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Micro-Computed Tomography Assesment of Structural Microporosity and Marginal Gaps in Different Flowable Composites Placed with Different Instruments

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ABSTRACT

Objectives: *The aim of this study was to evaluate the structural microporosity (MP) and marginal gap (MG) of different flowable composite resins placed with different instruments using micro-computed tomography (µCT).*
Materials and Methods: *Standard Class II MOD cavities were prepared on 108 lower third molar teeth. Three different flowable composite resins; Filtek Bulk-fill, SDR Bulk-fill and I-Flow conventional flowable composite resins were applied to the cavities using a sharp explorer, a microbrush or an injector. After they were covered with a paste-like nanohybrid composite resin, µCT images were examined in terms of MP and MG. Statistical analysis of the data was performed using two-way ANOVA and Tukey's post hoc tests.*
Results*: MP was observed less in explorer group than microbrush and injector groups (p<0.05). There was no significant difference between microbrush and injector groups (p>0.05). i-FLOW flowable composite resin showed the highest MP rate compared to the other two groups (p<0.05). There was no significant difference between SDR and Filtek Bulk-fill in MP (p > 0.05). In terms of MG, i-FLOW presented higher MG values than other two materials (p<0.05), while the instruments showed similar results (p>0.05).*
Conclusions: *Additional occluso-gingivally vibration of flowable materials with an explorer may be useful for placement. Bulk-fill flowable composite resins exhibited better MP and MG than conventional flowable composite resin used in this study.*

Keywords: *Flowable composite resins, Bulk-fill, µCT, Microporosity, Marginal gap.*

Farklı Aletlerle Yerleştirilmiş Farklı Akışkan Kompozitlerde Yapısal Mikropörözite ve Marjinal Gaplerin Mikro Bilgisayarlı Tomografi Değerlendirmesi

Süreç

Geliş: 10/05/2022
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ÖZ

Amaç: *Bu çalışmanın amacı, mikro bilgisayarlı tomografi (µCT) kullanarak farklı aletlerle yerleştirilen farklı akışkan kompozit rezinlerin yapısal mikro pörözite (MP) ve marjinal gap oluşumunu (MG) değerlendirmektir.*
Gereç ve Yöntemler: *Bu çalışmada 108 adet alt üçüncü molar dişe standart Sınıf II MOD kaviteler hazırlandı. Üç farklı akışkan kompozit rezin (Filtek Bulk-fill, SDR Bulk-fill ve I-Flow konvansiyonel akışkan kompozit), kavitelere keskin bir sond, bir mikrofırça veya bir enjektör kullanılarak uygulandı. Akışkan kompozit yüzeyleri pasta tipi bir nanohibrit kompozit ile kapatıldıktan sonra µCT görüntüleri MP ve MG açısından incelendi. Verilerin istatistiksel analizi, iki yönlü ANOVA ve Tukey's post hoc testleri kullanılarak yapıldı.*
Bulgular: *MP, sond grubunda mikrofırça ve enjektör gruplarına göre daha az gözlendi (p<0,05). Mikrofırça ve enjektör grupları arasında anlamlı fark yoktu (p>0,05). i-FLOW akışkan kompozit, diğer iki gruba kıyasla en yüksek MP oranını gösterdi (p<0,05). MP'de SDR ve Filtek Bulk-fill arasında anlamlı bir fark yoktu (p>0,05). MG açısından, i-FLOW diğer iki materyalden daha yüksek MG değerleri sunarken (p<0,05), uygulama aletleri açısından anlamlı fark gözlenmedi (p>0,05).*
Sonuçlar: *Akışkan materyallerin bir sond ile ilave oklüzo-gingival vibrasyonla uygulanması faydalı olabilir. Bulk-fill kompozit rezinler, MP ve MG açısından geleneksel akıcı kompozit rezinden daha iyidir.*

Anahtar Kelimeler: *Akışkan kompozit rezinler, Bulk-fill, µCT, Mikropörözite, Marjinal gap.*

