EVALUATION OF VOIDS IN CLASS II RESTORATIONS RESTORED WITH BULK-FILL AND CONVENTIONAL NANOHYBRID RESIN COMPOSITE

Miss Saiisara Chaidarun

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การประเมินการเกิดฟองอากาศในโพรงฟันชนิดคลาสทูที่ได้รับการบูรณะด้วยวัสดุอุดฟันชนิดบัลค์ฟิลล์และคอนเวนชั่นนอลนาโนไฮบริดเรซินคอมโพสิต

นางสาวสายอิสรา ชัยดรุณ

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By	Miss Saiisara Chaidarun
Field of Study	Esthetic Restorative and Implant Dentistry
Thesis Advisor	Associate Professor Chalermpol Leevailoj

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______________________________Dean of the Faculty of Dentistry

(Assistant Professor Suchit Poolthong, Ph.D.)

THESIS COMMITTEE

______________________________Chairman

(Assistant Professor Sirivimol Srisawasdi, Ph.D.)

______________________________Thesis Advisor

(Associate Professor Chalermpol Leevailoj)

______________________________External Examiner

(Assistant Professor Sirichan Chiaraputt, Ph.D.)

สายอิสรา ชัยดรุณ : การประเมินการเกิดฟองอากาศในโพรงฟันชนิดคลาสทูที่ได้รับการบูรณะด้วยวัสดุอุดฟันชนิดบัลค์ฟิลล์และคอนเวนชั่นนอลนาโนไฮบริดเรซินคอมโพสิต (EVALUATION OF VOIDS IN CLASS II RESTORATIONS RESTORED WITH BULK-FILL AND CONVENTIONAL NANOHYBRID RESIN COMPOSITE) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ทพ. เฉลิมพล ลี้ไวโรจน์, 78 หน้า.

วัตถุประสงค์: การวิจัยครั้งนี้มีวัตถุประสงค์เพื่อทำการประเมินอิทธิพลของวัสดุอุดฟันเรซินคอมโพสิตทั้ง 4 กลุ่มต่อการเกิดฟองอากาศในโพรงฟันชนิดคลาสทูขนาดเล็กและขนาดใหญ่ นอกจากนี้ความหนาของการอุดอินครีเมนท์ชั้นแรกได้ถูกศึกษาเพิ่มเติม

วิธีการและเครื่องมือ: ฟันกรามน้อยล่างซี่ที่สองชนิดพลาสติกจำนวน 80 ซี่ ได้ถูกแบ่งการเตรียมโพรงฟันออกเป็น 2 แบบโดยมีโพรงฟันมาตรฐาน 40 โพรงฟันในแต่ละแบบ หลังจากนั้นบูรณะโพรงฟันด้วยเรซินคอมโพสิต 4 กลุ่ม (เรซินคอมโพสิตชนิดบัลค์ฟิลล์ 3 กลุ่ม ได้แก่ โซนิคฟิลล์ทู, ฟิลเทคบัลค์ฟิลล์(ไซริ้งค์), ฟิลเทคบัลค์ฟิลล์(แคปซูล) และคอนเวนชั่นนอลนาโนไฮบริดเรซินคอมโพสิต 1 กลุ่มได้แก่ พรีมิส) ฟันที่ได้รับการบูรณะแล้วจะถูกตัดแบ่งเซคชั่นสำหรับการประเมินภายใต้กล้องจุลทรรศน์ และใช้สถิติครัสคอล-วอลลิสวิเคราะห์ในการประเมินการเกิดจำนวนฟองอากาศและเปอร์เซ็นต์พื้นที่ฟองอากาศ ส่วนความหนาของการอุดอินครีเมนท์ชั้นแรกได้ถูกวัดและวิเคราะห์

ผลการวิจัย: พบความแตกต่างอย่างมีนัยสำคัญในการเกิดจำนวนฟองอากาศและเปอร์เซ็นต์พื้นที่ฟองอากาศทั้ง 4 กลุ่ม ในโพรงฟันขนาดเล็ก กลุ่มของโซนิคฟิลล์ทูและฟิลเทคบัลค์ฟิลล์(แคปซูล)ที่ใช้เทคนิคแบบฉีดในการบูรณะพบว่าลดการเกิดฟองอากาศ ในทางตรงข้าม ไม่พบความแตกต่างอย่างมีนัยสำคัญ ทั้ง 4 กลุ่มในโพรงฟันขนาดใหญ่ ส่วนใหญ่ของความหนาในการอุดอินครีเมนท์ชั้นแรกของฟันที่บูรณะทั้ง 2 แบบโพรงฟันมีความหนาเกินกว่าความหนาที่ ได้กำหนดไว้

สรุปผลการวิจัย: การเกิดฟองอากาศลดลงเมื่อใช้เรซินคอมโพสิตแบบฉีดในการบูรณะโพรงฟันขนาดเล็กชนิดคลาสทู และพบผลการทดลองดีที่สุดในกลุ่มที่ใช้โซนิคฟิลล์ทู

สาขาวิชา	ทันตกรรมบูรณะเพื่อความสวยงาม	ลายมือชื่อนิสิต	....
	และทันตกรรมรากเทียม	ลายมือชื่อ อ.ที่ปรึกษาหลัก	....
ปีการศึกษา	2560		

5775825932 : MAJOR ESTHETIC RESTORATIVE AND IMPLANT DENTISTRY

KEYWORDS: BULK-FILL RESIN COMPOSITE, CLASS II CAVITY, CONVENTIONAL RESIN COMPOSITE, INCREMENT, VOID

SAIISARA CHAIDARUN: EVALUATION OF VOIDS IN CLASS II RESTORATIONS RESTORED WITH BULK-FILL AND CONVENTIONAL NANOHYBRID RESIN COMPOSITE. ADVISOR: ASSOC. PROF. CHALERMPOL LEEVAILOJ, 78 pp.

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.

Field of Study:	Esthetic Restorative and Implant Dentistry	Student's Signature	....
		Advisor's Signature	....
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CHAPTER I INTRODUCTION

Background and Rationale

Light cured resin composites are the most regular tooth colored filling materials that are being used nowadays. The depth of cure for conventional resin composite placement is recommended at 2-mm to create adequately cured and decrease polymerization shrinkage and stress. Base on this limitation, restoring a deep cavity with resin composites can be a time-consuming task because the incremental technique must be applied to ensure adequate light transmission for complete polymerization.[1] Moreover, incremental technique placement may increase the risk of moisture contamination, air trapping and marginal gap formation in class II direct composite restoration due to the polymerization shrinkage of resin composite. [2, 3]

The newly-developed, bulk-fill type resin composites are becoming widely used to overcome the various disadvantages of conventional resin composites. According to the manufacturers, bulk-fill materials can be applied 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 some properties that provide clinical advantages such as particularly increased depth of cure, which probably results from higher translucency, low polymerization shrinkage and stress, which relate to modification of filler content. [5] Furthermore, other studies reported that bulk-fill materials exhibited microhardness as same as hybrid composites, reduced cuspal deflection and provided better marginal adaptation.[6-9] Although, there are some controversies about void within material, ability to withstand occlusal loading, longevity, microhardness and depth of cure at the gingival floor. [2, 10] However, bulk-fill resin composite can be placed by one-step with 4-5 mm increment, applying this material into a deep cavity with more than 4 mm depth requires the use of the incremental technique to prevent an inadequate depth of cure. The insufficiently polymerized composites may result in the degradation of the resin composite, thus having a negative effect on physical properties and adverse biological reactions.[11, 12] Moreover, more voids and gaps could be created along the junction between the increment layers when the incremental technique was applied. These errors result in poor quality and negative risk to the longevity of restoration.[13, 14]

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.[15, 16] 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 been reduced the filler amount and increased the filler size.[7] Increasing the curing time increases the degree of conversion and microhardness in deeper composite layers.[6] In addition, cavity depth, width and volume do correlate with the amount of voids and gap spaces, but only for the high viscous composite material.[17]

At present, few studies exist focusing on voids in bulk-fill resin composites of Class II cavity 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 measurement of increment thickness that is created during placement. The thickness that exceeds the limited depth of cure can cause negative effects on the restorations.

Research question

Do different type and application technique of resin composite material affect the presence of voids in small and large Class II cavity restorations?

Objectives of the Study

To investigate the influence of bulk-fill composites and a conventional nanohybrid resin composite on the presence of voids in small and large Class II cavities. Furthermore, the thickness of the first increment of the restorations was studied.

Statement of hypothesis

Null hypothesis:

There are no significant differences in presence of voids of small Class II cavities placed with different resin composites.

There are no significant differences in presence of voids of large Class II cavities placed with different resin composites.

Alternative hypothesis:

1. There are significant differences in presence of voids of small Class II cavities placed with different resin composites.
2. There are significant differences in presence of voids of large Class II cavities placed with different resin composites.

Conceptual framework

Population in this study

- Class II resin composite

Intervention in this study

- Different composite material and application technique

Outcome measurement in this study

- Void (destructive method)

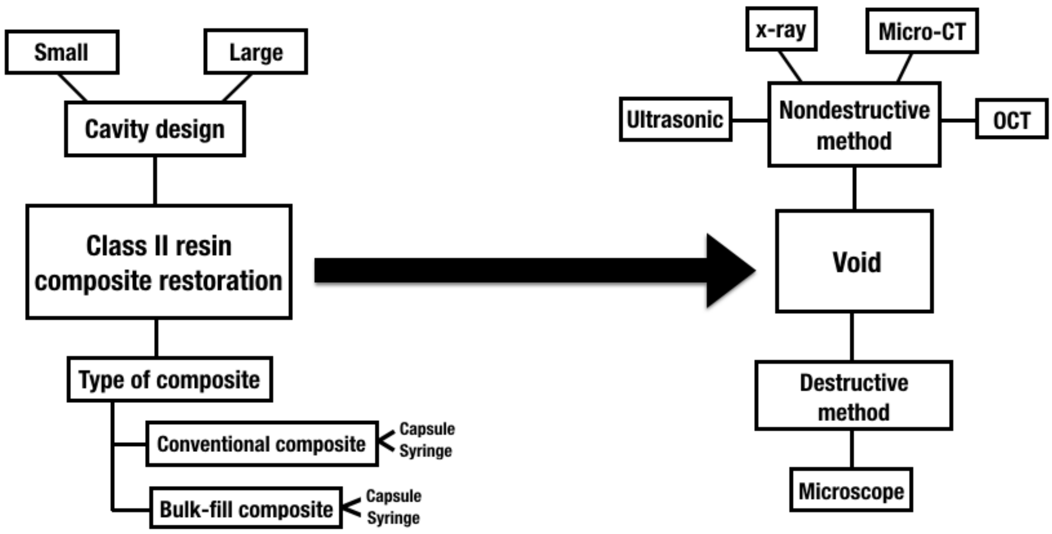


Figure 1 The conceptual framework

Assumptions

1. Light-cured resin composites directly taken from the syringe contain porosities 0.05-1.4% by volume.
2. Composites with larger filler size could result in increased voids.
3. High viscosity composites could result in higher voids.

Study limitation

This is an in vitro study, not a clinical study. Consequently, the results of this study may be inferred the some clinical outcomes of these products.

Keywords

Bulk-fill resin composite/ Class II cavity/ Conventional resin composite/ Increment/ Void

Expected benefits of the study

The results of this study will provide useful information for clinician in clinical use in both application techniques and selection of filling composite materials. Furthermore, these can be awareness for clinicians to control their practices.

CHAPTER II REVIEW OF LITERATURES

The literatures in these following topics will be reviewed.

