Original Article

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A micro-computed tomography study of internal gap with and without resin-modified glass-ionomer cement liner under occlusal resin composite restoration

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Objective: The aim of this *in vitro* study was to compare internal gaps between dentin and resin composite restorations with and without lining with resin-modified glass-ionomer cement (RMGIC) by micro-computed tomography (micro-CT).

Materials and methods: Twenty extracted human upper premolars without cracks, restoratives, or caries were collected and occlusal cavity was prepared on each tooth. Specimens were randomly divided into two groups (n=10). In Group G, specimens were lined with RMGIC (Vitrebond™ Light Cure Glass Ionomer Liner/Base, 3M ESPE, USA) for 0.5 mm and filled with the resin composite (A1, Filtek™ Z350 XT Universal Restorative, 3M ESPE, USA). In Group C, specimens were only filled with the resin composite (A1, Filtek™ Z350 XT Universal Restorative, 3M ESPE, USA). All two groups using Adper Single Bond 2 adhesive (3M ESPE, St Paul, MN, USA) before filled with resin composite. Specimens were scanned with micro-computed tomography (micro-CT) and bucco-palatal cut. Three images of each specimen were used to measure the size of internal gaps at bucco-pulpal and palato-pulpal surfaces, and gaps between the two filler materials were measured for group G.

Results: There was no gap formation between D-RMGIC; however, there were internal gaps between RMGIC-RC. In addition, the mean sizes of the internal gap between D-RC and RMGIC-RC were 29.9 ± 14.4 μm and 23.7 ± 11.2 μm, respectively. There was a significant difference in internal gap sizes between D-RMGIC and D-RC and between D-RMGIC and RMGIC-RC. However, the mean sizes of internal gaps between D-RC and RMGIC-RC were not statistically different (p<0.05).

Conclusion: Lining with RMGIC at the pulpal floor of the cavity provided better adaptation than restoration with resin composites. In addition, internal gap appeared between RMGIC liner and resin composite was not significantly different from internal gap between dentin and resin composite.

Key words: dentin bonding, resin-modified glass-ionomer cement, composite restoration, micro-computed tomography, internal gap.

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Introduction

Resin composites are commonly used for both anterior and posterior teeth because of their satisfactory esthetics and sufficient strength for withstanding loading on posterior teeth [1]. The degree of resin composite conversion depends on the transformation of monomers to polymers, termed "polymerization," which is associated with a volumetric shrinkage range of 2 to 5.6% [2]. This shrinkage mostly occurs at the beginning of the polymerization process.

The effects of polymerization shrinkage manifest in many ways. If the dental adhesive endures polymerization shrinkage, the polymerization stress will transfer to the tooth and cause tooth deformity or enamel fracture, cracked cusps, or cusp movement [3, 4]. However, if the adhesive cannot endure the shrinkage, internal gaps, post-operative sensitivity, microleakage, or

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secondary caries can occur [5]. Moreover, polymerization shrinkage can cause microcracks in resin composites before complete setting, but this phenomenon is rare [6].

To manage polymerization stress, resin-modified glass-ionomer cement (RMGIC) was introduced as a liner under resin composite restoration. The liner establishes a reliable gap-free chemical bond to the resin composite, reduces the composite volume, provides a relatively reliable form of adhesion to the dentin with little or no polymerization stress, and acts as a shrinkage stress absorber owing to the lower modulus of elasticity of the glass-ionomer cement with respect to the resin composite [7]. Furthermore, glass-ionomer cement acts as a dental insulator to protect pulp when restoring deep cavities [6].

In contrast, other studies found that the internal gap between the tooth surface and materials lined with RMGIC is larger than that without a liner [8-10]. Peliz *et al.* (2005) reported that lining materials do not have enough bond strength to dentin to resist the polymerization shrinkage of resin composites; therefore, stress developed by polymerization shrinkage causes the cement/detin bonding disruption [9]. However, one study found that there was no statistical difference in size of the internal gap between the tooth surface and materials between composite restorations with or without liners [11]. Therefore, conclusions regarding lining with RMGIC before resin composite restoration remain uncertain.

