Effects of Surface Pre-Treatments on Leakage of Resin-Modified Glass Ionomer Cement as the Restorative Material of Invasive Cervical Resorption on Root Dentin

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Abstract

The objective of this study was to evaluate the effects of different dentin pre-treatments by resin-modified glass ionomer cement (RMGIC) restorative material for an invasive cervical resorption (ICR) on root dentin, by using a glucose leakage method. Fifty-six buccal cavities of root specimens were prepared and treated with different dentin conditioners (Group I-10% polyacrylic acid, 20 s; Group II-90% trichloroacetic acid (TCA), 15 s; Group III-90% TCA, 30 s; and Group IV-untreated control). The cavities were filled with RMGIC and the sections of dentin-RMGIC specimens were prepared. The leakage was measured using the glucose filtration method.

The results showed some statistically significant differences in the mean concentrations of leaked glucose among groups (P=0.000) and some differences in all pairing groups (P=0.000), except for Groups I and IV (P=0.346).

Dentin pre-treatment by 90% TCA associated with RMGIC resulted in a greater amount of glucose leakage than that by 10% polyacrylic acid. When using TCA, the amount of glucose leakage was depended on the treatment duration time. No difference in the glucose leakage test was found with the pre-treatment by 10% polyacrylic acid or by no dentin conditioner.

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Introduction

Invasive cervical resorption (ICR) is one special form of external root resorption which is clinically classified into four classes depending on the amount of coronal dentin and root destruction.[1] By using 90% trichloroacetic acid (TCA) to control resorptive processes prior to curettage or grinding with a dental bur, Heithersay[2] has introduced a treatment protocol of ICR to establish a sound or glistened dentin suitable for restorations. Its success rate could be evaluated by the root resorption control and by the absence of pulpal, periradicular, and periodontal pathoses.

Various restorative materials have been suggested for some ICR restorations.[3-5] Glass ionomer cement (GIC) is one of the reasonable materials for the restorations of cervical or root dentin defects, because of its properties of chemical adhesion[6] and biocompatibility.[7] With an acid-base reaction, its setting mechanism is very sensitive to water loss and uptake causing conventional GIC to be difficult to handle. Consequently, the light-cured resin-modified glass ionomer cement (RMGIC) has been proposed due to its longer working time, shorter setting time,[8] and lower moisture contamination.[9]

Some incomplete preventions of the fluid leakage on Class V restorations and some gap formations on the cavities' axial wall have been revealed in an *in vitro* study.[10] The latter has been clinically relevant to the development of postoperative sensitivity,[11] due to the movement of fluid filled in the gaps.[12] Despite the possible proximity of ICR restoration to the pulpal cavity, there has been no *in vitro* study on the leakage of RMGIC restoration at the axial wall in ICR. Compared to other methods, a current glucose leakage one[13] has been considered more clinically significant, because glucose has a small molecular size[14] and is a nutrient for bacteria.[13] This leakage test may be an alternative method to present the leakage of restoration to dentin

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surfaces.

Some development of new dental materials, as well as some improvement of clinical techniques, affects the quality of restorations. TCA, a strong acid, has been used as a hemostatic agent to control gingival bleeding,[15] and a necrotizing agent on the ICR management.[2] TCA has been reported to etch the dentin surface,[16] resulting in a favorable bond strength.[17,18] Although pre-treatments by numerous dentin conditioners have been evaluated, no study has emphasized on the effects of different dentin pre-treatments by RMGIC restorative material for an ICR on root dentin, particularly by using a glucose leakage method. Thus, it was our objective to investigate such effects by RMGIC for an ICR using the glucose leakage method.

Materials and methods

This study was approved by the Ethics Committee of Naresuan University (IRB; Expedited review, No.470/59). Fifty-six human maxillary or mandibular premolars extracted for orthodontic reasons were collected. The teeth with complete root formations, but without caries, wear, or restoration, were included. Using a diamond blade (IsoMet 4000 Precision Cutter, Buehler, IL, USA), the teeth's crowns were removed at 1.00±0.05 mm below their cemento-enamel junctions. Using a high speed diamond cylinder bur #010 under a water coolant, an iatrogenic ICR cavity was prepared (1-mm below the root's upper border with a 1.00±0.05 mm depth and a 4.00±0.05 mm length) along the buccal root surface. The cavity's size was measured by using a digital vernier caliper (Mitutoyo, Mitutoyo Co., Kanagawa, Japan).