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Introduction

Flowable composite resins are often preferred as a base material under paste-like resin composite restorations. These materials have advantages such as low thermal permeability, compatible elastic modulus with dental tissues and easy penetration to anatomical details.[1]

Flowable composites are presented in an injector on the market. Clinicians apply directly to the cavity with the help of this injector or they apply additional fitting with the instruments such as explorer or microbrush. Flowable composites are known to be less viscous due to their low filler content, and microporosities (MP) or microgaps (MG) may remain in body structure and marginal areas during placement.[2] MP and MG occured in the composite resin structure lead to weakening of the physical and mechanical properties of the restoration.[1]

MP and MG formation may mostly be occurred by increased thickness and amount of applied material.[3] In addition, flowable composite resins may present higher amount of MP and MG in larger cavities such as Class II.[4] The formation of MG disrupts the compatibility of the material with the cavity walls that may cause microleakage and secondary caries, especially in areas difficult to reach such as gingival wall.[4]

Bulk-fill composite resins, which have been introduced to the market in recent years, can be applied in 4-6 mm thickness.[5] Some modifications in translucency, photoinitiator, the filler content and/or the organic matrix have been made to increase the curing depth in bulk-fill composites. Bulk-fill composite resins are more rigid with higher elastic modulus and more plastic (show higher plastic deformation and creep values) when compared to regular flowable composite resins. They also generally show lower mechanical properties than conventional composite resins.[6] Bulk-fill composite resins can be classified as high-viscosity and low-viscosity bulk-fill composites.[7] Low-viscosity bulk-fill composites may more likely expected that they show relatively higher rate of MP and MG due to higher thickness of material applied.

Defining MP and MG properties of materials can provide the dentist to make objective selection and can thus help in the difficult task of choosing between numerous materials and material brands. In the literature there is not sufficient study on MG and MP properties of flowable composite resins especially on bulk-fill composite resins. The aim of this study is to investigate the MP and MG formation of two different bulk-fill flowable composite resins and a conventional flowable composite resin placed with three different instruments using µCT. In the present study, the null hypothesis were as follows:

1) µCT would be an effective tool for the evaluation of MG and MP formation.
2) The use of a sharp explorer would reduce MP and MG formation.
3) Different flowable materials would present different level of MP and MG.

Materials and Methods

This study protocol was approved by Erciyes University Clinical Research Ethics Committee with the protocol number 96681246-2017/115.

Cavity preparations and adhesiveprocedures

In this study, 108 lower third molar teeth were used which were stored in 0.1% thymol solution until use. Standard MOD cavities (4 mm bucco-lingual width and 4 mm depth for the occlusal cavity, 4 mm bucco-lingual width and 6 mm depth for the proximal cavity) were prepared using a cylindrical diamond bur (959 KR 018; Komet Dental, Lemgo, Germany).

After cavity preparation, the teeth were washed with air/water spray and dried. After applying the Supermat Matrix System (Hawe Neos Dental, Gentilino, Switzerland) to the teeth, Clearfil Tri-S Bond (Kuraray Medical Inc, Kurashiki, Japan) which is a one-step self-etch adhesive was applied by rubbing with a disposable microbrush to the entire cavity walls for 10 sec. It was dried by blowing mild air for 5 sec and light cured by a LED light device (Valo, 1000 mW/ cm^2, Ultradent Products Inc, South Jordan, USA) for 10 sec. All restorative procedures were performed by an experienced operator.

Creating of the groups

Materials, manufacturers and compositions used in the study were showed in Table 1.