Confocal laser scanning microscopy and scanning electron microscopy are popular methods for measuring the sizes of internal gaps via 2D imaging after specimen sectioning [8-12]. However, these methods are invasive and thus can damage specimens and lead to cracking of the tooth structure or dislodgement of some materials during machine cutting. Micro-computed tomography (micro-CT), on the other hand, is a non-destructive method that can produce 3D reconstructed images of samples [13]. There have been studies that employed micro-CT to compare the internal adaptation between dentin and materials [13-15]. Micro-CT is advantageous as it yields high-resolution images from small and complex-shaped materials, does not require specimen preparation, and is noninvasive. In dentistry, micro-CT has been used to characterize bone and implant interfaces [16] and internal tooth structures and restorations [13-15]. This technique can be used to examine the internal and marginal gaps of dental restorations [14, 15]; however, a few studies investigated the internal adaptation of lining materials with restoration using micro-CT. Many two-dimensional sections can be obtained using micro-CT images, on which direct measurement can be performed without any additional preparation. Micro-CT technology appears to be a reliable and thus potentially useful tool for evaluating the fit of dental restorations [14, 15].

The aim of this *in vitro* study was to compare internal gaps between dentin and resin composite restorations with and without lining with RMGIC by micro-CT. The null hypothesis was that there was no difference in internal gap size between the two groups of resin composite restoration with and without RMGIC.

Material and Methods

Specimen preparation

The ethic of this study was approved by the Faculty of Dentistry/Faculty of Pharmacy, Mahidol University, Institutional Review Board (MU-DT/PY-IRB) (COE. No. MU-DT/PY-IRB 2016/013.1307). Twenty extracted human upper premolars containing no cracks, restoratives, or caries were collected and disinfected with 0.1% thymol at 4°C for one week. An occlusal cavity (size 3 mm × 3 mm × 3 mm) was prepared on the occlusal surface of all teeth using a high-speed cylindrical carbide bur (56; KG Sorensen, Sao Paulo, Brazil), which was changed every five cavities. The size of the cavity was controlled by a UNC 15 periodontal probe (Hu-Friedy, Chicago, IL, USA). After cavity preparation, all the teeth were inspected and were excluded if pulpal exposure was present.

The specimens were randomly divided into two groups (*n*=10) as follows (Table 1):

Group G (experimental group): RMGIC liner (Vitrebond™ Light Cure Glass Ionomer Liner/Base, 3M ESPE, USA) with resin composite restoration (A1, Filtek™ Z350 XT Universal Restorative, 3M ESPE, USA)

Group C (control group): Resin composite restoration (A1, Filtek™ Z350 XT Universal Restorative, 3M ESPE, USA)

Specimens in group G were lined with 0.5 mm of RMGIC on the pulpal floor using a dental dispensing gun (Campule tip gun, Dentsply Sirona, Konstanz, Germany) with a dental dispensing tip to minimize voids within the liner and to avoid liner attachment to the lateral wall. Specimens were cured with a light-emitting diode curing device (Bluephase G2, Ivoclar Vivadent, Schaan, Liechtenstein) for 20 s.

Cavities were etched with 32% phosphoric acid (Scotchbond™ Universal Etchant – Etching Gel, 3M ESPE, USA) for 15 s followed by gentle rinsing with water for 10 s. After blow-drying using a triple syringe, dental adhesive (Adper Single Bond 2 Adhesive, 3M ESPE, USA) was applied two layers and cured with the light curing device for 20 s. The resin composite was placed using a horizontal incremental technique for a 2 mm thickness, and each incremental layer was cured for 40 s. Specimens in group C were etched, bonded, and restored with resin composite similar to the procedure for group G.