1. Resin composite material

   1.1 Nanohybrid resin composite

   1.2 Bulk-fill resin composite

2. Resin composite restoration

   2.1 Failure and problem of direct composite restoration

   2.2 Quality of direct composite restoration

3. Porosities or voids in restoration

   3.1 Characteristic of porosities or voids

   3.2 Causes of porosities or voids

   3.3 Negative effects of porosities or voids

   3.4 Evaluation of porosities or voids

4. Review of materials used

   4.1 SonicFill 2™ (Kerr)

   4.2 Filtek™ Bulk Fill Posterior Restorative (3M ESPE)

4.3 Presmise™ (Kerr)

Resin composite restoration

Nanohybrid resin composite

Dental composites can be distinguished by different formulations used. Resin composites have usually been classified according to filler features, such as type, distribution or average particle size. [1, 18] Filler particles have been developed to improve the mechanical properties of the composite. Based on filler particle size can be divided into macrofill or conventional composite, midifiller, minifiller, microfiller and nanofiller. [19]

The hybrid composite is a combination of a small amount of microfiller and reducing in the particle size of the conventional composites through further grinding. Small particle hybrid composites were further distinguished as midifills and minifills. These minifills came to be referred to as microhybrids. These materials are generally considered to be universal composites as they can be used for anterior and posterior restorations. The most recent innovation has been the development of the nanofill composites which containing only nanoscale particles. The modified formulations of microhybrids to include more nanoparticles and pre-polymerized particles called as nanohybrid composite. [1]

Bulk-fill resin composite

This new bulk-fill material type includes flowable and high consistency paste material types. Flowable bulk-fill resin composite (such as SDR ®, Dentsply Caulk; Venus ® Bulk Fill, Heraeus Kulzer; Filtek ™ Bulk Fill Flowable Restorative, 3M ESPE) is similar to flowable composites. They have many advantages for using as flowable composites such as applying into deep cavities that difficult to access, ability to form layered structure can reduce void trapping and using as liner. These materials must be covered with an additional layer of 2 mm of conventional resin composites at the occlusal surface. High consistency bulk-fill resin composites (such as Tetric N-Ceram ® Bulk Fill, Ivoclar vivadent; X-tra fil, VOCO;) have high filler content. Their handling properties are comparable to regular hybrid composites, which can be used in increments of up to 4 mm without the need for an extra occlusal layer capping. Another new high consistency bulk-fill resin composite, a sonic-activated bulk-fill resin composite

(SonicFill™, Kerr) was introduced. According to the manufacturer instruction, it needs a special sonic handpiece for its application. [5, 8, 10, 20]

Resin composite restoration

Failure and problem of direct composite restoration

The major causes of failure of resin composite restorations are secondary caries and fracture. [21, 22] The secondary caries is related to the polymerization shrinkage and shrinkage stress created at the interfacial bond, as well as the durability of this bond, and on the quality of the placement of the restoration. For fracture is due to limitations of the mechanical properties of the materials, cavity design, amount and quality of supportive tooth structure, and the specific occlusion.[1] With regard to the previous, direct composite restorative seems to be technique sensitivity.

Quality of direct composite restoration

The quality or clinical success of direct composite restoration depends on placement technique. Furthermore, the clinical success has been associated with undesirable characteristics such as marginal leakage, porosities or voids, white line, improper contact and contour. These are causes of post-operative sensitivity and secondary caries that affect the longevity of restorations. [23, 24]

Porosities or voids in restoration

Characteristic of porosities or voids

Porosities or voids which containing oxygen inside a composite restoration were found to be a result of air trapped within the material itself or between layers. [24-26] Voids within the composite material are spherical and well defined. For the ovoid and elongated voids are commonly found at interlayers, these are considered to be gaps created during placement.[27]

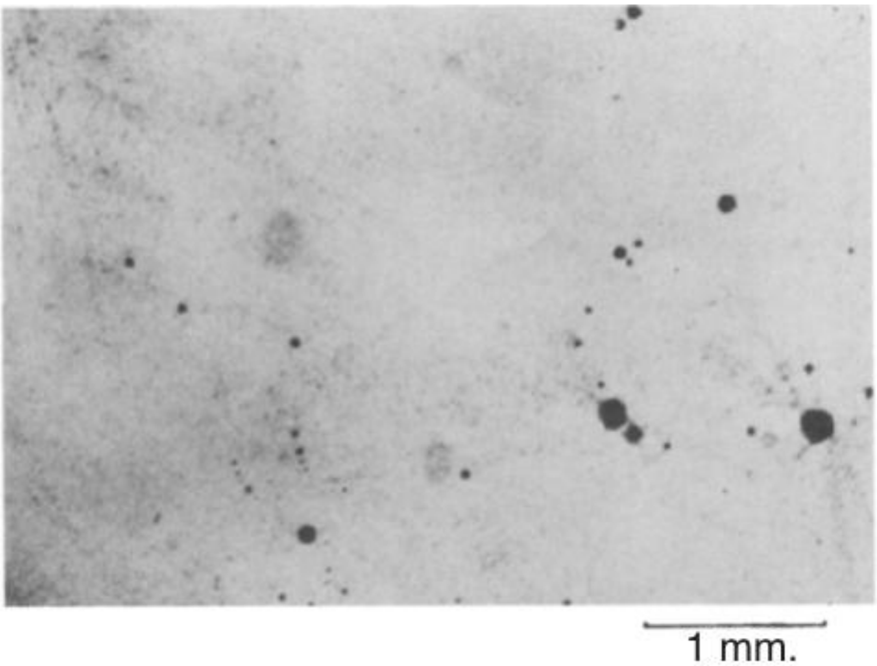


Figure 2 The representative example of voids (spherical) in resin composite as seen with scanning electron microscopy. (28)

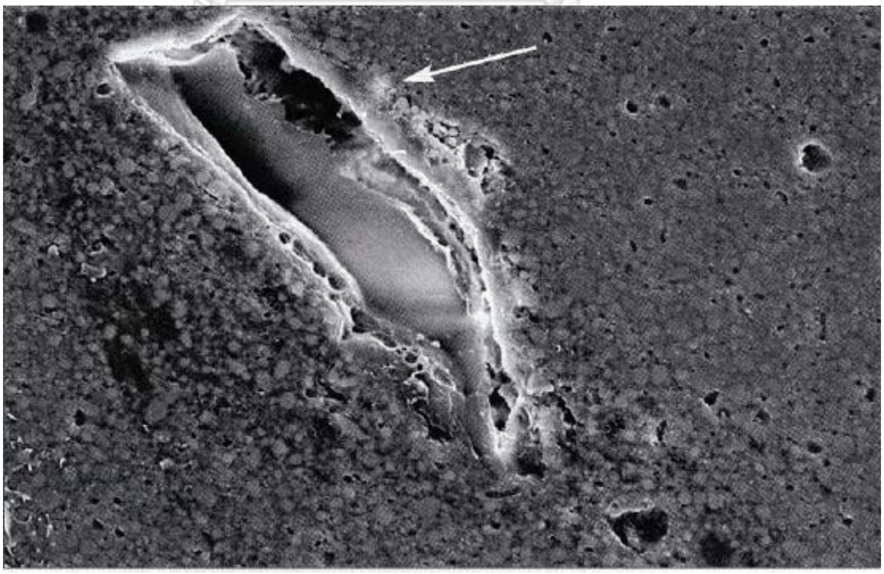


Figure 3 An electron microscope image showing a gap (50x10 microns)(27)

According to the previous study, voids can be classified into 3 groups by diameter length: 1) small void (≤50 μm), 2) medium void (>50 - ≤150 μm) and 3) large void (>150 μm). [29]

Causes of porosities or voids

The presence of porosities or voids within composite material may originate as a result of the manufacture process or handling techniques. [13, 30] Light-cured resin composites directly taken from the syringe contain porosities 0.05-1.4% by volume. [31] Handling technique performed by dentist is an important factor that affects the performance of restoration. Resin composites were categorized into 2 specific characteristics of application method, which were injectable and packable resin composite. Packable resin composite can be taken a volume of composite from the syringe, and placed directly into a cavity with a hand instrument. Injectable resin composite can be injected into the cavity from a pre load tip.

Moreover, the viscosity of resin composite, resin filler size, resin filler load, cavity design and size have been found related to the presence of voids. [13, 17, 24, 26, 32, 33] Some other studies found that high viscosity and increasing in filler size resin composites have higher porosities and voids.[13, 32] In contrast, the study from Balthazard and others [33] showed that lower viscosity of materials have higher intrinsic void rate, regardless the handing conditions.

It has been reported that the injection technique significantly decreased the void area of resin composite compared to hand placement because the design of the tip allows good access, creates less voids and good adaptation. [24, 26, 29] Hand placement can increase voids due to resin composite always stick at the tip of hand instrument and is pulled away from the cavity wall, air will be entrapped.[34]

Negative effects of porosities or voids

The presence of porosities or voids could affect the quality of restorations. 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. [24, 26, 34, 35]

The void diameter can be considered the most important. Large voids probably also lead to a lower fatigue resistance and wear resistance. Moreover, large voids at the interface between composite resin and tooth may lead to gross microleakage and failure of restoration because of secondary caries or pulpal sensitivity. [24, 26, 28, 29]

Evaluation of porosities or voids

Evaluation of voids can be found in vitro studies. Different methods have been used in order to investigate and measure the defects in resin composite materials. These methods can be divided into destructive method and non-destructive method.

1) Destructive method

The assessment of voids by section the sample and observing under microscope is the most basic methods. [24, 26, 28, 36, 37]

2) Non-destructive method

These methods do not require section the samples, which are ultrasonic technique, X-ray radiography, micro-computed tomography (micro-CT) and optical coherence tomography (OCT). [32, 33, 38-40]

a) Ultrasonic technique

Ultrasonic C scan imaging is an effective NDE technique used for material analysis. C-scan imaging is used to map variations in ultrasonic echo peak amplitude that occur when scanning across a material part. It provides quantitatively a two-dimensional view of a specimen in which differences in image contrast result from the objects interaction with an impinging ultrasonic wave.[40]

b) Micro-computed tomography (micro-CT)

Micro-computed tomography differs from conventional medical CAT-scanning in its ability to resolve details as small as a few micrometers in size. It is a nondestructive technique for visualizing object interiors. The method is based on the X-ray absorption principle. This procedure produces a series of projection images. The projection images are then processed using computer software to show the internal structure of the sample. The reconstructed images can then be taken and modeled into 3D volumetric objects for quantitative analysis or visualization. [32, 33]

c) Optical coherence tomography (OCT)

Optical coherence tomography (OCT) is a fundamentally new type of nondestructive and noninvasive optical imaging technique, which uses infrared light waves that have long broadband light source to reflect the internal microstructure and provides real time 1D depth, 2D cross-sectional and 3D volumetric images with μm level resolution and mm level of imaging depth. Images are reconstructed by measuring the backscattered or back-reflected light. [38, 39]

Review of materials used

SonicFill 2 TM (Kerr)

SonicFill 2 ™ is a bulk-fill resin composite system used for posterior restorations, which comes in 4 tooth-colored shades. It is the only sonic-activated, which activated by means of sound vibration, producing a momentary drop in consistency during application. Once the sonic activation is stopped the material returns to a consistency suitable for sculpturing. This resin can be placed in single step with 5 mm. The set comprises with a SonicFill handpiece and unidose capsules. The proprietary sonic activation enables a rapid flow of composite into the cavity.

Filtek ™ Bulk Fill Posterior Restorative (3M ESPE)

This bulk fill material is a true nanofiller technology product and can be placed in one-step placement with 4-5 mm. They are packed in traditional syringes and single-dose capsules. Material offered in 5 shades (A1, A2, A3, B1, and C2). The shades are semi-translucent and low stress curing, which also useful for anterior restorations.

Presmise TM (Kerr)

Premise is a universal nanofilled restorative composite by utilizing three types of fillers (tri-modal). Premise is designed to offer high polishability, high mechanical strength, and decreased polymerization shrinkage. It is indicated for all restorations. This composite is offered in either a bulk syringe or unidose capsule delivery, and has many shades.