Table 1. Materials, manufacturers and compositions used in the study

Material	Manufacturer	Composition
Clearfil Tri-S Bond Plus Lot#000004	Kuraray Medical Inc., Okayama, Japan	MDP, Bis-GMA, HEMA, Colloidal silica, Ethanol, Water, Qamforokinon, Initiators, accelerators
Filtek Z550 Lot#N617603	3 M ESPE, St. Paul, MN, USA	Silanized ceramic, Bisphenol A polyethylene glycol, Dietherdimetacrylate, Bis-GMA, Silanized silica, UDMA
Filtek Bulk Fill Flowable Lot#N666493	3 M ESPE, St. Paul, MN, USA	Bis-GMA, UDMA, Bis-EMA, Procrylate resins, zirconia / silica filler, ytterbium trifluoride filler
Surefil SDR Flow Lot#09301	Dentsply Caulk, Milford, USA	Polymerization regulators, Dimethacrylate resins, Modified UDMA, TEGDMA, Ba-B-F-Al silicate glass, SiO_2, Amorphous Sr-Al silicate glass, TiO_2
i-Flow Lot#151208	i-Dental, Medicinos Linja, UAB, Lithuania	Bis-GMA, UDMA, TEGDMA, Bis-EMA and barium borosilicate glass fillers

Abbreviations: Bis-GMA, Bis-phenol A diglycidyl methacrylate; HEMA, 2-hydroxyethyl methacrylate; MDP, 10-methacryloxydexyl dihydrogen phosphate; UDMA, Urethane Dimethacrylate; Bis-EMA, Ethoxylated Bisphenol A dimethacrylate; TEGDMA, Polyethylene glycodimetacrylate.

The samples were divided into three main groups according to the instrument used (explorer, microbrush, and injector) and then subdivided into three subgroups according to the materials used i-FLOW (i-dental, Medicinos Linja UAB, Lithuania), Filtek Bulk-Fill Flowable (3M ESPE, St. Paul, MN, USA), and Surefil SDR Bulk-fill (Dentsply, Caulk, Milford, USA).

Restorative procedures

Injector group: The tip of the injector was contacted with the cavity floor and injected with a slight movement horizontally and occluso-gingivally for 3-4 sec.

Explorer group: Following injector application, additional occluso-gingivally movement was applied for 3-4 sec with a sharp explorer (Hu-Friedy, Chicago, IL, USA).

Microbrush group: The same motion as in the explorer method was repeated with a microbrush.

The total thickness of each layer did not exceed 2 mm in i-FLOW group. In the SDR and Filtek Bulk-fill groups, the cavities were filled up with bulk-fill composite to 4 mm and the top layer (2mm) of the cavities were left for the conventional paste-like resin composite. Flowable composite resins were polymerized with the same LED light device for 20 sec. Then it was covered with a nanohybrid resin composite (Filtek Z550, 3M ESPE, St Paul, MN, USA) and polymerized with LED light device for 20 sec.

Finishing and polishing procedures were completed under water cooling using yellow belt diamond burs and polishing discs (SofLex PopOn, 3M ESPE, St. Paul, USA).

µCT evaluation

A high-resolution micro-CT (Skyscan 1272, Bruker CCT, Kontich, Belgium) was used to evaluate the MP and MG of the samples. A 4 mm part of each restorations were scanned to evaluate MP and MG. A total of 900 micro-CT images were taken from each restoration. Display settings were set to acceleration voltage: 80kV, beam flow: 125 µA, Al filter: 1mm, resolution: 4 µm, rotation: 360°, and step: 0.400°. Images were analyzed for 3D reconstruction using an image analysis software (Mimics software, version 18, Materialize, Leuven, Belgium). The region of interest for each image was manually selected for 3D space calculation.

Statistical Analysis

The normality of data was tested using Kolmogorov-Smirnov test and it was decided to use parametric tests. The data were analyzed using a two-way ANOVA and Tukey's post-hoc tests using a statistical program (SPSS 20.0, SPSS Inc., Chicago, IL, USA) ($\alpha = 0.05$).

Results

The mean MP and MG percentage (%), standard deviations and statistical differences of the groups are given in Table 2. Also, some µCT images ofmicroporosity and microgaps from the groups arepresented in Figure 1-3.