All specimens were stored in distilled water for 24 h at 37 °C in an incubator. After that, they were scanned with a Skyscan micro-CT (Skyscan 1173, Bruker Company, Belgium) with an acceleration voltage of 110 kV, beam current of 72 μA, Al filter sized 1.0 mm, and resolution of 8 μm. The 3D images were cut by three lines through the bucco-palatal cusp using the DataViewer program (version 1.5.4.6, 64-bit). The first line was cut in the center of the tooth, and two other lines were cut 5 mm to the right and left of the first line (Figure 1). The width of internal gaps at the bucco-gingival angle, palato-gingival angle and center of the pulpal floor of each section were measured using the CTAN program (version 1.16.1.0 + (64-bit)) (Figure 2). The internal gaps (μm) were averaged from three sections of each specimen.

Table 1 Materials tested in this study.

Material	Composition*	Manufacturer
Vitrebond™ Light Cure Glass Ionomer Liner/Base	Powder: HEMA, bis-GMA, water, initiators, and a radiopaque fluoroaluminosilicate glass Liquid: resin-modified polyalkenoic acid, HEMA, water, and initiators (including campho+B8rquinone)	3M ESPE, St Paul, MN, USA
Scotchbond™ Universal Etchant (Etching gel)	32% phosphoric acid	3M ESPE, St Paul, MN, USA
Adper Single Bond 2 Adhesive	Bis-GMA, HEMA, dimethacrylates, ethanol, water, a novel photoinitiator system, and a methacrylate functional copolymer of polyacrylic and polyitaconic acids	3M ESPE, St Paul, MN, USA
Filtek™ Z350 XT Universal Restorative	Bis-GMA, UDMA, PEGDMA, bis-EMA(6), and inorganic filler 63.3% (by volume)	3M ESPE, St Paul, MN, USA

**bis-EMA(6): ethoxylated bisphenol A glycol dimethacrylate; bis-GMA: bisphenol A glycol dimethacrylate; HEMA: 2-hydroxyethylmethacrylate; PEG: polyethylene glycol; UDMA: urethane dimethacrylate*

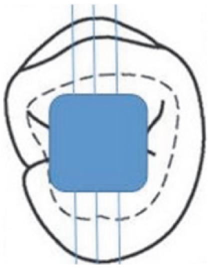

Figure 1 Three-dimensional micro-CT images were cross-sectioned into three lines.

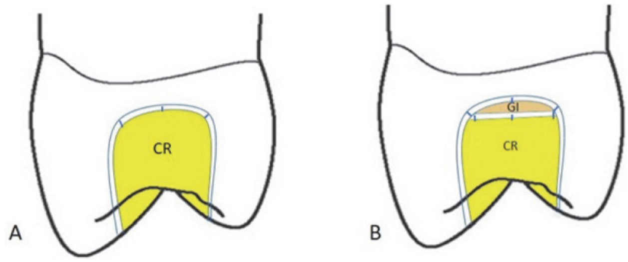

Figure 2 Area of measurements after cross-sectioning of (A) group C and (B) group G. The lines showed the area that measure using micro-CT.

Statistical analysis

Because of the complete absence of dentin-RMGIC (D-RMGIC) internal gaps in all group G specimens, a one-sample *t*-test was used to compare the D-RMGIC internal gaps in group G with the dentin-resin composite (D-RC) internal gaps in group C. For internal gaps between RMGIC and resin composite (RMGIC-RC) in group G, an independent-samples *t*-test was used to compare the mean internal gaps between D-RC and RMGIC-RC. The data were analyzed by SPSS (Statistical Product and Service Solutions) version 16.0

Results

In group G, there was no RMGIC-DC gap formation. However, in group C, the sizes of the RMGIC-RC and D-RC internal gaps were 23.67 ± 11.18 µm (Table 2) and on average 29.85 ± 14.35 µm, respectively.

The one-sample *t*-test results showed that there were statistically significant differences ($p<0.05$) between the D-RMGIC and D-RC internal gap interfaces and between D-RMGIC and RMGIC-RC within the same specimens. In addition, the mean sizes of the D-RC and RMGIC-RC internal gaps were not statistically different ($p<0.05$).