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 1 Restorative materials used

CHAPTER III MATERIALS AND METHODS

Research design

- Experimental study

Research Methodology

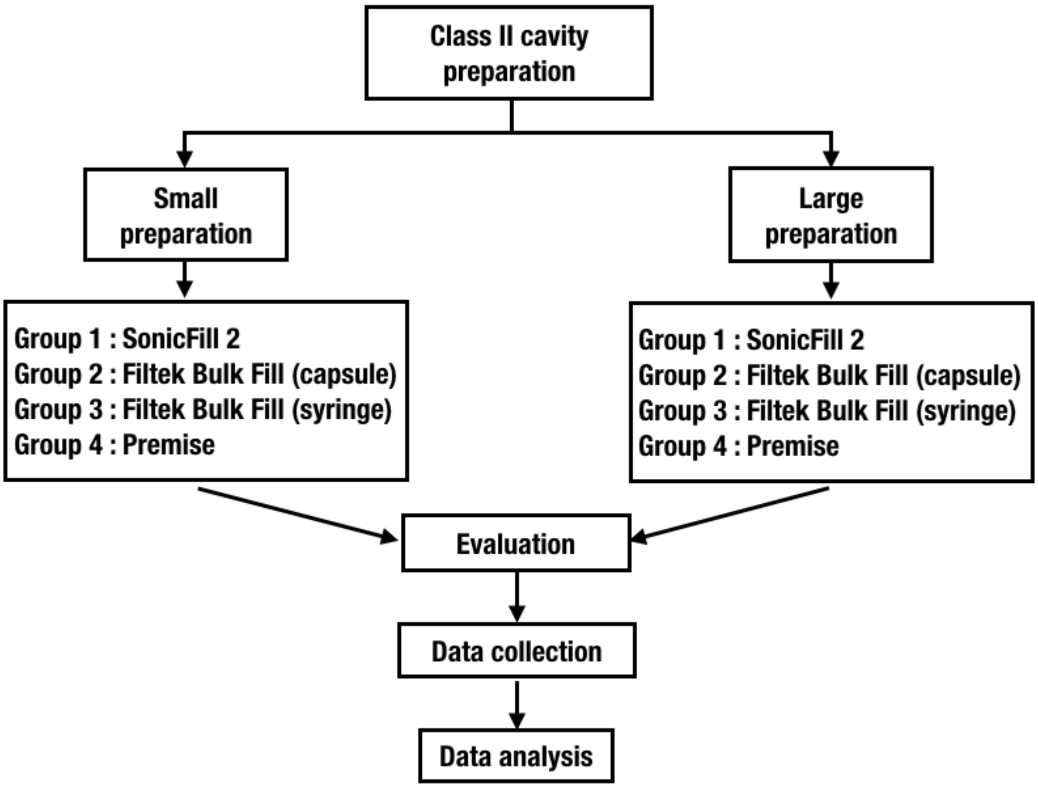


Figure 4 The research methodology

Dental materials

1. SonicFill 2 ™ (Kerr, Orange, CA, USA)
2. Filtek ™ Bulk Fill Posterior Restorative, capsule & syringe type (3M ESPE, St. Paul, MN, USA)
3. Premise™, syringe type (Kerr, Orange, CA, USA)
4. OptiBond ™ Solo Plus (Kerr, Orange, CA, USA)
5. Cylinder diamond bur, diameter 1 mm, 1.5 mm (Intensiv, Montagnola, Switzerland)
6. Fine grit diamond bur (Intensiv, Montagnola, Switzerland)
7. Triodent ® V3 Ring Sectional Matrix System (Ultradent, UT, USA)

8. Methylene Blue solution
9. Silicon carbide abrasive paper (Grit sizes: 800, 1000 and 1200)
10. Dentoform teeth (Nissin Dental Products INC, Kyoto, Japan)
11. (IL,USA ,Friedy, Chicago-Hu) Plugger: 5A XTS
12. (IL,USA ,Friedy, Chicago-Hu) Interproximal Carver Carver: IPC

13. Periodontal probe: 12 UNC color-code probe (Hu-Friedy, Chicago, IL, USA)

Equipment

1. LED Light-Curing System: Demi ™ Plus with 1,100 mW/cm^2 intensity (Kerr, Orange, CA, USA)
2. Low Speed Cutting Machine: ISOMET 1000 (Buehler, Lake Bluff, IL, USA)
3. Polishing Machine: NANO 2000T (PACE technologies, Tucson, Arizona, USA)
4. Ultrasonic Cleaner: BRANSONIC 5210 (LabX, Midland, ON, Canada)
5. Stereo Microscope: ML 9300 (MEIJI TECHNO, Saitama, Japan)
6. Digital Camera for microscope: resolution 5 magapixel, AxioCam MRc 5 (Carl Zeiss, Gottingen, Germany)

Methods

Sample description

The population of sample size was calculated from the pilot study by the equation shown below:

$$n = \frac{2\ (Z_{\frac{\alpha}{2}} + Z_{\beta})^2\ \sigma^2}{(\mu_1 - \mu_2)^2}$$

$$\sigma^2 = \frac{(n_1-1)S_1^2+(n_2-1)S_2^2}{n_1+n_2-2}$$

$$\sigma^2 = \frac{(12-1)(0.90)^2+(12-1)(1.42)^2}{22}$$

$$\sigma^2 = 1.41$$

The α and β values derived from 0.05 and 0.80 respectively.

The values of μ_1, μ_2 and σ^2 are 0.58 , 1.75 and 1.41 which obtained from the pilot study result.

$Z_{\frac{\alpha}{2}}$ = 1.96 at 95 % confidence interval (for a two-tailed hypothesis test)

Z_{β} = 0.84 at 80% power of test

$$n = \frac{2\ (1.96+0.84)^2 \times 1.41}{(0.58-1.75)^2}$$

$$n = 16.16$$

From the calculation, the sample size of 16 should be adequate to detect the significant difference between groups. In this study, a number of 20 teeth were applied in each group.

Tooth preparation

Standardized Class II cavities were prepared under a dental loupe (2.5x magnification) at the mesial surface of each lower second premolar artificial tooth (Nissin Dental Products INC, Kyoto, Japan), using cylinder diamond bur diameter 1 mm, 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 Fig. 5. The dimension was a 2-mm mesio-distal width, a 3-mm bucco-lingual width and a 5-mm occluso-gingival depth.

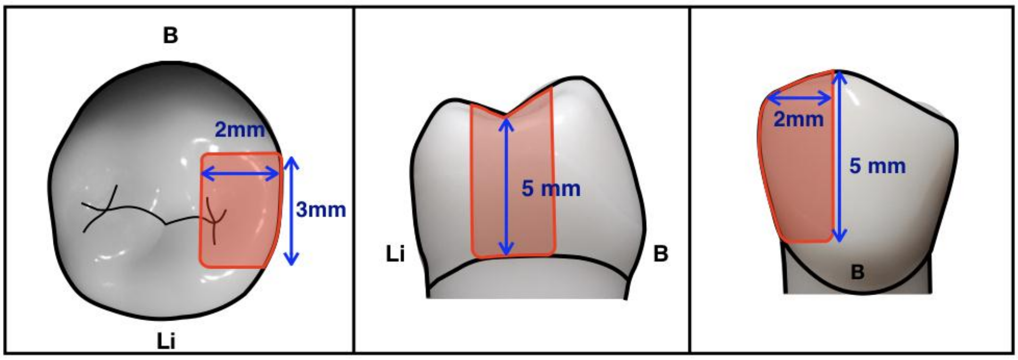


Figure 5 Small cavity preparation

- A large cavity was prepared as shown in Fig. 6. 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.

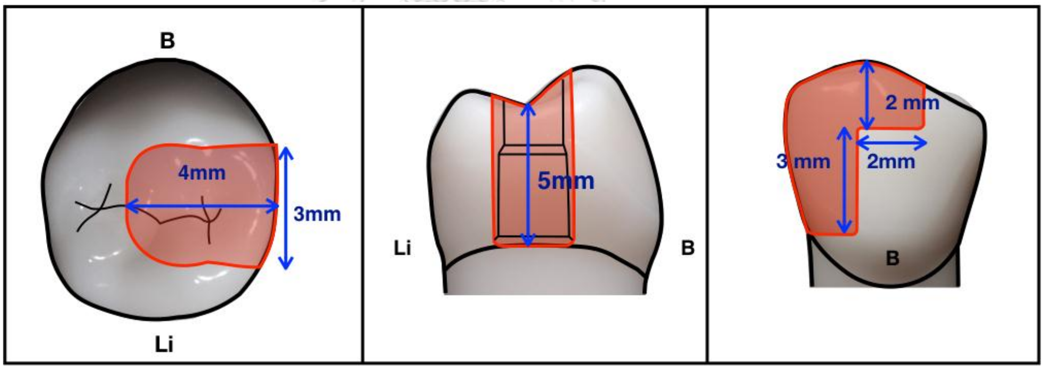


Figure 6 Large cavity preparation

Allocation technique

The eighty artificial lower second premolars were divided into 2 groups, one group was prepared for small Class II cavities and the other one was prepared for large Class II cavity. 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 (n=10).

Filling material

1) Bulk-fill resin composite

- SonicFill 2™, shade B1 and A3 (Kerr, Orange, CA, USA)
- Filtek ™ Bulk Fill Posterior Restorative, shade A1 and C2 (3M ESPE, St. Paul, MN, USA)

2) Conventional resin composite

- Premise™, shade A1 and A4 (Kerr, Orange, CA, USA)

In each cavity design, teeth were marked with 4 colors according to the material groups (black for SonicFill 2 ™, red for Filtek ™ Bulk Fill : capsule type, green for Filtek ™ Bulk Fill : syringe type and blue for Premise ™). Operator randomly selected the tooth and started the procedure by following the instruction of each material.

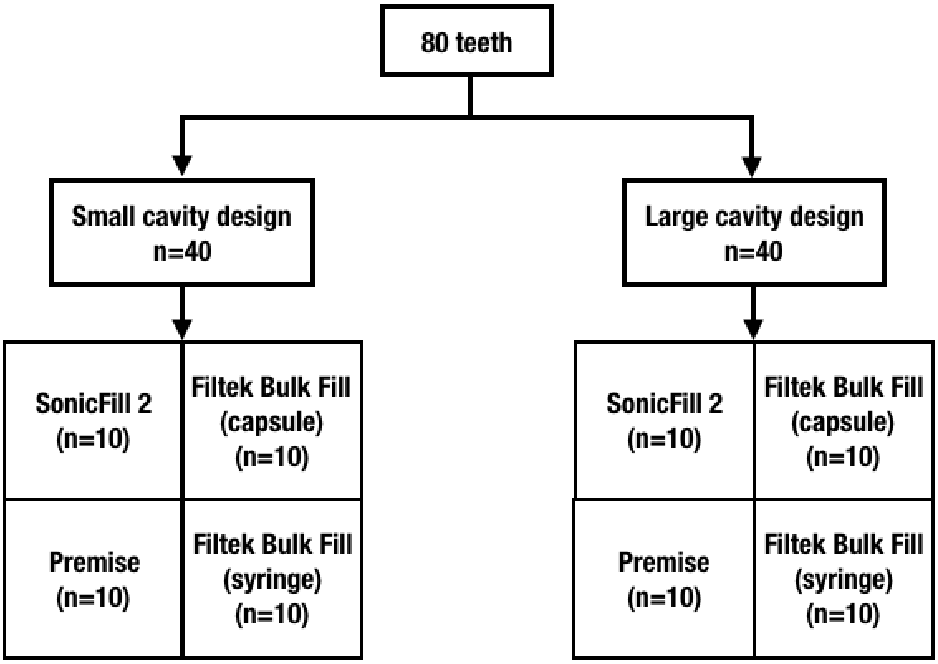


Figure 7 The allocation techniqueRestorative procedure

After cavity preparation of 80 teeth, the cavities were cleaned with water and air-dried using triple syringe. Teeth were mounted in a dentoform model (Nissin Dental Products INC, Kyoto, Japan) and a Triodent ® V3 Ring Sectional Matrix System (Ultradent, UT, USA) was adapted. Then, a layer of Optibond ™ Solo Plus adhesive

(Kerr, Orange, CA, USA) was applied, gently air-dried and light cured for 20 seconds by following the manufacturer's instruction.

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. All cavities were restored in horizontal incremental layers. 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.

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 times 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)

Table 2 Material applications according to the manufacturers' instructions

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 dispened 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.

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 direction along the long axis with a low-speed cutting machine: ISOMET 1000 (Buehler, Lake Bluff, IL, USA), resulting in two sections of each specimen to be inspected. Then, the sections were polished to ensure a surface free of deep scratches using polishing machine: NANO 2000T (PACE technologies, Tucson, Arizona, USA) with varying grits of silicon carbide abrasive paper (Grit sizes: 800, 1000 and 1200). After the sections were cleaned for one minute to remove surface debris that covered voids with an Ultrasonic Cleaner: BRANSONIC 5210 (LabX, Midland, ON, Canada) in deionized water, they were immersed in Methylene Blue solution for 5 minutes to provide a contrast of high clarity, which showed surface voids. To improve the visibility of voids, a small brush was used to disperse the dye. Then the specimens were rinsed with water and air-dried. The sections were observed under a stereomicroscope: ML 9300 (MEIJI TECHNO, Saitama, Japan) with 20X magnification and photographed with a digital camera for microscope: AxioCam MRc 5 (Carl Zeiss, Gottingen, Germany). Each section was assessed for number of voids, void diameter, total view area, total void area and thickness of the first increment with analysis Image-Pro Plus image analysis software (Media Cybernetics, USA).

Data collection

A total of 160 sections were inspected. One examiner evaluated the specimens under a stereomicroscope and photographed. Each section was evaluated for the number of voids, void diameter and location of void. Only large void (> 150 μm length) were counted and calculated for percentage of void with the following equation:

$$\text{Percentage (\%) void} = \frac{\text{total void area}}{\text{total viewing area}} \times 100$$

This study classified voids into 5 locations: inter incremental junction, internal cavity wall, gingival margin, external surface and void within restoration. These locations are illustrated in the following Figure 8 and 9.