Table 2. Mean, standard deviation, statistical differences of microporosity and microgap values.

		Microporosity (%)				Microgap (%)			
	Groups and Subgroups	**Statistical differences**	**P values**	**Mean**	**Standard Deviation**	**Statistical differences**	**P values**	**Mean**	**Standard Deviation**
nstruments	Explorer	a		0.16	0.09	a		0.35	0.19
	Microbrush	b	0.034	0.26	0.13	a	0.68	0.35	0.22
	Injector	b		0.28	0.17	a		0.27	0.24
Materials	İ-Flow Flowable	X		0.38	0.14	X		0.42	0.19
	SDR Bulkfill	Y	0.029	0.12	0.11	Y	0.041	0.27	0.14
	Filtek Bulkfill	Y		0.18	0.08	Y		0.29	0.11
Subgroups	İ-flow + Injector	D		0.53	0.13	C,D		0.46	0.22
	İ-flow + microbrush	B,C		0.37	0.13	C,D		0.41	0.19
	İ-flow + explorer	A,B		0.24	0.07	C,D		0.39	0.25
	SDR + Injector	A		0.05	0.02	A		0.15	0.11
	SDR + microbrush	A,B	0.00	0.26	0.09	C,D	0.001	0.36	0.15
	SDR + explorer	A		0.06	0.03	B,C		0.29	0.13
	Filtek + Injector	A,B		0.25	0.09	A,B		0.21	0.14
	Filtek + microbrush	A		0.15	0.06	B,C		0.29	0.19
	Filtek + explorer	A		0.15	0.07	C,D		0.38	0.29

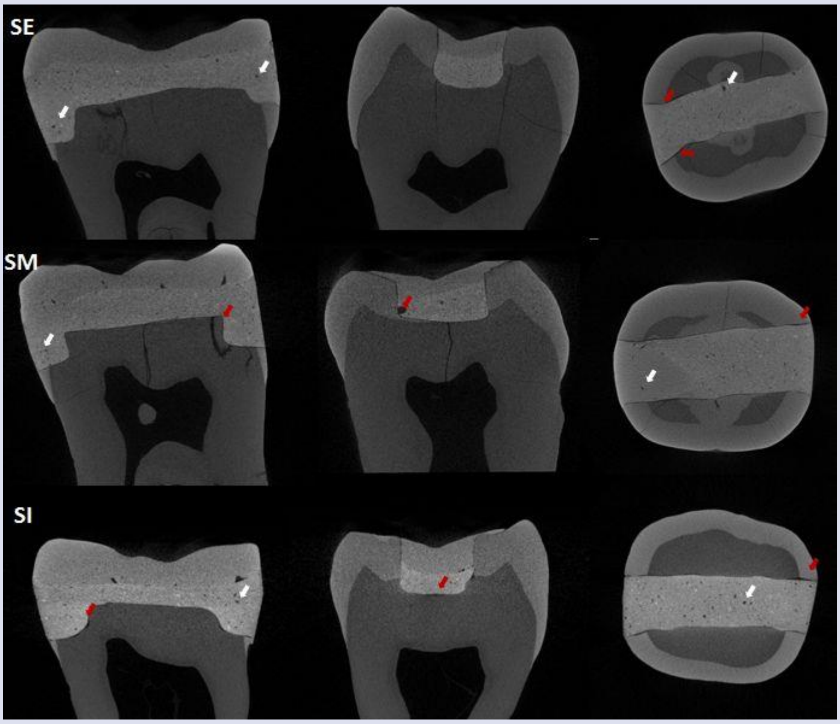

Figure 1. µCT images of microporosity and microgaps from SDR Bulk-fill group. SE, SDR + Explorer; SM, SDR + Microbrush; SI, SDR + Injector.

