Original Article

A Comparison of Remineralizing Effect of Resin-modified Glass Ionomer Cement and Resin-modified Calcium Silicate Cement on Demineralized Dentin

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Abstract

The purpose of this study was to compare the remineralizing ability of resin-modified glass ionomer cement (RMGIC) and resin-modified calcium silicate cement (RMCSC). Twenty-four permanent molars were cut at the middle third of the occlusal surface and prepared to obtain class I cavity. The class I cavity was divided into three areas for the microhardness test; control area, demineralized area and remineralized area. Nail varnish was coated externally, surrounding the tooth surface and 1/3 of the cavity for the control area. The specimens were subjected to a pH-cycling model, and nail varnish coated another 1/3 of the cavity for the demineralized area. All the specimens were divided into two groups (n=12): RMGIC group and RMCSC group. Each cavity was filled with tested material according to the group. All specimens were immersed in deionized water at 37°C for 30 days. All specimens were embedded in acrylic resin and cut mesiodistally into halves. Knoop microhardness test was performed on each tested area at 20, 40, 60, 100, 150 and 200 μm from restoration margin. Three indentations were made for each level, 100 μm apart. The difference of average knoop microhardness value on each area was calculated. The pair *t*-test was used to compare the depth of remineralization of each material. The independent *t*-test was used to compare the remineralization effect between two materials. The significant level was set at $p<0.05$. The result showed that the depth of remineralization between two materials was not different. The change in microhardness value after remineralization of the RMCSC group was lower than the RMGIC group. From the results of this study, RMGIC seems to be more effective in remineralization than RMCSC.

Keywords: Demineralized dentin, Knoop microhardness, Resin-modified calcium silicate cement, Resin-modified glass ionomer cement

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Introduction

Resin-based composite (RBC) has been used as a popular restorative material because it can mimic natural tooth color and adhere to tooth structure using dental adhesive. Secondary caries is one of the most common failures of RBC restoration.[1-3] The setting reaction of RBC is a polymerization reaction causing volumetric shrinkage of the RBC resulting in stress between restoration and tooth cavity. If shrinkage stress overcomes bond strength, a microgap between the cavity wall and the restoration occurs. Cariogenic bacteria can penetrate underneath the restoration and cause secondary caries.[4] Therefore, using a remineralizing cavity liner may be beneficial for demineralized dentin.

Resin-modified glass ionomer cement (RMGIC) has been used as a cavity liner for a long time. This material can adhere to tooth structures via both a chemical bond and micromechanical retention.[5] Fluoride release is an advantage of glass ionomer cement. It is sustainable for a very long period.[6] Fluoride ions can penetrate demineralized tooth structure and substitute the hydroxyl group resulting in fluorapatite which is less soluble and more caries resistant than hydroxyapatite.[7] There are several studies proving that the hardness of demineralized dentin adjacent to RMGIC increased.[8-10]

Recently, a new type of cavity liner is resin-modified calcium silicate cement (RMCSC). This material was launched to the market in 2011.[11] Calcium silicate is a bioactive material, which can induce apatite crystal formation and thus promote remineralization.[12] The prototype of calcium silicate cement is mineral trioxide aggregate (MTA) which is used in endodontic treatment.[13] However, some of the drawbacks of MTA include a long setting time, risk of tooth discoloration, and a difficult handling characteristic.[14] A later generation of calcium silicate is Biodentine™ (Septodont, Saint Maur-des-Fossés, France) which improved to a shorter setting time, handling and mechanical properties compared with MTA.[15] However, Biodentine™ is weak at the initial setting. In the case of RBC as a definite restoration, the placement of RBC must be delayed for at least two weeks in order to wait for the maturation stage of Biodentine™ which can resist the contraction force of RBC.[16-18] To overcome the limitations of hydraulic calcium silicate cement, RMCSC was introduced. This material is able to release calcium ions resulting in remineralization.[19] The aim of this study was to compare the remineralizing ability of RMGIC and RMCSC.