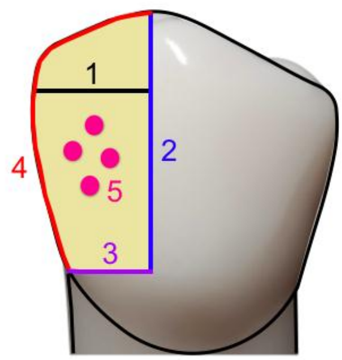


Figure 8 The location of void in small cavity

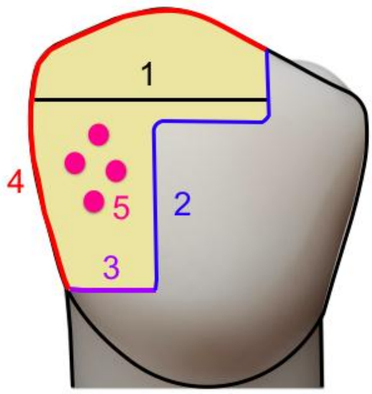


Figure 9 The location of void in large cavity

1 = void along inter incremental junction

2 = void along internal cavity wall

3 = void along gingival margin

4 = void along external surface

5 = void within restoration

Data 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).

CHAPTER IV 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 voids (Figure 10).

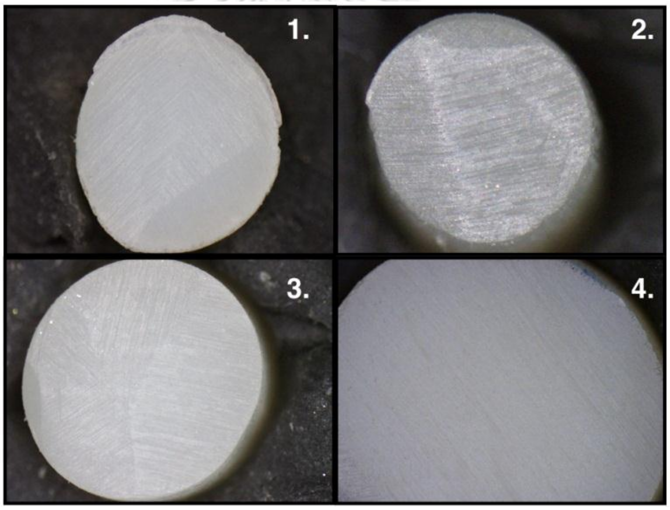


Figure 10 Cured composite samples from manufacturer batch (1 = SonicFill 2™, 2 = Filtek™ Bulk Fill (capsule), 3 = Filtek™ Bulk Fill (syringe), 4 = Premise™)

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 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 in the number of voids among the 4 groups.

Group	Small Cavity	Large Cavity
	Number of Voids Mean (SD)	Number of Voids Mean (SD)
SonicFill 2 ™	1.60 (1.31) [a,b]	3.30 (1.42) [A]
Filtek ™ Bulk Fill (capsule)	2.05 (2.06) [b,c]	2.70 (1.13) [A]
Filtek ™ Bulk Fill (syringe)	3.00 (1.92) [c]	3.45 (1.64) [A]
Premise ™	4.70 (2.52) [d]	4.30 (2.20) [A]

- Void composed of > 150 μm in diameter

- Kruskal-Wallis test: Means with the same superscript letters are not statistically different ($p < 0.05$)

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

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 percent void area of the 4 material groups in large cavities are presented in Table 4. The evaluation showed no significant difference in the percent of void area among the 4 groups.

Group	Small Cavity	Large Cavity
	Percent Void Area (%) Mean (SD)	Percent Void Area (%) Mean (SD)
SonicFill 2™	0.43 (0.63) ^{a}	0.67 (0.45) ^{A}
Filtek™ Bulk Fill (capsule)	0.49 (0.70) $^{a, b}$	0.69 (0.71) ^{A}
Filtek™ Bulk Fill (syringe)	1.08 (1.41) $^{b, c}$	0.73 (0.89) ^{A}
Premise™	0.99 (0.81) ^{c}	0.67 (0.42) ^{A}

- Void composed of > 150 μm in diameter

- Kruskal-Wallis test: Means with the same superscript letters are not statistically different ($p < 0.05$)

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

In this study, voids could be found scattered in all parts of the section and varied from round to irregular shapes. These voids in each cavity design were classified into 5 locations as represented in Table 5 and 6.

Group	Inter incremental junction	Internal cavity wall	Gingival margin	External surface	Void within restoration
SonicFill 2™	13	7	4	2	6
Filtek™ Bulk Fill (capsule)	5	3	1	5	27
Filtek™ Bulk Fill (syringe)	8	16	6	2	29
Premise™	16	22	7	18	31

- Void composed of > 150 μm in diameter

Table 5 The description of voids in each location for small cavity preparation

Group	Inter incremental junction	Internal cavity wall	Gingival margin	External surface	Void within restoration
SonicFill 2™	21	19	4	4	18
Filtek™ Bulk Fill (capsule)	7	16	2	3	26
Filtek™ Bulk Fill (syringe)	11	14	6	5	33
Premise™	6	21	2	24	34

- Void composed of > 150 μm in diameter

Table 6 The description of voids in each location for large cavity preparation

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. 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 7. For the overall result of large cavity preparations, 91.30% of the first increments were thicker than the recommended thickness.

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 Percent of Incorrect Thickness 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.

Table 7 The number and percent of the first increment thicker than the recommended thickness for small and large cavity preparation

CHAPTER V DISCUSSIONS

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 voids. However, a few microporosities (<150 μm in diameter) were found in the materials. This result is in accordance with previous studies.[13, 31, 36]

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 the restorations, but gaps are more frequently situated within the high consistency composite restorations, which could be detected at the gingival and the internal cavity walls.[17] In this study, voids were found distributed evenly within the section. Voids were commonly found along the junction between increment layers, along the internal cavity wall and gingival margin (Figure 11 and 12). Presence of voids is equally important to the formation of gaps, which may result from an improper adaptation of the resin composite. The previous studies of Wilson and Norman,[14] Ironside and Makinson[13] stated that porosities are commonly found along the junction between the resin composite layers when the incremental technique is applied. Moreover, the external surface was another area where voids could be found (Figure 13). The presence of these large voids may cause negative effects within a restoration because large voids have the most pronounced effect on restorations. Large voids could be detected in intraoral radiographs. For voids ≥ 350 μm could be detected by all radiographic imaging techniques. Digital intraoral techniques have better detection for voids < 350 μm than analogue intraoral radiographs and CBCT images technique.[41] The presence of large marginal voids revealed by intraoral radiographs, replacement of composite restoration was also required.[42] Large voids were sometimes a reason for replacement of the defective restorations because of post-operative sensitivity, microleakage, esthetic reason and secondary caries.[23, 24]

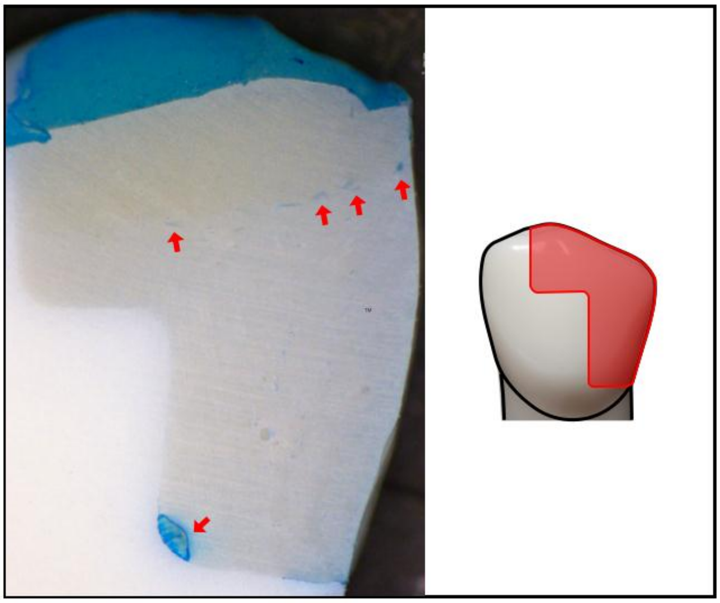


Figure 11 Voids along the interface layer and internal cavity wall

(Large cavity preparation)

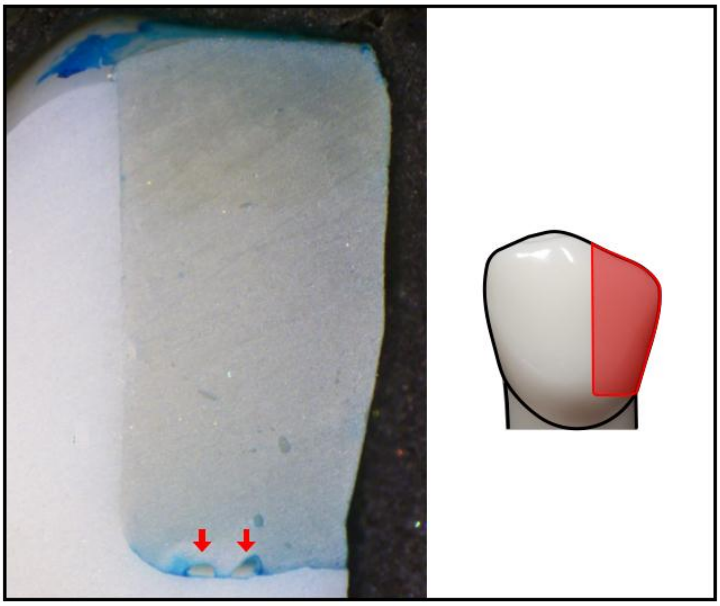


Figure 12 Voids along the gingival margin (Small cavity preparation)

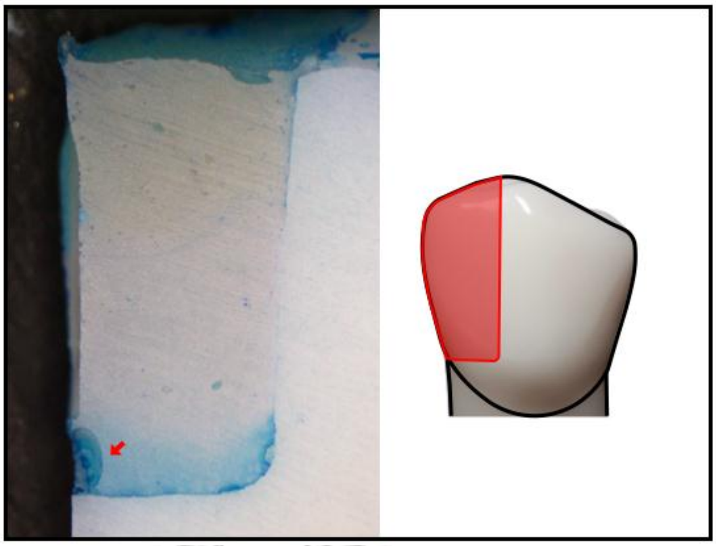


Figure 13 Void at the external surface (Small cavity preparation)

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 Filtek ™ Bulk Fill (syringe) and Premise ™ 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 Filtek ™ Bulk Fill (syringe) and Premise ™. Hence the first null hypothesis was rejected. These findings are consistent with previous studies.[24, 26] From previous study concerning mode of application, it is known that the injection technique can decrease voids and eliminate large voids.[26] 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.[34]

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[13]reported on the occurrence of voids at the line angle and the sharp angle. The study of Opdam and others,[24] 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.[17] 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.[32, 43] 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.[17, 26] In this study, all the resin composites used were thick-consistency composites.

Regarding the thickness of the first increment as manufacturer's recommendations, the injection technique type used with a 1.5 mm diameter for

SonicFill 2™ capsule tip 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 quality 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, 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.[12]

In addition, curing light 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.[16, 44] 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/cm2 to a peak of 1330 mW/cm2.[45] 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.[6] 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.[6, 46]

From the results, effect of large voids in fracture toughness of restoration should be further investiagted. Regarding the increment thickness, 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.

CHAPTER VI CONCLUSIONS

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 porosities among the 4 resin composites.

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.

REFERENCES

1. Ferracane JL. Resin composite--state of the art. Dent Mater. 2011;27(1):29-38.

2. Flury S, Hayoz S, Peutzfeldt A, Husler J, Lussi A. Depth of cure of resin composites: is the ISO 4049 method suitable for bulk fill materials? Dent Mater. 2012;28(5):521-8.

3. Tjan AH, Bergh BH, Lidner C. Effect of various incremental techniques on the marginal adaptation of class II composite resin restorations. J Prosthet Dent. 1992;67(1):62-6.

4. Ilie N, Bucuta S, Draenert M. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Oper Dent. 2013;38(6):618-25.

5. Lassila LV, Nagas E, Vallittu PK, Garoushi S. Translucency of flowable bulk-filling composites of various thicknesses. Chin J Dent Res. 2012;15(1):31-5.

6. Tarle Z, Attin T, Marovic D, Andermatt L, Ristic M, Taubock TT. Influence of irradiation time on subsurface degree of conversion and microhardness of high-viscosity bulk-fill resin composites. Clin Oral Investig. 2015;19(4):831-40.