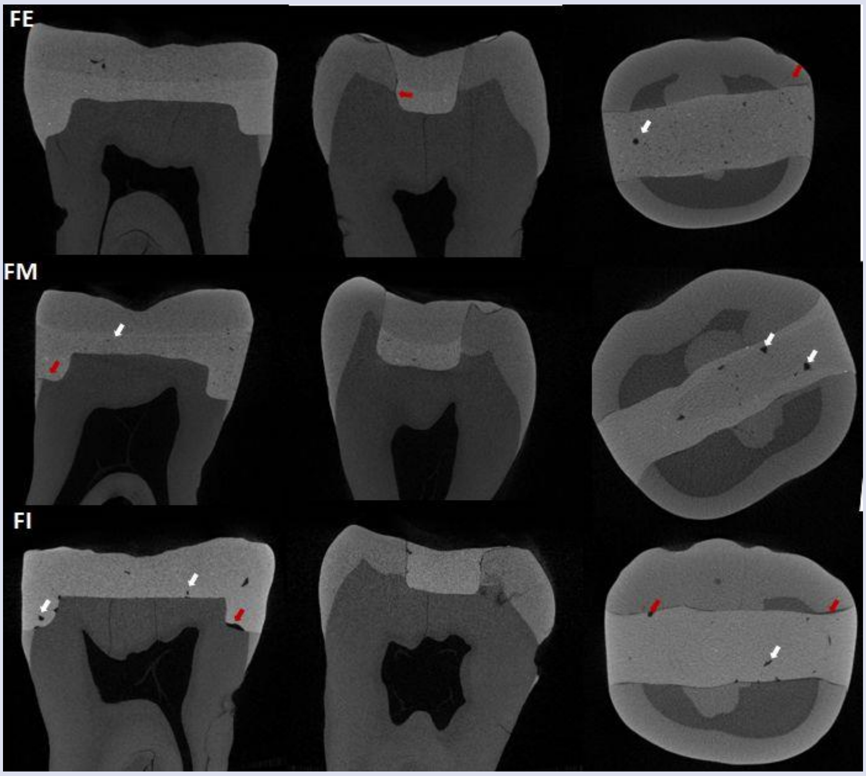

Figure 2. µCT images of microporosity and microgaps from Filtek Bulk-fill group. FE, Filtek Bulk-fill + Explorer; FM, Filtek Bulk-fill + Microbrush; FI, Filtek Bulk-fill + Injector.