Materials and Methods

The study protocol was approved by the Human Research Ethics Committee of the Faculty of Dentistry, Chulalongkorn University (HREC-DCU 2019-031). Twenty-four sound extracted human molars were used. They were stored in 0.1% thymol solution for no longer than two months before use. The teeth were inspected with a stereo microscope (Stereo microscope SZ 61, Olympus, Japan) at 10x magnification. The exclusion criteria were as follows: teeth with carious lesions, restorations, crack lines or other pathology. Each tooth was cut at the middle third of the crown using a slow speed sectioning machine (Isomet precision saw, Buehler, USA) under water coolant. Class I cavity was prepared with cylindrical diamond burs (Jota, Rüthi/SG, Switzerland) size 1 mm. The cavity was 2 mm in depth, 6 mm in length and 4 mm in width. The dimension of the cavity was checked with a digital vernier caliper (Mitutoyo, Japan). After five cavities, the burs were replaced with new ones. After cavity preparation, teeth were ultra-sonicated in distilled water (Branson5210, BRANSONIC, Germany) for five minutes. The teeth were then inspected with a stereomicroscope (Stereo microscope SZ 61, Olympus, Japan) at 10x magnification to check whether there was any pulpal exposure. The specimen was excluded from experiment if any pulpal exposure was detected.

The cavity was divided into three areas for the microhardness test; control area, demineralized area and remineralized area as shown in Figure 1. To protect the external surface and surrounding wall of cavity and control area, two layers of nail varnish (Revlon, USA) were coated without contact to the demineralized and remineralized areas. After the nail varnish was dry, all specimens were immersed in 10 ml demineralizing solution (2.2 mM $CaCl_2$, 2.2 mM NaH_2PO_4 and 50 mM acetic acid, pH 4.8) for 8 hours and 10 ml remineralizing solution (1.5 mM $CaCl_2$, 0.9 mM NaH_2PO_4 and 0.15 mM KCL, pH 7.0) for 16 hours. This procedure was repeated for 14 cycles at room temperature.[20] Demineralizing and remineralizing solutions were prepared by the Department of Biochemistry, Faculty of Dentistry, Chulalongkorn University.

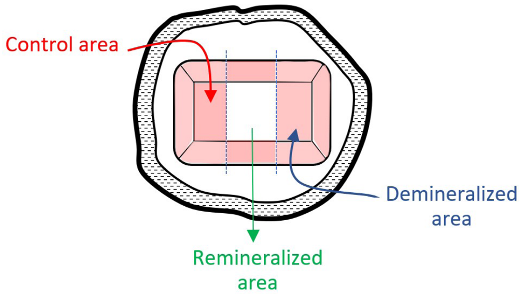

Figure 1 *Diagram of the prepared cavity with three divided area*

After completion of the pH cycling procedure, all specimens were coated with two layers of nail varnish on the demineralized area, and all specimens were randomized into two groups (n=12): Group A, cavities were filled with RMGIC (GC Fuji ll LC® Capsule; GC Corp., Tokyo, Japan) and Group B, cavities were filled with RMCSC (Theracal LC®; Bisco Inc., Schaumburg, IL, USA). The compositions of materials were shown in Table 1. For Group A, the cavities were treated with dentin conditioner for 10 seconds, rinsed with water and gently air dried without desiccation. RMGIC was manipulated according to the manufacturer's instructions, immediately filled the cavities and light cured for 20 seconds using a light curing unit (Elipar TriLight, 3M ESPE, USA). Then the restorations were coated with petroleum jelly. For Group B, the cavities were rinsed with deionized water, a cotton pellet gently absorbed the excess water and material was immediately injected into the cavity by a layering technique. Each layer did not exceed 1 mm. The material was light cured for 20 seconds for each layer. After the filling procedure was done, all specimens were immersed in deionized water at 37 °C for 30 days. Deionized water was renewed every seven days.

Table 1 *Material composition*[21,22]

Materials	Manufacturers	Compositions	Batch numbers
GC Fuji ll LC® Capsule (RMGIC)	GC Corp., Tokyo, Japan	Powder: 100% Fluoro aluminosilicate Liquid: 25% distilled water, 24% polyacrylic acid, 6% tartaric acid, 35% 2-hydroxyethyl methacrylate, 0.10% camphorquinone (by weight)	1901161
Theracal LC® (RMCSC)	Bisco Inc.; Schaumburg, IL, USA	44% Portland cement (type III), 7% fumed silica, 3% barium sulfate, 3% bismuth oxide, 43% resins and initiator (by weight)	1900001041
Dentin conditioner	GC Corp., Tokyo, Japan	77% Distilled water, 20% polyacrylic acid, 3% aluminum chloride hydrate	1812111

All specimens were embedded in acrylic resin using a silicone mold, and sectioned mesio-distally into halves using a slow-speed sectioning machine under water coolant. The cut surfaces were polished with silicon carbide paper #800, 1000 and 1200, respectively using a polishing machine (NANO 2000, Pace Technologies, USA). Knoop microhardness test was determined using a force load 10 g for ten seconds on three areas: control area, demineralized area and remineralized area as shown in Figure 2. Indentations were performed in each specimen at 20, 40, 60, 100, 150 and 200 µm from the restoration margin. Three indentations were made at each level, 100 µm apart, to calculate average Knoop microhardness numbers (KHN) at each level.