According to the protocol elsewhere for ICR lesions,[2] the cavities were treated with 10 µL of 90% TCA (Sigma-Aldrich, St. Louis, MO, USA) for 1 min. To remove the excess acid, they were rinsed with 20 mL of distilled water for 20 s and then dried with the air syringe for 10 s. Using a #010 high speed round diamond bur, the dentin was refreshed by grinding with a 0.5-mm depth to provide a normal dentin surface suitable for bonding with GIC.[19] The procedures provided specimens for a pilot study, in which their dentin surfaces were demineralized using a 90% TCA for 1 min and then refreshed to various depths to determine an optimal depth, which a glistening dentinal base was revealed under a light microscope (Olympus SZX16, Olympus Corporation, Tokyo, Japan). According to the types of dentin treatments, the root specimens were divided into the following four groups (n = 14 for each group): Group I treated with 10% polyacrylic acid (GC Corporation, Tokyo, Japan) for 20 s, Groups II treated with 90% TCA for 15 s, Groups III treated with 90% TCA for 30 s, and Group IV (control) treated with no conditioner. The dentin surfaces were then rinsed with 20 mL of distilled water and the excess water was blotted with cotton pellets. In each group, twelve specimens were assigned for a glucose leakage measurement and two for a surface evaluation under a scanning electron microscope (SEM; LEO1455vp, LEO Electron Microscopy Ltd, Cambridge, UK).

RMGIC (Fuji II LC; GC Corporation, Tokyo, Japan) in a capsule was mixed according to the manufacturer's instructions, filled into all cavities, and activated with an LED light curing unit (Mini LED, Satelec, Mérignac, France) at a constant 5-mm distance above the material for 20 s. All restorations were polished with a high speed superfine diamond bur (Diamond Point FG, Shofu, Kyoto, Japan). The RMGIC was protected with two coats of varnish (GC Fuji Varnish; GC Corporation, Tokyo, Japan). The specimens were stored in a 100% humidity controlled chamber (Medical and Environment Equipment Research Laboratory, Bangkok, Thailand) at 37 ºC for 24 h.

All restored root specimens were vertically embedded in cylinder molds with clear acrylic resin. The dentin-RMGIC sections, 2.0 mm thick, were cut perpendicularly to the root's long axis using a diamond blade (Figure 1). All were then thermocycled for 500 cycles with a temperature range of 5±1 ºC to 55±1 ºC, the dwell time of 60 s, and the transfer time of 2 s to simulate thermal changes in oral cavity.[20] The leakage was measured with a glucose filtration model modified from those previously reported.[13,21] The model was consisted of coronal and apical chambers embedded in an acrylic resin cube and fixed together with four metal screws at the cube's four corners. All areas of the upper and lower parts of the specimens were coated twice with a nail varnish (Revlon Inc., NY, USA), except the interface between dentin and RMGIC (1-mm from the area to be tested). The specimen was inserted between the two chambers and

sealed with 4-mm-thick silicone O-rings (3-mm internal diameter). Glucose (1 mol/L) input was pumped with a 1.7 mL/s flow rate of saliva[22] through the tested area. After 60 min, the testing solution was taken from the apical chamber for an analysis (Figure 2). The samples were analyzed with a glucose kit (Glucose Oxidase/Peroxidase Reagent; Sigma-Aldrich) and measured by a spectrophotometer (Evolution 60S UV-Visible Spectrophotometer, Thermo Fisher Scientific Inc., WI, USA) at 540 nm to determine the glucose concentration and thereby the extent of leakage. By using a one-way analysis of variance (ANOVA), differences in mean concentrations of leaked glucose solution among each group were statistically analyzed at a 95% confidence level and inter-group differences were analyzed by using a Dunnett's T3.

Two specimens from each group were fixed with 2.5% glutaraldehyde buffered in phosphate solution (pH 7.3) at 4 ºC for 2 h. Post-dehydration through ethanol with ascending concentrations, the specimens were dried with a hexamethyldisilazane agent (Polaron CPD7501, Watford, UK), coated with gold using the SPI-Module Sputter Coater (Structure Probe, Inc, West Chester, PA, USA), and examined under the SEM.

Results

Concentrations (mean ± standard deviation) of the leaked glucose solution are shown in Table 1. Their highest and lowest ones were seen in Group III (38.67±5.98 µg/mL) and Group I (2.35±0.80 µg/mL), respectively. Using a one-way ANOVA, there was a statistically significant difference (P=0.000) among groups. *Post-hoc* test by a Dunnett's T3 showed significant differences (P=0.000) in all pairing groups, except for Groups I and IV (P=0.346).

From SEM micrographs, some dentinal tubules in Group I were occluded with smear plugs (Figure 3A). Group II showed some opened dentinal tubules, some dentin surfaces occluded with smear layers, partially decalcified peritubular dentins, and some exposed collagen fibers (Figure 3B). When compared to those in Group II, a larger amount of decalcified peritubular dentin and some exposed dentinal tubules were seen in Group III. An etched-like appearance and some collagen fibers exposed on the tubular walls were observed within the dentinal tubules (Figure 3C). Group IV (control) showed dentin surfaces covered with a smear layer and some partially exposed dentinal tubules (Figure 3D).

Group	Mean±standard deviation (µg/mL)
Group I (10% polyacrylic acid, 20 s)	2.35±0.80[a]
Group II (90% TCA, 15 s)	7.52±0.83[b]
Group III (90% TCA, 30 s)	38.67±5.98[c]
Group IV (control)	2.97±0.81[a]

Table 1. Means and Standard Deviations of the Leaked Glucose Solution's Concentrations in Each Group. Different superscript letters are statistically significant difference (P<0.05).