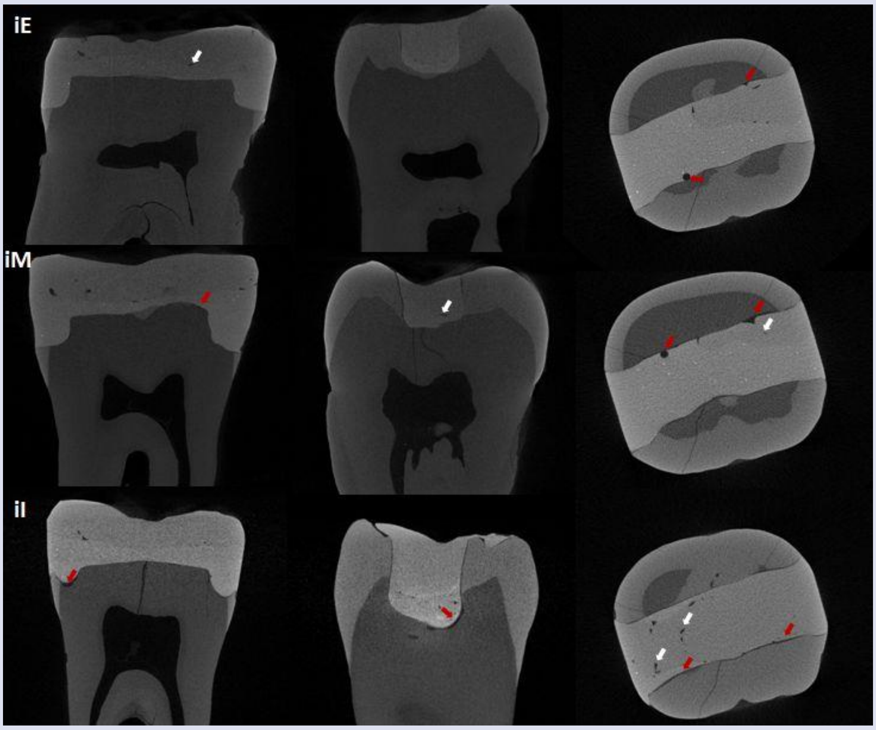

Figure 3. µCT images of microporosity and microgaps from i-FLOW group. iE, i-FLOW + Explorer; iM, i-FLOW + Microbrush; iI, i-FLOW + Injector.

Microporosity assesment

The mean MP formation in flowable composite resins placed with the help of an explorer (0.16±0.09%) was significantly less than the injector (0.28±0.17%) and microbrush (0.26±0.13%) ($p<0.05$). However, no significant difference was found between injector and microbrush group ($p>0.05$).

When compared to the used materials in terms of MP formation, SDR Bulk-fill (0.12±0.11%) and Filtek Bulk-fill (0.18±0.08%) were found to be similar (p>0.05) while i-FLOW (0.38±0.14%) showed significantly higher MP ($p<0.05$).

In SDR group, the lowest MP values were obtained regardless of the method applied and there was no statistical difference between the methods ($p>0.05$). Filtek Bulk-fill composite resin was found to be more successful in terms of MP with the application of explorer and microbrush than the injector method, but there was no statistical difference between these three groups ($p>0.05$).

i-FLOW flowable composite resin presented significantly higher MP values in injector applications than the explorer and microbrush ($p<0.05$). The explorer method was found to be the best, followed by the microbrush method, and there was no statistical significant difference between the explorer and microbrush groups ($p>0.05$).

Microgap assesment

All instruments showed similar results in terms of MG ($p>0.05$).

When compared the used materials, i-FLOW presented the highest MG values (0.42±0.19%) ($p<0.05$). SDR (0.29±0.14%) and Filtek Bulk-fill composite resins (0.27±0.11%) presented similar MG values ($p>0.05$).

When all composite resins were separately evaluated in terms of instrument used, different instruments did not change the MG values ($p>0.05$).

Discussion

Tooth-colored composite resin materials are frequently preferred by both patients and clinicians in the restoration of posterior teeth as in anterior teeth. Packable composite resins are used in the posterior region due to their good physical and mechanical strength against chewing forces.[8,9] On the other hand, flowable composite resins are recommended as liners under posterior composite resins due to their low viscosity, increased elasticity and wettability.[10] It is thought that the use of low-viscosity flowable composite resins together with the posterior composites will allow restorations with better marginal adaptation and less microleakage, since flowable composite resins better fill the irregular inner surfaces of the cavity.[11,12] Flowable composite resins are also used as liners since they can act as a flexible intermediate layer that helps relieve stresses during polymerization shrinkage of the restorative material.[13] For this reason, this study focused on the use of flowable composites as a liner under conventional composite resin.

During placement of the composite resins, MP and MG may be caused by the iatrogenic factors, as well as microstructure and chemical structure of the materials.

MP and MG can affect the durability of the material, discoloration, microleakage, wear, and polishing properties[14], and consequently can negatively affectthe longevity of the restoration.[15] The chemical structure and geometric shape of the instruments used during the placement of the material may also affect the formation of MP and MG.[16] Since the probability of MP and MG is higher in the flowable materials[2], the MP and MG of three different flowable composites placed using three different instruments were examined in this study.

This study was performed using a micro-CT which is an important device in the analysis of polymerization shrinkage, gap formation, marginalintegrity.[17,18] Micro-CT is also a non-invasive method because it provides highly sensitive and quantitative results and allows the analysis of the samples without causing any stress, distortion, crack or any damage.[19] In this study, the µCT method clearly revealed the difference between the measured materials and provided measurable quantitative values. Therefore, the first hypothesis of the study was accepted.