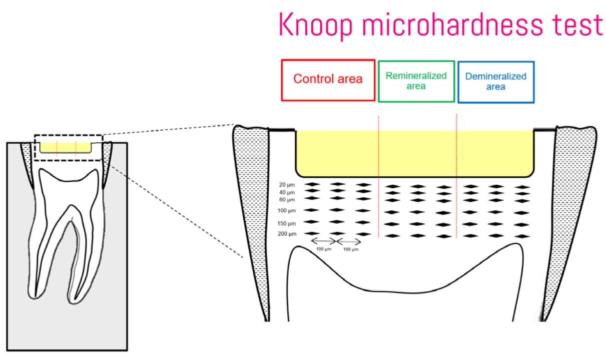

Figure 2 *Area of Knoop microhardness indentation*

Collected data were analyzed using the software SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). Normality of data was examined by the Shapiro-Wilk test and the equality of variances was tested by the Levene's test. The paired *t*-test was used to compare statistically significant differences of average KHN at each level according to the type of materials. To compare the remineralizing ability between materials, the 'differences' of average KHN (ΔKHN) on the remineralized and demineralized areas at each level were calculated and the independent *t*-test was used. The significant level was set at $p<0.05$.

Results

The Shapiro-Wilk test showed data was normally distributed ($p>0.05$). The results are summarized in Tables 2 and 3. Table 2 showed that the average KHN increased along with the increased distances. Table 3 showed that the ΔKHN [Remin-Demin] of the RMGIC group were higher than the RMCSC group at all distances tested. ΔKHN [Remin-Control] and ΔKHN [Demin-Control] in two groups were negative at all distances tested.

Table 2 Mean ± SD of KHN of tested materials at 6 distances from restoration margin

Distance from restoration margin (µm)	RMGIC			RMCSC		
	Control area	Demineralized area	Remineralized area	Control area	Demineralized area	Remineralized area
20	53.63 ± 5.75[a]	11.56 ± 3.37[b]	15.50 ± 3.51[c]	56.04 ± 7.20[a]	10.63 ± 2.31[b]	12.86 ± 2.63[c]
40	56.79 ± 5.14[a]	13.93 ± 4.50[b]	19.42 ± 3.88[c]	57.96 ± 7.00[a]	14.19 ± 3.01[b]	15.14 ± 1.87[c]
60	57.90 ± 6.25[a]	15.97 ± 4.39[b]	22.03 ± 4.29[c]	58.32 ± 6.75[a]	17.31 ± 3.47[b]	18.83 ± 3.78[c]
100	58.64 ± 7.05[a]	24.15 ± 5.02[b]	28.58 ± 5.02[c]	59.92 ± 8.63[a]	31.99 ± 10.46[b]	33.83 ± 11.77[c]
150	59.26 ± 6.91[a]	30.46 ± 4.39[b]	36.40 ± 4.17[c]	60.27 ± 7.97[a]	40.69 ± 10.83[b]	42.45 ± 11.29[b]
200	61.74 ± 7.08[a]	35.82 ± 3.87[b]	43.68 ± 6.38[c]	60.49 ± 7.94[a]	46.00 ± 12.20[b]	49.26 ± 13.83[c]

Within the same row, a different letter indicates statistically significant difference (p<0.05)

Table 3 Mean ± SD of ΔKHN of tested materials at 6 distances from restoration margin