7. Bucuta S, Ilie N. Light transmittance and micro-mechanical properties of bulk fill vs. conventional resin based composites. Clin Oral Investig. 2014;18(8):1991-2000.

8. Kim EH, Jung KH, Son SA, Hur B, Kwon YH, Park JK. Effect of resin thickness on the microhardness and optical properties of bulk-fill resin composites. Restor Dent Endod. 2015;40(2):128-35.

9. Furness A, Tadros MY, Looney SW, Rueggeberg FA. Effect of bulk/incremental fill on internal gap formation of bulk-fill composites. J Dent. 2014;42(4):439-49.

10. Leprince JG, Palin WM, Vanacker J, Sabbagh J, Devaux J, Leloup G. Physico-mechanical characteristics of commercially available bulk-fill composites. J Dent. 2014;42(8):993-1000.

11. Kovarik RE, Ergle JW. Fracture toughness of posterior composite resins fabricated by incremental layering. J Prosthet Dent. 1993;69(6):557-60.

12. Matsumoto H, Gres JE, Marker VA, Okabe T, Ferracane JL, Harvey GA. Depth of cure of visible light-cured resin: clinical simulation. J Prosthet Dent. 1986;55(5):574-8.

13. Ironside JG, Makinson OF. Resin restorations: causes of porosities. Quintessence Int. 1993;24(12):867-73.

14. Wilson MA, Norman RD. An investigation into the incidence of voids in indirect composite inlays formed using different packing techniques. J Dent. 1991;19(5):296-300.

15. Porto IC, Soares LE, Martin AA, Cavalli V, Liporoni PC. Influence of the photoinitiator system and light photoactivation units on the degree of conversion of dental composites. Braz Oral Res. 2010;24(4):475-81.

16. Aguiar FH, Braceiro A, Lima DA, Ambrosano GM, Lovadino JR. Effect of light curing modes and light curing time on the microhardness of a hybrid composite resin. J Contemp Dent Pract. 2007;8(6):1-8.

17. Lagouvardos P, Nikolinakos N, Oulis C. Volume fraction and location of voids and gaps in ultraconservative restorations by X-ray computed micro-tomography. Dent Res J (Isfahan). 2015;12(6):520-7.

18. de Moraes RR, Goncalves Lde S, Lancellotti AC, Consani S, Correr-Sobrinho L, Sinhoreti MA. Nanohybrid resin composites: nanofiller loaded materials or traditional microhybrid resins? Oper Dent. 2009;34(5):551-7.

19. Bayne SC, Heymann HO, Swift EJ, Jr. Update on dental composite restorations. J Am Dent Assoc. 1994;125(6):687-701.

20. Baroudi K, Rodrigues JC. Flowable Resin Composites: A Systematic Review and Clinical Considerations. J Clin Diagn Res. 2015;9(6):ZE18-24.

21. Kubo S. Longevity of resin composite restorations. Japanese Dental Science Review. 2011;47(1):43-55.

22. Demarco FF, Correa MB, Cenci MS, Moraes RR, Opdam NJ. Longevity of posterior composite restorations: not only a matter of materials. Dent Mater. 2012;28(1):87-101.

23. Sarrett DC. Clinical challenges and the relevance of materials testing for posterior composite restorations. Dent Mater. 2005;21(1):9-20.

24. Opdam NJ, Roeters JJ, Joosten M, Veeke O. Porosities and voids in Class I restorations placed by six operators using a packable or syringable composite. Dent Mater. 2002;18(1):58-63.

25. Chuang SF, Liu JK, Chao CC, Liao FP, Chen YH. Effects of flowable composite lining and operator experience on microleakage and internal voids in class II composite restorations. J Prosthet Dent. 2001;85(2):177-83.

26. Opdam NJ, Roeters JJ, Peters TC, Burgersdijk RC, Teunis M. Cavity wall adaptation and voids in adhesive Class I resin composite restorations. Dent Mater. 1996;12(4):230-5.

27. Samet N, Kwon KR, Good P, Weber HP. Voids and interlayer gaps in Class 1 posterior composite restorations: a comparison between a microlayer and a 2-layer technique. Quintessence Int. 2006;37(10):803-9.

28. Ogden AR. Porosity in composite resins--an Achilles' heel? J Dent. 1985;13(4):331-40.

29. Medlock JW, Zinck JH, Norling BK, Sisca RF. Composite resin porosity with hand and syringe insertion. J Prosthet Dent. 1985;54(1):47-51.

30. Chadwick RG, McCabe JF, Walls AW, Storer R. The effect of placement technique upon the compressive strength and porosity of a composite resin. J Dent. 1989;17(5):230-3.

31. Fano V, Ortalli I, Pozela K. Porosity in composite resins. Biomaterials. 1995;16(17):1291-5.

32. Elbishari H, Silikas N, Satterthwaite J. Filler size of resin-composites, percentage of voids and fracture toughness: is there a correlation? Dent Mater J. 2012;31(4):523-7.

33. Balthazard R, Jager S, Dahoun A, Gerdolle D, Engels-Deutsch M, Mortier E. High-resolution tomography study of the porosity of three restorative resin composites. Clin Oral Investig. 2014;18(6):1613-8.

34. Hansen EK, Asmussen E. Efficacy of dentin-bonding agents in relation to application technique. Acta Odontol Scand. 1989;47(2):117-20.

35. Olmez A, Oztas N, Bodur H. The effect of flowable resin composite on microleakage and internal voids in class II composite restorations. Oper Dent. 2004;29(6):713-9.

36. Kwon SR, Oyoyo U, Li Y. Influence of application techniques on contact formation and voids in anterior resin composite restorations. Oper Dent. 2014;39(2):213-20.

37. Opdam NJ, Roeters JJ, de Boer T, Pesschier D, Bronkhorst E. Voids and porosities in class I micropreparations filled with various resin composites. Oper Dent. 2003;28(1):9-14.

38. Shimada Y, Sadr A, Sumi Y, Tagami J. Application of Optical Coherence Tomography (OCT) for Diagnosis of Caries, Cracks, and Defects of Restorations. Curr Oral Health Rep. 2015;2(2):73-80.

39. Nazari A, Sadr A, Saghiri MA, Campillo-Funollet M, Hamba H, Shimada Y, et al. Non-destructive characterization of voids in six flowable composites using swept-source optical coherence tomography. Dent Mater. 2013;29(3):278-86.

40. Im K-H, Hsu DK, Cha C-S, Sim J-K, Yang I-Y. A study on ultrasonic evaluation of material defects in carbon/carbon composites. KSME international journal. 2002;16(12):1652-63.

41. Huybrechts B, Bud M, Bergmans L, Lambrechts P, Jacobs R. Void detection in root fillings using intraoral analogue, intraoral digital and cone beam CT images. Int Endod J. 2009;42(8):675-85.

42. Nordbo H, Leirskar J, von der Fehr FR. Saucer-shaped cavity preparation for composite resin restorations in class II carious lesions: three-year results. J Prosthet Dent. 1993;69(2):155-9.

43. Elbishari H, Satterthwaite J, Silikas N. Effect of filler size and temperature on packing stress and viscosity of resin-composites. Int J Mol Sci. 2011;12(8):5330-8.

44. Franco EB, dos Santos PA, Mondelli RF. The effect of different light-curing units on tensile strength and microhardness of a composite resin. J Appl Oral Sci. 2007;15(6):470-4.

45. Kameyama A, Haruyama A, Asami M, Takahashi T. Effect of emitted wavelength and light guide type on irradiance discrepancies in hand-held dental curing radiometers. ScientificWorldJournal. 2013;2013:647941.

46. Zorzin J, Maier E, Harre S, Fey T, Belli R, Lohbauer U, et al. Bulk-fill resin composites: polymerization properties and extended light curing. Dent Mater. 2015;31(3):293-301.

APPENDIX

Table 8 Data of number of voids and percent void area of Group SonicFill 2 ™ in small and large cavity

Section	Small Cavity		Large Cavity	
	Number of voids	Percent void area	Number of voids	Percent void area
1	2	2.29	3	1.24
2	2	0.74	3	0.50
3	3	0.31	4	1.13
4	5	0.32	2	0.39
5	3	0.42	4	0.58
6	0	0.00	1	0.28
7	0	0.00	2	0.12
8	1	0.18	5	0.49
9	2	0.10	4	0.44
10	2	0.27	4	1.38
11	1	0.19	5	0.56
12	1	0.07	1	0.34
13	2	0.62	2	0.10
14	0	0.00	5	0.71
15	0	0.00	2	1.87
16	2	0.16	4	0.58
17	3	1.96	2	0.86
18	2	0.78	3	0.41
19	1	0.13	4	0.46
20	0	0.00	6	0.99

Table 9 Data of number of voids and percent void area of Group Filtek™ Bulk Fill (capsule) in small and large cavity

Section	Small Cavity		Large Cavity	
	Number of voids	Percent void area	Number of voids	Percent void area
1	2	1.84	2	0.21
2	2	0.18	1	0.13
3	0	0.00	3	1.55
4	1	0.11	2	0.10
5	1	0.07	3	2.43
6	4	0.36	3	0.44
7	3	0.98	4	0.66
8	2	0.30	3	0.92
9	3	0.48	2	2.58
10	0	0.00	2	0.71
11	0	0.00	1	0.11
12	2	0.19	3	0.68
13	2	0.32	1	0.05
14	4	1.50	2	0.49
15	2	0.14	4	0.48
16	0	0.00	4	0.28
17	9	2.55	3	0.65
18	2	0.55	4	0.52
19	2	0.22	5	0.38
20	0	0.00	2	0.36

Table 10 Data of number of voids and percent void area of Group Filtek™ Bulk Fill (syringe) in small and large cavity

Section	Small Cavity		Large Cavity	
	Number of voids	Percent void area	Number of voids	Percent void area
1	3	0.22	5	1.72
2	4	0.80	6	0.58
3	2	2.16	5	0.51
4	6	1.74	4	1.05
5	2	0.36	3	0.70
6	1	0.03	5	0.37
7	2	0.18	1	0.04
8	4	0.41	5	0.53
9	5	0.62	2	0.09
10	5	0.44	2	0.16
11	2	0.16	5	2.30
12	0	0.00	2	0.20
13	1	0.23	1	0.06
14	5	0.88	4	0.44
15	2	0.84	3	0.25
16	7	3.38	2	0.31
17	2	0.55	3	0.61
18	1	0.13	5	0.89
19	4	2.94	5	3.65
20	3	5.44	1	0.10

Table 11 Data of number of voids and percent void area of Group Premise™ in small and large cavity

Section	Small Cavity		Large Cavity	
	Number of voids	Percent void area	Number of voids	Percent void area
1	3	2.23	3	0.27
2	2	0.13	2	0.28
3	7	1.21	6	1.04
4	6	0.97	0	0.00
5	2	0.49	2	0.11
6	2	0.22	5	0.76
7	5	0.87	4	0.77
8	6	0.99	4	0.46
9	5	1.11	6	0.86
10	10	3.57	3	1.09
11	3	0.50	5	1.49
12	8	1.34	6	0.64
13	3	0.33	2	0.19
14	7	1.91	4	0.73
15	1	0.41	9	1.54
16	4	0.93	5	0.65
17	4	0.66	7	0.90
18	3	0.44	7	0.78
19	9	0.99	4	0.36
20	4	0.44	3	0.56

Table 12 Descriptive statistics of experimental groups in number of voids

Group		Number of voids					
		n	Min	Max	Mean	Median	SD
Small cavity	SonicFill2™	20	0	5	1.60	2.00	1.31
	Filtek™ Bulk Fill (capsule)	20	0	9	2.05	2.00	2.06
	Filtek™ Bulk Fill (syringe)	20	0	7	3.00	2.50	1.92
	Premise™	20	1	10	4.70	4.00	2.52
Large cavity	SonicFill2™	20	1	6	3.30	3.50	1.42
	Filtek™ Bulk Fill (capsule)	20	1	5	2.70	3.00	1.13
	Filtek™ Bulk Fill (syringe)	20	1	6	3.45	3.50	1.64
	Premise™	20	0	9	4.30	4.00	2.20

Table 13 Descriptive statistics of experimental groups in percent void area

Group		Percent void area					
		n	Min	Max	Mean	Median	SD
Small cavity	SonicFill2™	20	0.00	2.29	0.43	0.19	0.63
	Filtek™ Bulk Fill (capsule)	20	0.00	2.55	0.49	0.21	0.70
	Filtek ™ Bulk Fill (syringe)	20	0.00	5.44	1.08	0.50	1.41
	Premise™	20	0.13	3.57	0.99	0.90	0.81
Large cavity	SonicFill2™	20	0.10	1.87	0.67	0.53	0.45
	Filtek™ Bulk Fill (capsule)	20	0.05	2.58	0.69	0.49	0.71
	Filtek™ Bulk Fill (syringe)	20	0.04	3.65	0.73	0.48	0.89
	Premise™	20	0.00	1.54	0.67	0.69	0.42