In the present study, all materials presented MP and MG formation. However, according to the results of the study the use of an explorer reduced the formation of MP, but did not change MG. Therefore, the second hypothesis of the study was partially accepted. This effect of explorer on MP may be caused by sharp geometry of the tip and rigid structure of instrument. The vibrations that occur during back and forth movements of the explorer may activate the molecules to move that consequently eliminating the voids.

The injector and microbrush did not show the same effect as the explorer. The geometry of the tip of the injector may not be thin sufficiently and has a lumen which may cause air bubbles during movement. And microbrush has a non-metallic soft bristle structure trapping material or air into it consequently creating of new bubbles during movement.

In the study, SDR and Filtek Bulk-fill composite resins were presented less MP compared to i-FLOW. Therefore the third hypotheses of the study was also accepted. Undoubtedly, the chemical structure of the three flowable resin materials used in study is not the same totally that may affect to formation of MP and MG. The thickness of the resin placed to cavity may also affect the formation of MP and MG. However, i-FLOW was placed up to 2 mm of layers because it is a conventional flowable composite resin while the other two bulk-fill composite resins were applied as 4 mm monolayer. i-FLOW offered higher MP and MG, while it was expected that it would offer less MP and MG because of its lower thickness of each layer placed than bulk-fill resins. This may be related to the fact that bulk-fill composite resins have different chemical structure (fillers, organic monomer matrix, etc.) compared to conventional composite resins. In addition, the polymerization shrinkage may affect the MP and MG formation. The fact that bulk-fill composites showed less MP and MG in our study may be a result of the bulk-fill composite resins showing less polymerization shrinkage, as stated in a meta-analysis by Cidreira Boaro *et al.*[20]

The MG values of the different instruments used in this study was similar. This may be caused by surface tension of the adhesive agent applied to the cavity before the composite resin placement as well as intermolecular attraction force between the adhesive and composite resins that may compensate the difference between the instruments. In present study, it was found that both bulk-fill resins offered less MG than conventional flowable resin. Similarly, Kapoor *et al.*[21] found better adaptation and less cavity formation in the pulpal wall when bulk-fill resins were used compared to conventional composite resins.

In a study by Hirata *et al.* [3], when sonic application was performed, they found that bulk-fill composite resins showed more void formation compared to conventional composite resin and they reported that SDR flowable resin should not be used with sonic application. They attributed this to the changes in the rheological structure of the material caused by sonic application that increases the flow of material offered by the manufacturer. They also argued that the small voids already present in the material structure become larger voids with the sonic effect. However, in the present study, sonic application was not applied. This difference between the results of this study and our study may be caused by the differences in the method.

In this study, MOD cavities were prepared in molar teeth. It should not be underestimated that different materials and different cavities with smaller c-factor may present different MP and MG values. In addition, in the present study, a bonding agent was applied to the cavity before the restorative procedures in order to mimic the clinical conditions. It is not clear whether this bonding application changes the MP and MG values. Further studies involving different size of cavities, methods or materials are needed.

Conclusions

Within the limitation of this study, it can be concluded;

1. µCT is an effective tool for the evaluation of MG and MP formation.
2. Additional occluso-gingivally vibration of flowable materials with an explorer may be useful in the placement.

Bulk-fill flowable composite resins exhibited better MP and MG than conventional flowable composite resin used in this study.

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Conflicts of Interest

The authors of the present study declare no conflict of interest.

References

1. Ilie N, Bucuta S, Draenert M. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Oper Dent 2013; 38(6):618-625.

2. Nazari A, Sadr A, Shimada Y, Tagami J, Sumi Y. 3D assessment of void and gap formation in flowable resin composites using optical coherence tomography. J Adhes Dent 2013; 15(3):237-243.