Table 2 Means of the width of internal gaps (mean ± SD) (n=10)

Group	Type	Mean (µm) (± SD)	SE
G	D-RMGIC	0	-
	RMGIC-RC	23.67 (±11.18)	3.54
C	D-RC	29.85 (±14.35)	4.54

The micro-CT scan 3D images demonstrated that group C specimens (Figure 3) had D-RC gaps. In addition, group G specimens (Figure 4) had RMGIC-RC gaps, but no D-RMGIC gaps were observed.

Discussion

This study evaluated gaps between tooth surfaces and materials between specimens with and without the use of a liner. The results showed that there was a statistical difference between the two groups and that the no-liner group had a greater internal gap size than the liner group. Therefore, the null hypothesis of this study was rejected.

A pilot study was performed before this experiment by cross-sectioning specimens using a blade for scanning electron microscopy evaluation. The results indicated large D-RMGIC gaps and cracks within the liner material. This may be attributable to breaking of the D-RMGIC bond or dislodgement of the RMGIC occurring during cutting of the specimen (Figure 5).

Therefore, this project analyzed internal gaps using micro-CT, which is a non-invasive technique and does not cause damage to the liner material that might lead to misinterpretation of the results. The micro-CT results demonstrated no D-RMGIC interfacial gaps, which differs from other studies that reported larger gap formation between a glass

Figure 3 Two representative of Micro-CT images of resin composite restoration group (group C) (E = enamel, D = dentin, C = resin composite).

Figure 4 Two representative of Micro-CT images of RMGIC liner with resin composite restoration (group G) (E = enamel, D = dentin, C = resin composite, GI = resin-modified glass-ionomer cement).

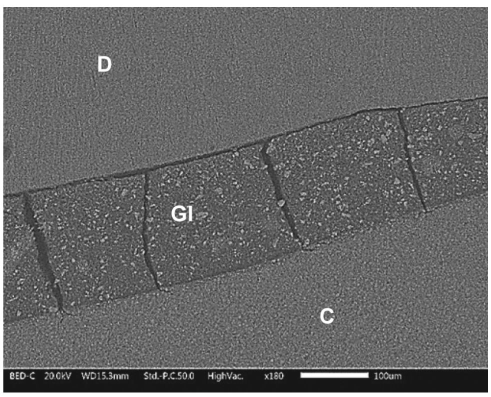

Figure 5 Scanning electron micrograph of gap formation and cracks after sectioning a specimen with a glass-ionomer lining material (GI) and resin composite (C).

ionomer and dentin compared with a resin composite and dentin [8-10, 12]. However, such studies sectioned specimens to evaluate gaps. In addition, this project used dispenser tip gun to apply RMGIC liner at the floor of cavity instead of using a common application that using dycal carrior in order to reduce an error during hand placing RMGIC and decrease voids within the materials. However, the gap between RMGIC and tooth surface in this study may not be the same as the real clinical situation that using hand application with the dycal carrier. Gaps between liner and tooth surface when using hand application depend on the operator skill whether leads to small or large gap.

Internal gaps between the tooth surface and resin composite without liner and gap at resin composite/RMGIC interface can result from polymerization shrinkage of the resin composite or from operator error. Therefore, this result can conclude that the RMGIC not reducing the polymerization shrinkage of the resin composite. Furthermore, the polymerization shrinkage of resin composite did not affect the bonding between RMGIC and dentin.

Although the *in vitro* studies showed a different results in internal gap formation when using RMGIC prior to the resin composite, previous clinical studies [17-19] have demonstrated no statistical difference between liner and no-liner groups in terms of postoperative sensitivity, restoration quality, and pulp complications. Previous studies concluded that the inclusion or omission of a lining with RMGIC led to no differences in clinical results.

Conclusion

Lining with RMGIC at the pulpal floor of the cavity provided better adaptation than restoration with resin composites. Therefore, polymerization shrinkage of resin composite did not cause the disruption of the bond between RMGIC and tooth surface. In addition, internal gap appeared between RMGIC liner and resin composite was not significantly different from internal gap between dentin and resin composite.

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Conflict of interest The authors declared that there is no conflict of interest.
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