Table 14 Statistics comparison of number of void in small cavity

Comparison	p-value
SonicFill2 ™ & Filtek ™ Bulk Fill (capsule)	0.575
SonicFill2 ™ & Filtek ™ Bulk Fill (syringe)	0.027*
SonicFill2 ™ & Premise ™	0.000*
Filtek ™ Bulk Fill (capsule) & Filtek ™ Bulk Fill (syringe)	0.097
Filtek ™ Bulk Fill (capsule) & Premise ™	0.000*
Filtek ™ Bulk Fill (syringe) & Premise ™	0.043*

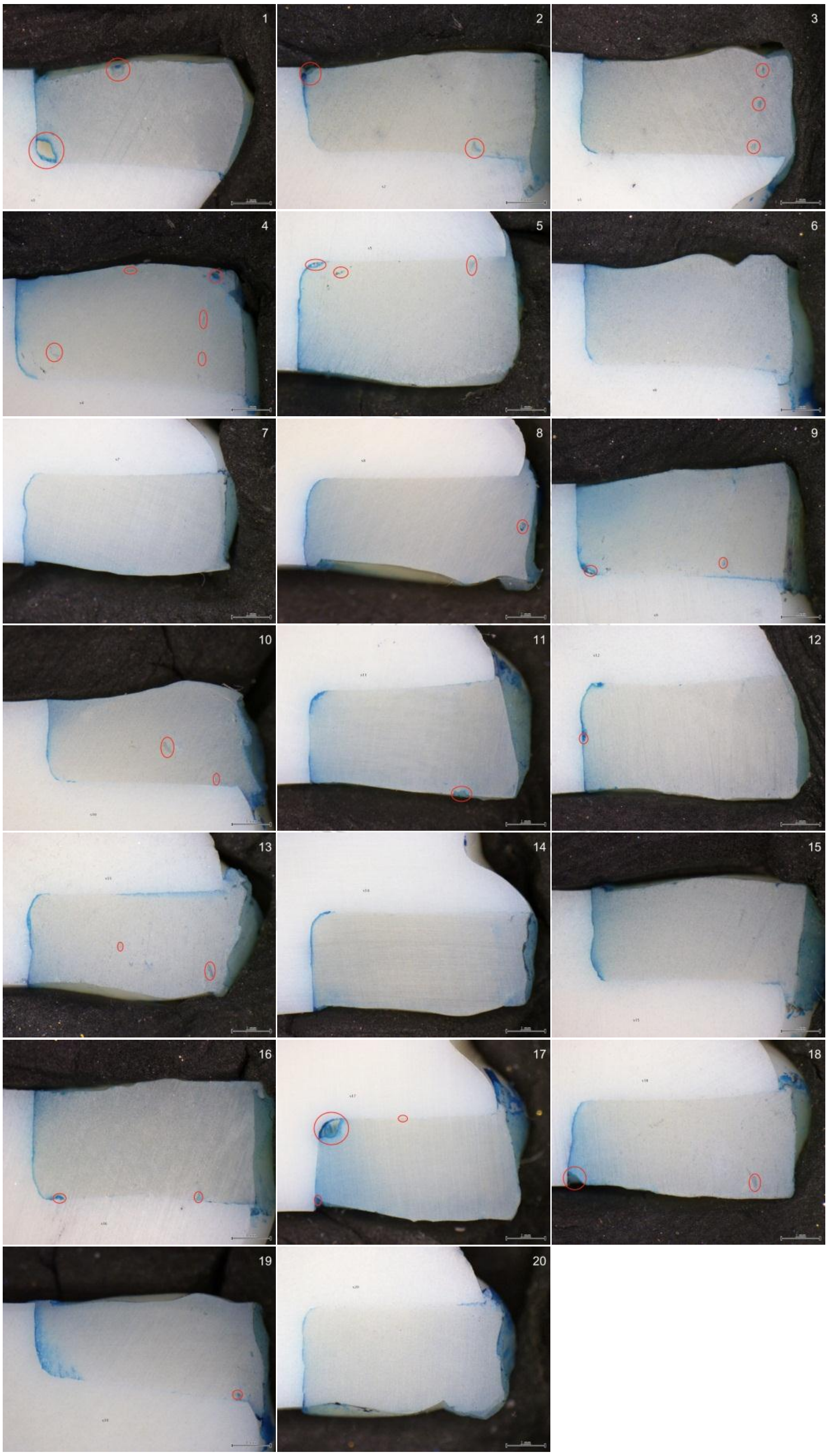
* Statistically significant difference at a level of 0.05

Table 15 Statistics comparison of percent void area in small cavity

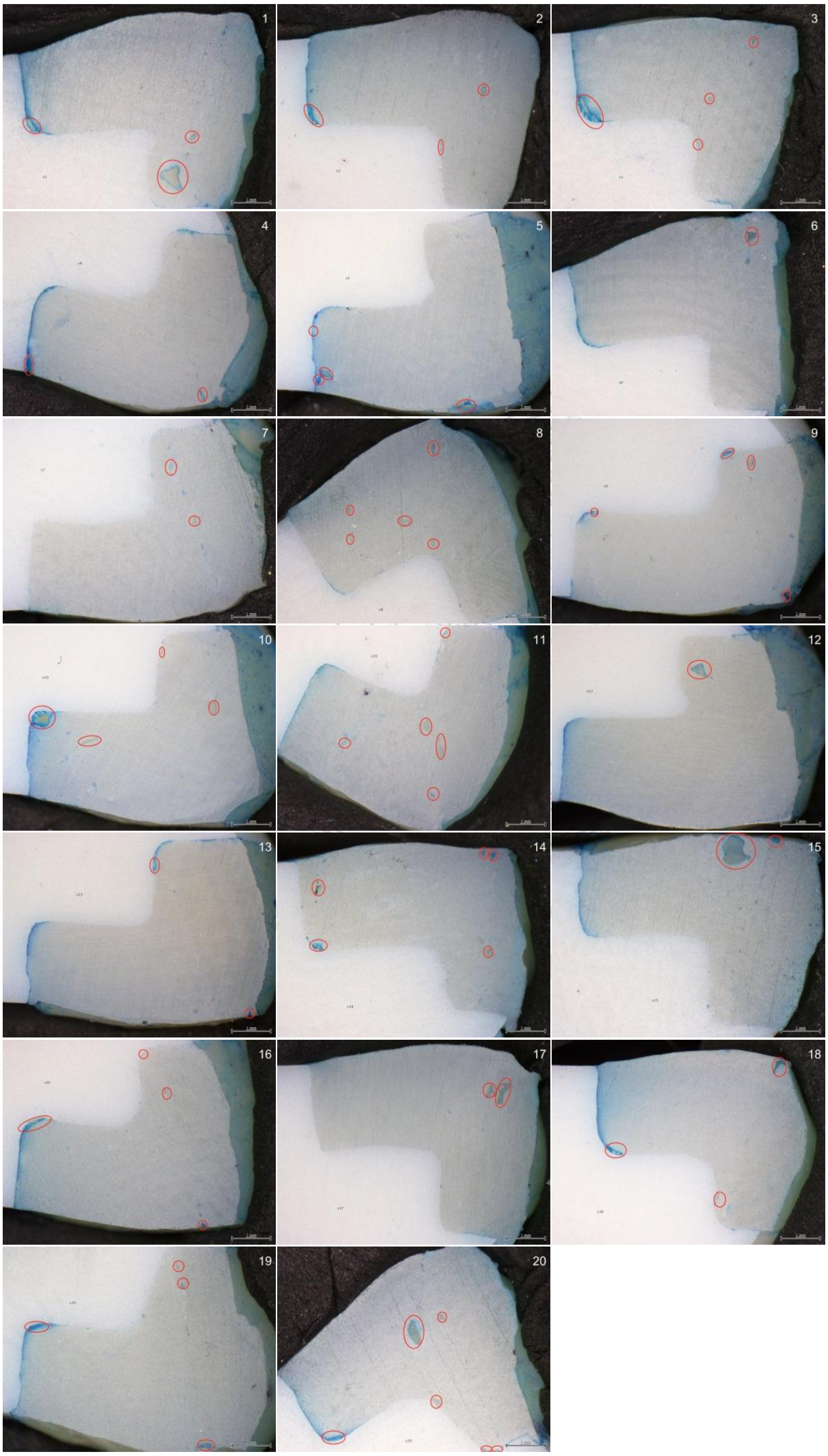
Comparison	p-value
SonicFill2 ™ & Filtek ™ Bulk Fill (capsule)	0.796
SonicFill2 ™ & Filtek ™ Bulk Fill (syringe)	0.032*
SonicFill2 ™ & Premise ™	0.001*
Filtek ™ Bulk Fill (capsule) & Filtek ™ Bulk Fill (syringe)	0.059
Filtek ™ Bulk Fill (capsule) & Premise ™	0.002*
Filtek ™ Bulk Fill (syringe) & Premise ™	0.236

*Statistically significant difference at a level of 0.05

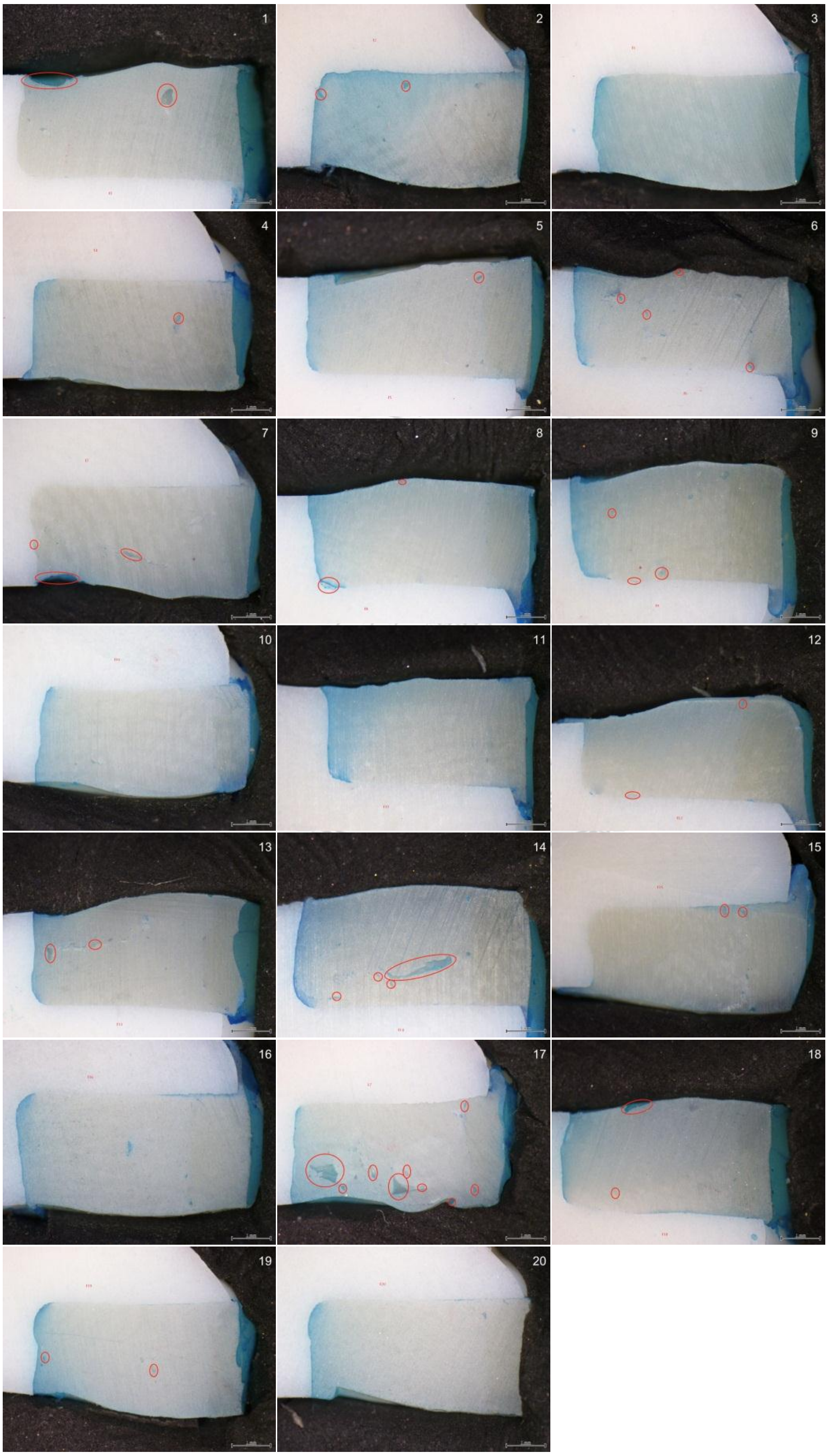
The sections with voids (>150 μm) of Group SonicFill2™ in small cavity