3. Hirata R, Pacheco RR, Caceres E, Janal MN, Romero MF, Giannini M, Coelho PG, Rueggeberg FA. Effect of Sonic Resin Composite Delivery on Void Formation Assessed by Micro-computed Tomography. Oper Dent 2018; 43(2):144-150.

4. Nahedh HA, Sibai NS. Evaluation of Interfacial Gap Volume of Two Low-shrinkage Composites Using Micro-Computed Tomography. Oper Dent 2017; 42(6):658-668.

5. Ilie N, Hickel R. Investigations on a methacrylate-based flowable composite based on the SDR™ technology. Dent Mater 2011; 27(4):348-355.

6. Ilie N, Bucuta S, Draenert M. Bulk-fill resin-based composites: an in vitro assessment of their mechanical performance. Oper Dent. 2013 Nov-Dec;38(6):618-625.

7. Chesterman J, Jowett A, Gallacher A, Nixon P. Bulk-fill resin-based composite restorative materials: a review. Br Dent J. 2017 Mar 10;222(5):337-344.).

8. Leevailoj C, Cochran MA, Matis BA, Moore BK, Platt JA. Microleakage of posterior packable resin composites with and without flowable liners. Oper Dent 2001; 26(3):302-307.

9. Tredwin CJ, Stokes A, Moles DR. Influence of flowable liner and margin location on microleakage of conventional and packable class II resin composites. Oper Dent 2005; 30(1):32-38.

10. Attar N, Tam LE, McComb D. Flow, strength, stiffness and radiopacity of flowable resin composites. J Can Dent Assoc 2003; 69:516-521.

11. Neme AM, Maxson BB, Pink FE, Aksu MN. Microleakage of Class II packable resin composites lined with flowables: an in vitro study Oper Dent 2002; 27:600-605.

12. Korkmaz Y, Ozel E, Attar N. Effect of flowable composite lining on microleakage and internal voids in Class II composite restorations. J Adhes Dent 2007; 9(2):189-194.

13. (Kemp-Scholte CM & Davidson CL. Complete marginal seal of Class V resin composite restorations effected by increased flexibility. J Dent Res 1990; 69(6):1240-1243.

14. Hickel R, Manhart J. Longevity of restorations in posterior teeth and reasons for failure. J Adhes Dent 2001; 3(1):45-64.

15. Peutzfeldt A, Asmussen E. Determinants of in vitro gap formation of resin composites. J Dent 2004; 32(2):109-115.

16. Balthazard R, Jager S, Ferry O, Dahoun A, Mortier E. Porosity of flowable resin composites is not influenced by applicator tip diameter. Am J Dent 2017; 30(3):125-130.

17. Algamaiah H, Sampaio CS, Rigo LC, Janal MN, Giannini M, Bonfante EA, Coelho PG, Reis AF, Hirata R. Microcomputed Tomography Evaluation of Volumetric Shrinkage of Bulk-Fill Composites in Class II Cavities. J Esthet Restor Dent 2017; 29(2):118-127.

18. Carrera CA, Lan C, Escobar-Sanabria D, Li Y, Rudney J, Aparicio C, Fok A. The use of micro-CT with image segmentation to quantify leakage in dental restorations. Dent Mater 2015; 31(4):382-390.

19. Almeida LJDS Junior, Penha KJS, Souza AF, Lula ECO, Magalhães FC, Lima DM, Firoozmand LM. Is there correlation between polymerization shrinkage, gap formation, and void in bulk fill composites? A μCT study. Braz Oral Res. 2017; 31:e100.

20. Cidreira Boaro LC, Pereira Lopes D, de Souza ASC, Lie Nakano E, Ayala Perez MD, Pfeifer CS, Gonçalves F. Clinical performance and chemical-physical properties of bulk fill composites resin -a systematic review and meta-analysis. Dent Mater 2019; 35(10):e249-e264.

21. Kapoor N, Bahuguna N, Anand S. Influence of composite insertion technique on gap formation. J Conserv Dent 2016; 19(1):77-81.