Distance from restoration margin (µm)	Remin – Demin		Remin – Control		Demin - Control	
	RMGIC	RMCSC	RMGIC	RMCSC	RMGIC	RMCSC
20	3.94 ± 2.75[a]	2.23 ± 1.32[a]	-38.14 ± 7.46[a]	-43.19 ± 8.06[a]	-42.07 ± 6.85[a]	-45.41 ± 8.20[a]
40	6.05 ± 3.82[a]	0.94 ± 1.49[b]	-36.81 ± 8.09[a]	-42.83 ± 7.72[a]	-42.86 ± 8.17[a]	-43.77 ± 8.37[a]
60	7.23 ± 5.77[a]	1.52 ± 1.94[b]	-34.86 ± 9.20[a]	-39.49 ± 8.20[a]	-42.09 ± 6.93[a]	-41.01 ± 8.04[a]
100	4.43 ± 3.41[a]	1.83 ± 2.80[a]	-30.06 ± 7.71[a]	-26.09 ± 12.83[a]	-34.49 ± 9.35[a]	-27.93 ± 12.44[a]
150	5.94 ± 4.80[a]	1.76 ± 3.12[b]	-22.85 ± 6.84[a]	-17.82 ± 12.32[a]	-28.80 ± 9.31[a]	-19.58 ± 12.09[b]
200	7.86 ± 5.74[a]	3.26 ± 4.13[b]	-18.06 ± 9.16[a]	-11.23 ± 13.38[a]	-25.92 ± 9.87[a]	-14.49 ± 11.75[b]

Within the same row, different letters indicate statistically significant differences (p<0.05)

Discussion

Various studies have used different methods to evaluate remineralization effects. Microhardness test is commonly used for evaluating remineralization of enamel and dentin. There is a correlation between mineral loss and microhardness value; a microhardness test can detect the mineral change in the enamel or the dentin structure.[23,24]

RMGIC has succeeded in dentin remineralization of demineralized dentin. The present study showed that there was an increase of microhardness value on the remineralized area compared with the demineralized area at every distance from the restoration margin. This finding corresponds to previous studies.[9,25,26] This could be explained by the fluoride releasing materials which promote remineralization and inhibit demineralization.[7] Fluoride is one of the components in the powder of GIC. When polyacrylic acid from a liquid component reacts with glass particles, ions are released. The cations (Ca^{2+}, Al^{3+} ions) form cross-linking polyacrylic salt. Fluoride ions do not react and remain in matrix, subsequently leaching out to the environment.[27] Fluoride ions penetrate the dentin and form fluoridated carbonate apatite, which is less soluble than carbonate apatite.[28] The RMGIC used in this study is a restorative type which is more viscous than the liner type. The flowable consistency of the liner type allows for better adaptation to the cavity.[29] However, the present study intended to compare the remineralizing effect between the two materials, the accurate powder/liquid ratio is a more considerable issue.

RMCSC has been indicated as a light-curable MTA cement.[19] Portland cement type III is an active composition of RMCSC. The material does not contain water; therefore the material must be placed on moist dentin to allow for a hydration reaction. When the material is in a moist environment which contains phosphate ions, the hydration reaction occurs and subsequently releases calcium ions.[19,30,31] The amount of calcium ions in demineralized dentin is less than remineralized dentin when contacted to RMCSC.[32] This proved that RMCSC has a remineralizing effect. The present study showed that the ΔKHN [Remin-Demin] was positive at every distance from the restoration margin. However, the ΔKHN [Remin-Demin] value of the RMCSC group was less than the RMGIC group. This suggested that RMGIC could remineralize the demineralized dentin better than RMCSC. Table 2 showed that there were statistical differences of average KHN of demineralized and remineralized dentin in every distance of both materials except for the RMCSC group at 150 μm, which suggested that the depth of remineralization of both materials was 200 μm or more. The average KHN of control and the demineralized area were statistically significant different at every distance of both materials. This can be assumed that the demineralizing depth reached 200 μm. The present study used a pH cycling model as an artificial dentin caries induction method.[20] The formula of solution and protocol used in the present study followed Marquezan *et al.* The authors proved that microhardness of artificial dentin caries induced by a pH cycling model is close to the microhardness of caries-affected dentin and the depth of demineralization was 200 μm.[20]

Both tested materials have a remineralization ability by ion-releasing method. The factor affecting ion-releasing of materials is the composition of two materials. The RMGIC used in this study comprises of 2-HEMA, which is hydrophilic resin, 35% by weight, whereas RMCSC is composed of resin 43% by weight.[33] However, TheraCal LC is composed of 10-30 % resin matrix, which mainly consists of polyethylene glycol dimethacrylate (PEGDMA), and 30-50 % Portland cement which is a calcium ion releasing component.[34] The high resin matrix content of TheraCal LC may limit the ion penetration to surrounding environment.[31]

According to the results shown in Table 3, both tested materials were not able to remineralize the dentin to the same hardness of the control area in every distance. The present study only compared the remineralizing ability between fluoride and calcium ion-releasing material, however the combined effect of the two materials in remineralization is recommended for future study.

Conclusion

Though there are limitations to this study, RMGIC seems to be more effective in remineralization than RMCSC.

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