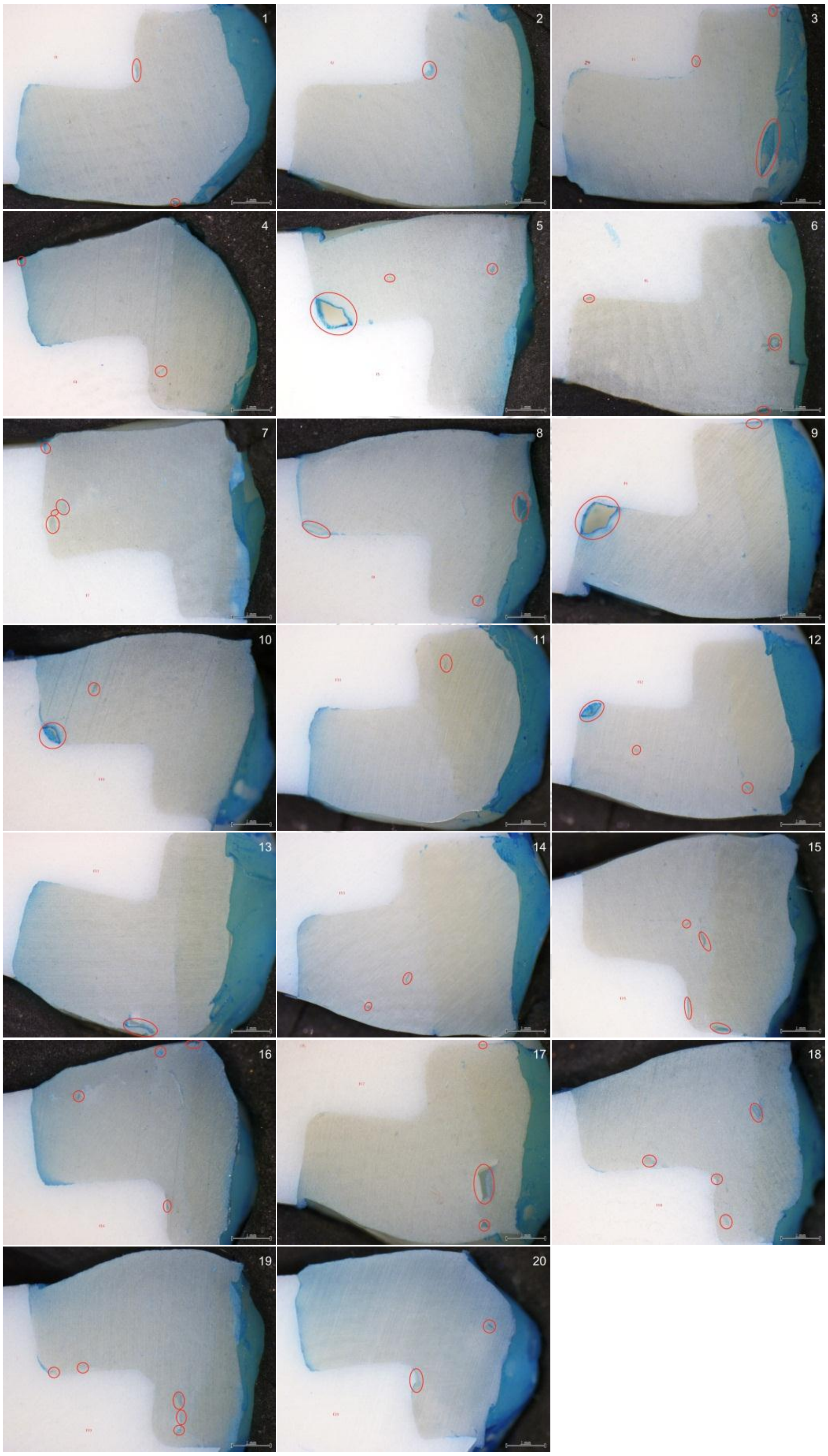
The sections with voids (>150 μm) of Group SonicFill2™ in large cavity



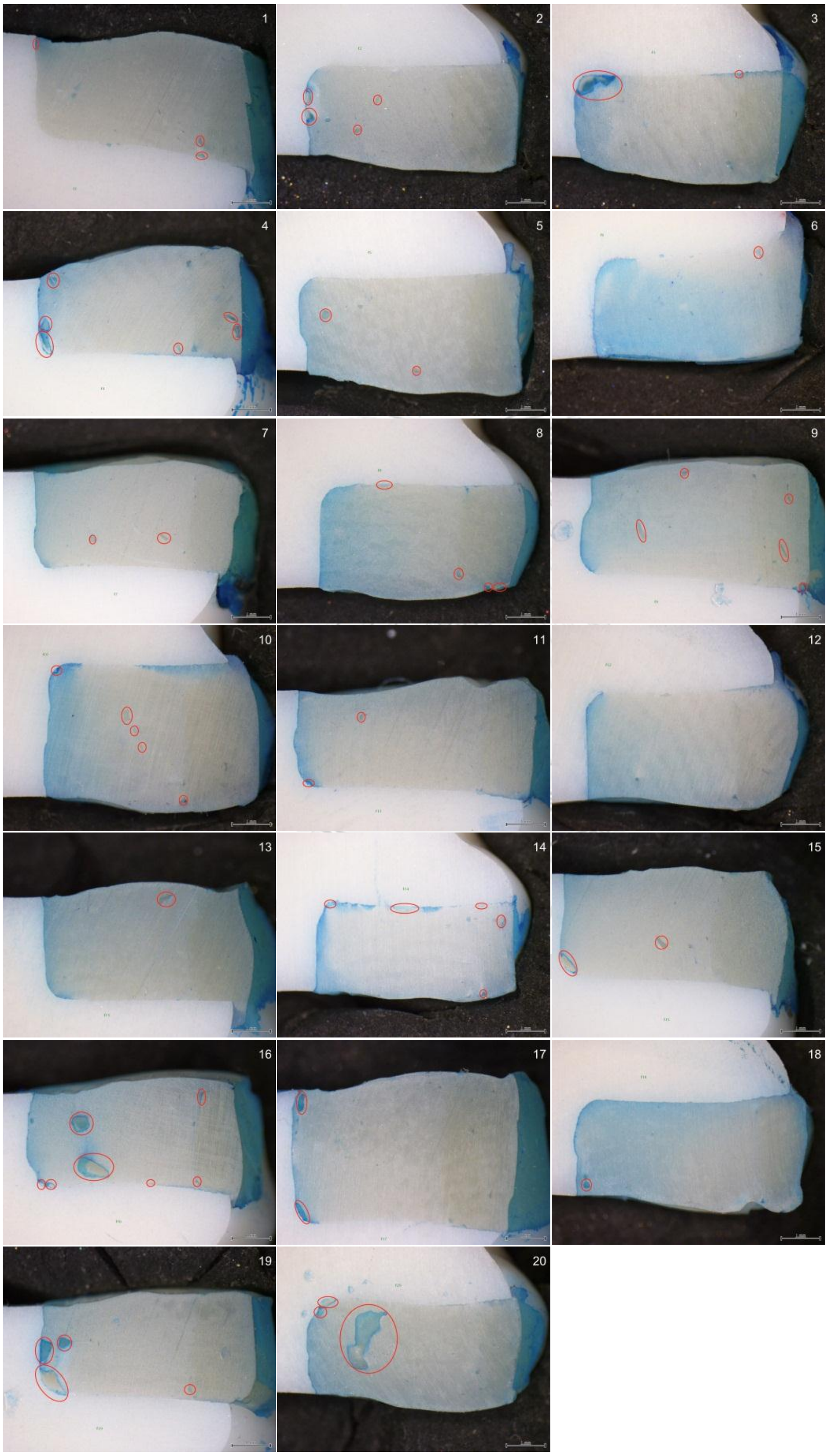
The sections with voids (>150 μm) of Group Filtek™ Bulk Fill (capsule) in small cavity



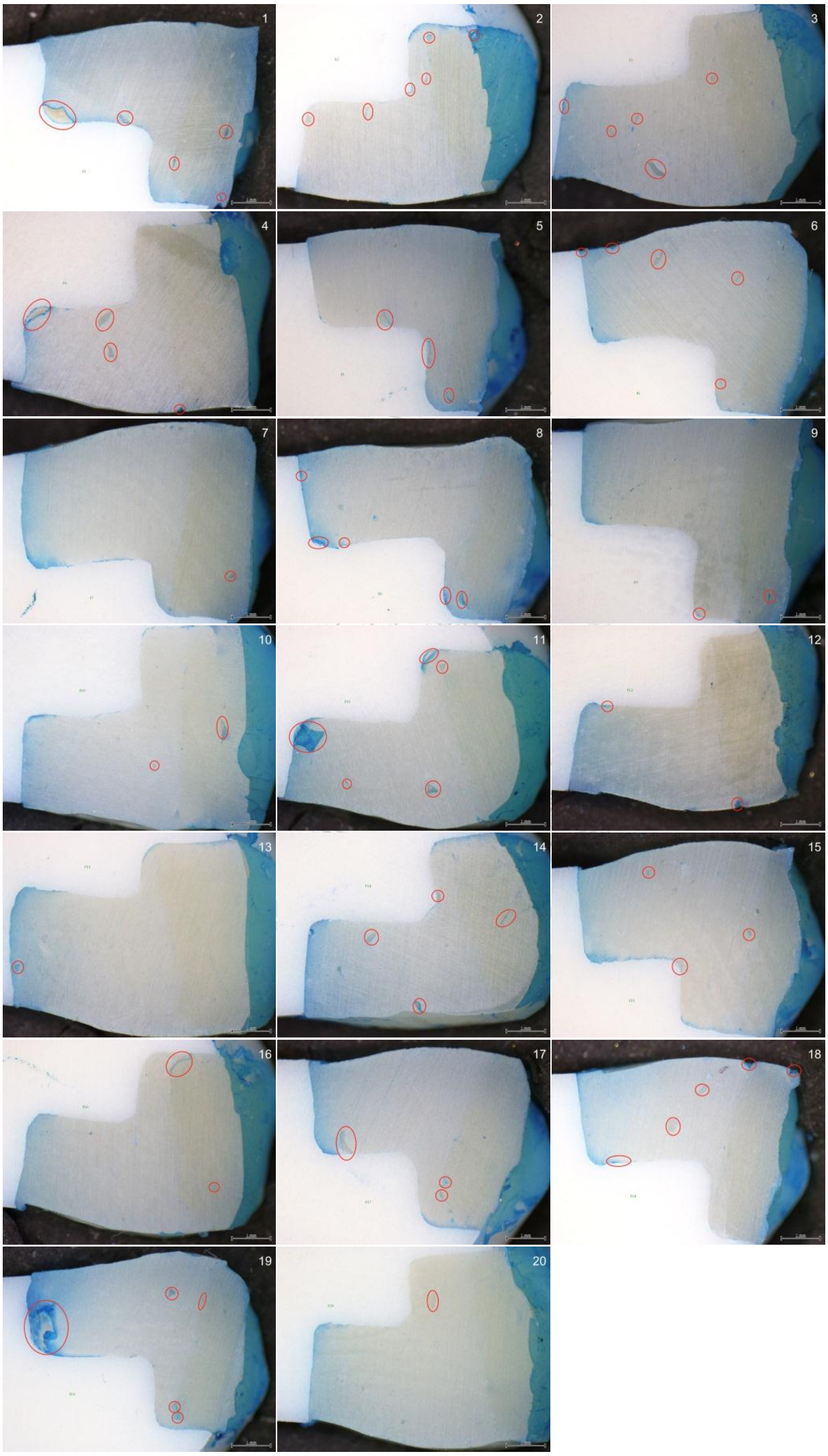
The sections with voids (>150 μm) of Group Filtek™ Bulk Fill (capsule) in large cavity



