that voids could be formed no matter where the interface was. Placement with hand instrument could cause air trapping at the round line angles and at the interfaces between cavity walls and resin composite (Figure 16 and 17).

The placement of flowable resin composite can improve adaptation in the gingival floor of proximal cavity. (6) Moreover, the ultrasonic 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 was 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 vibration of the tip of handpiece stopped, this bulk-fill resin composite became higher viscosity. (16) 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, it could be drawn some advices for clinical practice to reduce void formation in Class II cavity restored with bulk-fill resin composite such as placement with injectable dispenser or injectable dispenser and sonic-activated handpiece. The operator should place dispensing tip 0.5 mm above the deepest part of the cavity to avoid air trapping within resin composite. During the material placement, pull the dispensing tip up to occlusal surface and keep the dispensing tip inside resin composite at all time. However, in case of using syringe-type bulk-fill resin composite which quite common be used in clinical practice, one bulk placement can reduce void and also step and time of restoring.

CHAPTER VI 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 hand instrument had significantly higher void formation than placement with injectable dispenser.

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APPENDIX

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

Group	Percentage of voids
1	1.0144
1	0.0350
1	0.5713
1	0.8654
1	0.3141
1	0.4130
1	0.7149
1	0.3720
1	0.8701
1	1.4092

Group 2: Two-bulk placement with hand instrument with syringe-type Filtek™ One Bulk Fill Restorative (3M ESPE, USA)

Group	Percentages of voids
2	1.7936
2	1.5035
2	0.9503
2	0.9588
2	1.1163
2	0.8175
2	1.3627
2	1.0160
2	0.7478
2	0.5001

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

Group	Percentages of voids
3	0.0179
3	0.0870
3	0.1808
3	0.0124
3	0.0233
3	0.0084
3	0.0694
3	0.2738
3	0.2272
3	0.1426

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

Group	Percentages of voids
4	0.3136
4	0.2921
4	0.0461
4	0.2287
4	0.1502
4	0.0230
4	0.0473
4	0.0091
4	0.1416
4	0.1794

Descriptive Statistics

Descriptives

Voids

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	10	.657940	.3997632	.1264162	.371967	.943913	.0350	1.4092
2	10	1.076660	.3830952	.1211453	.802610	1.350710	.5001	1.7936
3	10	.104280	.0968042	.0306122	.035030	.173530	.0084	.2738
4	10	.143110	.1110233	.0351087	.063689	.222531	.0091	.3136
Total	40	.495498	.4901094	.0774931	.338753	.652242	.0084	1.7936

Descriptives

	Group			Statistic	Std. Error
Voids	1	Mean		.657940	.1264162
		95% Confidence Interval for Mean	Lower Bound	.371967	
			Upper Bound	.943913	
		5% Trimmed Mean		.650811	
		Median		.643100	
		Variance		.160	
		Std. Deviation		.3997632	
		Minimum		.0350	
		Maximum		1.4092	
		Range		1.3742	
		Interquartile Range		.5487	
		Skewness		.363	.687
		Kurtosis		.049	1.334
	2	Mean		1.076660	.1211453
		95% Confidence Interval for Mean	Lower Bound	.802610	
			Upper Bound	1.350710	
		5% Trimmed Mean		1.068861	
		Median		.987400	
		Variance		.147	
		Std. Deviation		.3830952	
		Minimum		.5001	
		Maximum		1.7936	
		Range		1.2935	
		Interquartile Range		.5978	
		Skewness		.547	.687
		Kurtosis		.031	1.334

3	Mean		.104280	.0306122
	95% Confidence Interval for Mean	Lower Bound	.035030	
		Upper Bound	.173530	
	5% Trimmed Mean		.100189	
	Median		.078200	
	Variance		.009	
	Std. Deviation		.0968042	
	Minimum		.0084	
	Maximum		.2738	
	Range		.2654	
	Interquartile Range		.1759	
	Skewness		.666	.687
	Kurtosis		-.993	1.334
4	Mean		.143110	.0351087
	95% Confidence Interval for Mean	Lower Bound	.063689	
		Upper Bound	.222531	
	5% Trimmed Mean		.141083	
	Median		.145900	
	Variance		.012	
	Std. Deviation		.1110233	
	Minimum		.0091	
	Maximum		.3136	
	Range		.3045	
	Interquartile Range		.2042	
	Skewness		.305	.687
	Kurtosis		-1.328	1.334

Test of Normality

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Group	Statistic	df	Sig.	Statistic	df	Sig.
Voids	1	.130	10	.200*	.979	10	.962
	2	.163	10	.200*	.967	10	.863
	3	.199	10	.200*	.885	10	.149
	4	.206	10	.200*	.917	10	.332

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Welch's ANOVA and Games-Howell Post Hoc Analyses

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Voids	Based on Mean	6.206	3	36	.002
	Based on Median	5.121	3	36	.005
	Based on Median and with adjusted df	5.121	3	19.575	.009
	Based on trimmed mean	6.113	3	36	.002

ANOVA

Voids

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6.414	3	2.138	26.050	.000
Within Groups	2.954	36	.082		
Total	9.368	39			

Robust Tests of Equality of Means

Voids

	Statistic[a]	df1	df2	Sig.
Welch	23.653	3	18.388	.000

a. Asymptotically F distributed.

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Voids

Games-Howell

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1	2	-.4187200	.1750921	.115	-.913668	.076228
	3	.5536600*	.1300698	.008	.156102	.951218
	4	.5148300*	.1312009	.012	.116090	.913570
2	1	.4187200	.1750921	.115	-.076228	.913668
	3	.9723800*	.1249532	.000	.591090	1.353670
	4	.9335500*	.1261301	.000	.550989	1.316111
3	1	-.5536600*	.1300698	.008	-.951218	-.156102
	2	-.9723800*	.1249532	.000	-1.353670	-.591090
	4	-.0388300	.0465803	.838	-.170718	.093058
4	1	-.5148300*	.1312009	.012	-.913570	-.116090
	2	-.9335500*	.1261301	.000	-1.316111	-.550989
	3	.0388300	.0465803	.838	-.093058	.170718

*. The mean difference is significant at the 0.05 level.

VITA

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