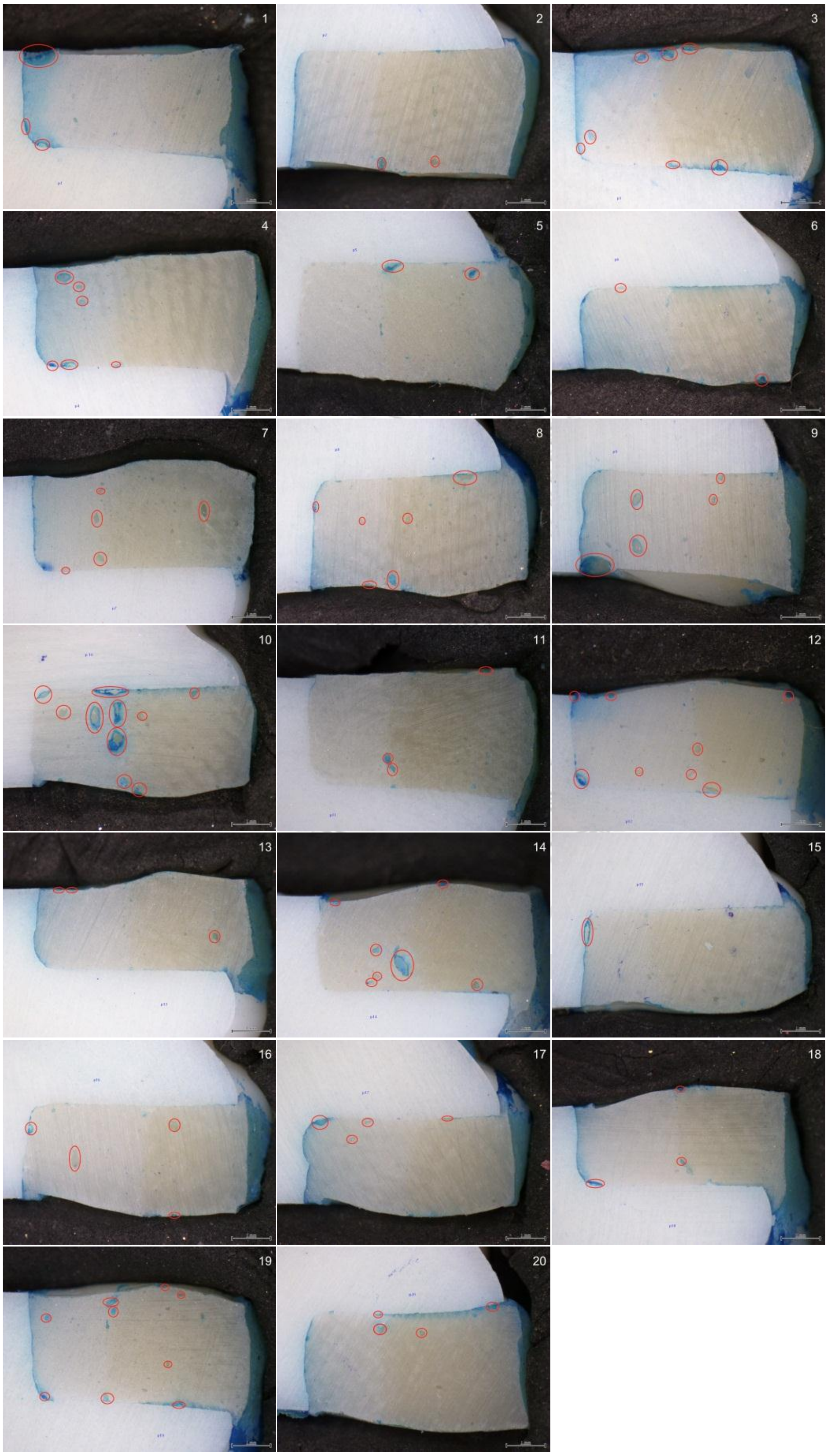
The sections with voids (>150 μm) of Group Filtek™ Bulk Fill (syringe) in small cavity



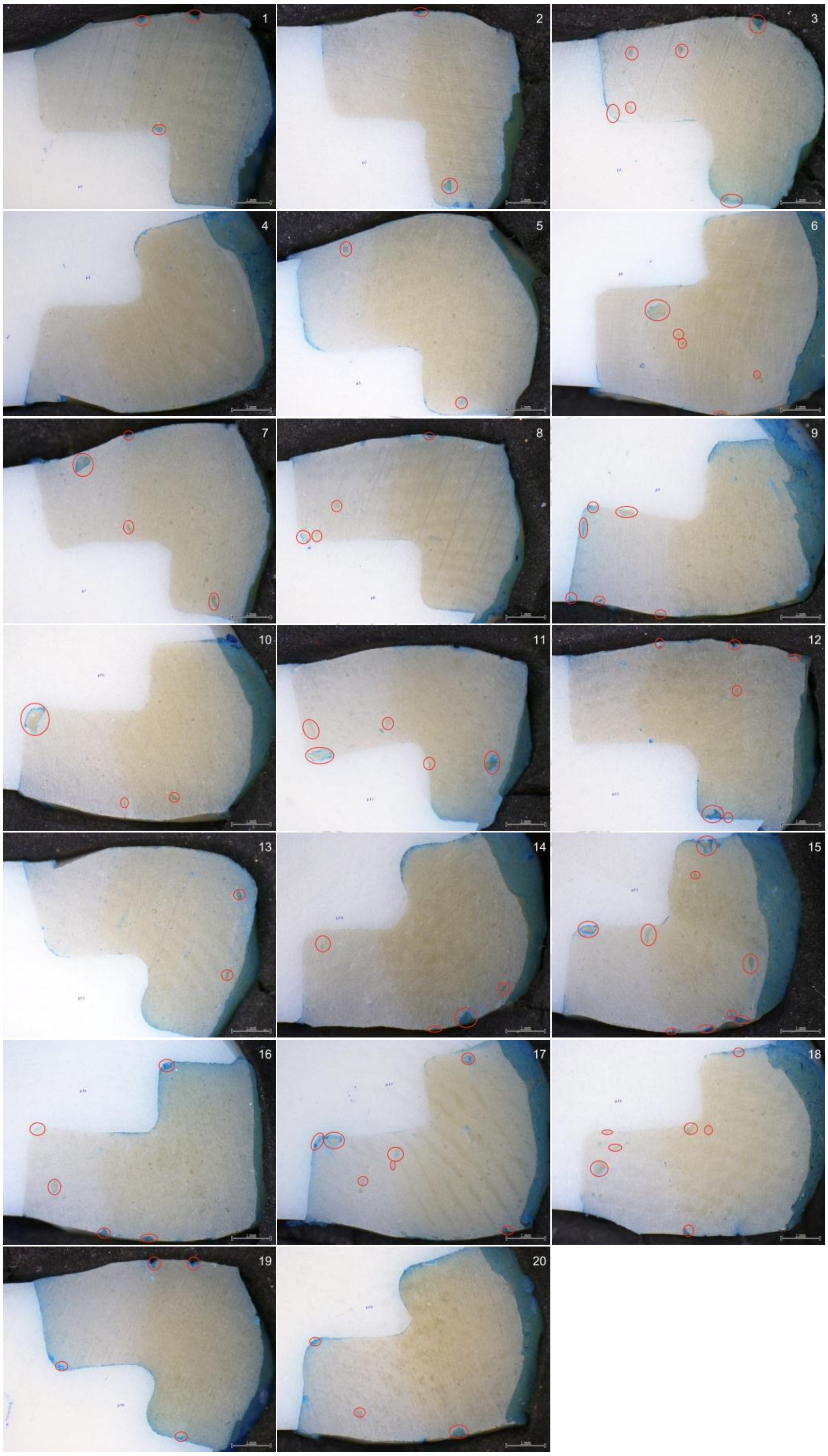
The sections with voids (>150 μm) of Group Filtek™ Bulk Fill (syringe) in large cavity



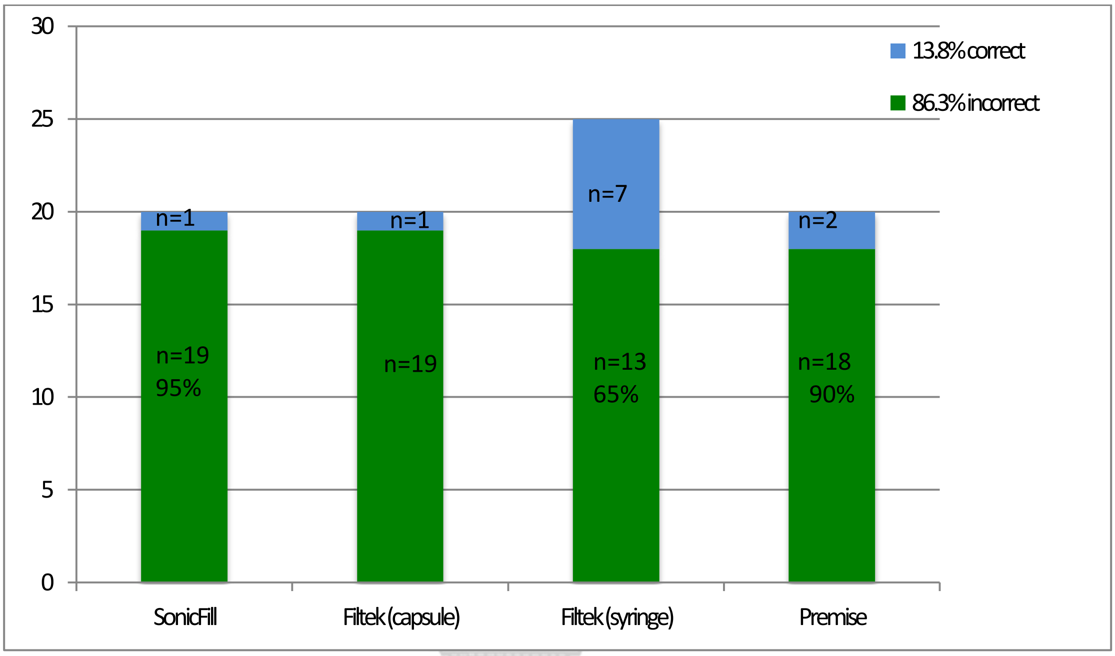
The sections with voids (150 μm) of Group Premise™ in small cavity



The sections with voids (150 μm) of Group Premise™ in large cavity

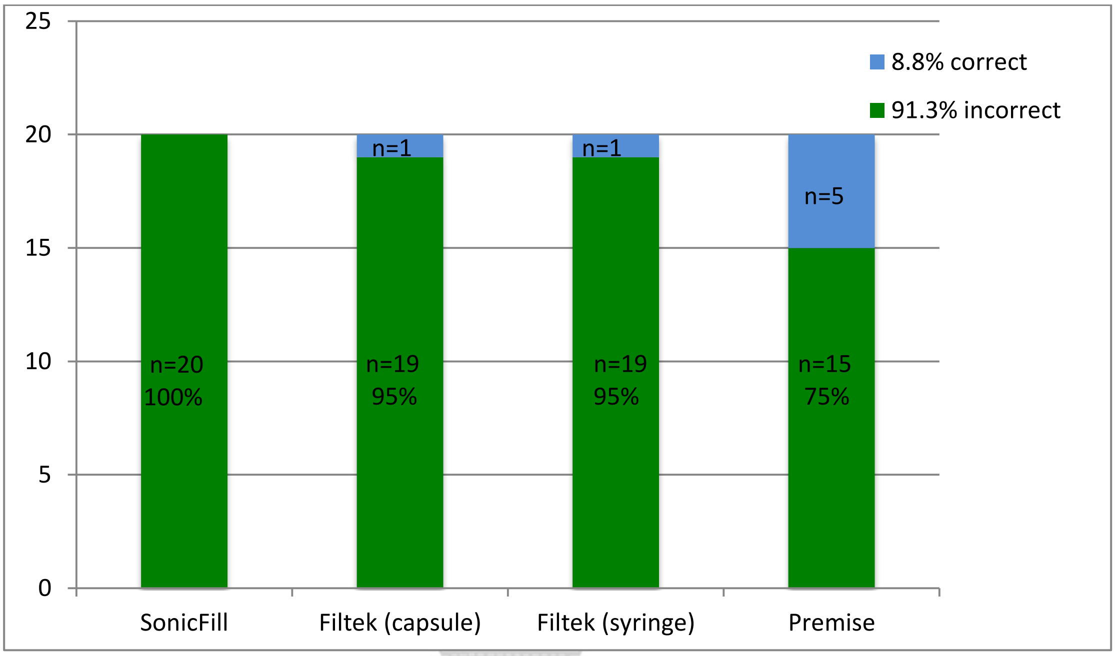


Bar Chart 1 The number and percentage of the first increment that is thicker than the recommended thickness of small cavity



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

Bar Chart 2 The number and percentage of the first increment that is thicker than the recommended thickness of large cavity



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

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

VITA

My name is Saiisara Chaidarun. I was born on December 8,1987. I graduated with a bachelor's degree in Doctor of Dental Surgery (D.D.S.) from Faculty of Dentistry, Chiangmai University in 2012. Now, I am a master degree's student in Esthetic Restorative and Implant Dentistry (International Program) at Faculty of Dentistry, Chulalongkorn University. I have got a certification in Advanced Implantology of Preceptorship Program from UCLA, Los Angeles School of Dentistry in 2015.