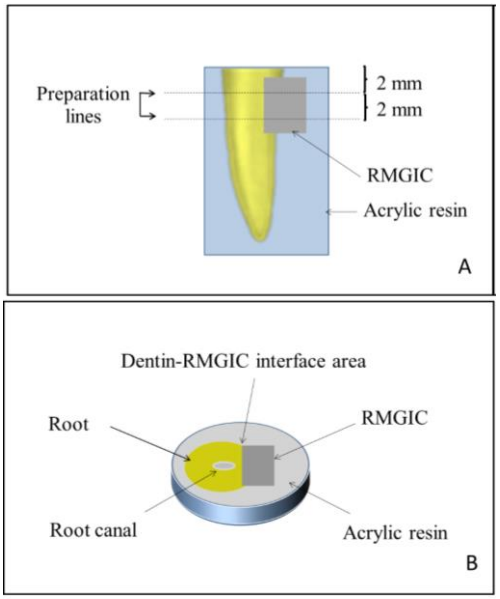

Figure 1. Preparations of the dentin-RMGIC specimens observed from (A) a proximal view of the root cavity with the RMGIC restoration in an acrylic resin block and preparation lines and (B) a top view of the dentin-RMGIC specimen in an acrylic resin block.

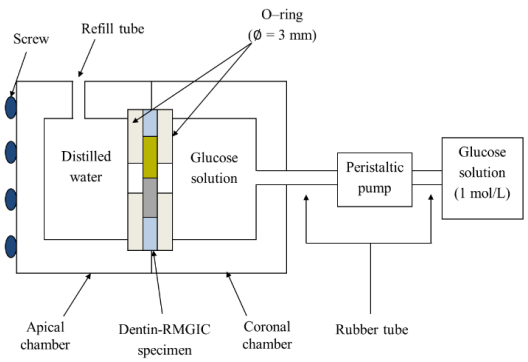

Figure 2. A Schematic Model of the Glucose Filtration Test Used in this Study.

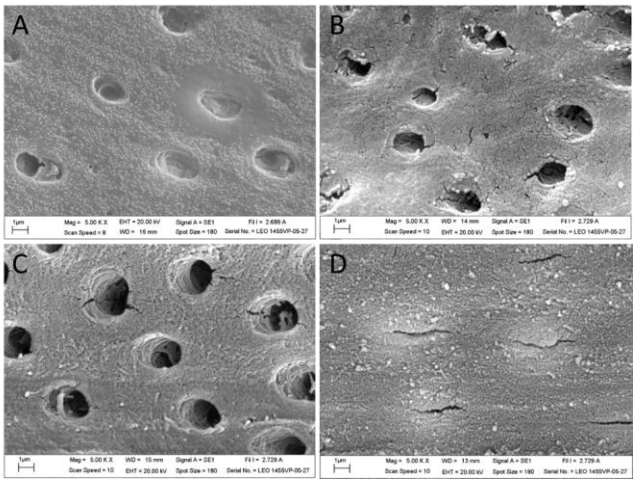

Figure 3. Scanning electron micrographs of the dentin surfaces post-treated by (A) 10% polyacrylic acid, 20 s (Group I), (B) 90% TCA, 15 s (Group II), (C) 90% TCA, 30 s (Group III), and (D) no dentin conditioner (untreated control, Group IV), magnification x 5000.

Discussion

The quality of adhesion between GIC and dentin is dependent on both chemical and micro-mechanical bonds. The former is obtained from the reactions between polyalkenoic acid's carboxyl group and the tooth structure's calcium of hydroxyapatite,[23] while the latter from glass ionomer cement's penetrations into the treated dentin.[24] Pre-treatment of dentin surface was likely to promote the chemical reactions between RMGIC's carboxyl group and the dentin's calcium by an elimination of the contaminants and an alteration of the surface energy of the tooth surface to encourage the adaptation of the materials.[25]

Despite their low amount, glucose leakages in our study were seen in all groups, when compared to those previously reported.[13,26] Such differences were likely caused by our small testing areas with a 3-mm diameter defined and limited by the remaining dentin thickness post-refreshment. When compared to controls and that by polyacrylic acid, pre-treatment of the dentin by 90% TCA caused some more glucose leakages. Because of their decalcification degrees, some treatment durations were reported to affect the enamel's and the dentin's microhardness and morphological structures.[27] These were applicable to some reductions of the adhesions between RMGIC and dentin by TCA in the present study, resulting in more glucose leakages. The stronger acidity of TCA, the more decalcification of dentin. A less amount of calcium was then left for RMGI bonding and glass ionomer cement may not fill all deeply decalcified dentin.[24] Hence, the pre-treatment of root dentin with 90% TCA for 15 and 30 s may not improve the adhesions of RMGIC restorations. Some results of the bond strength in a previous investigation were inconsistent with ours.[18] Such discrepancies were contributed to different methods between theirs and ours. In addition, it has been documented that some materials' bond strength and their leakage results were not directly related.[28]

Unlike TCA, polyacrylic acid, a weak acid with a mild decalcifying effect,[29] was shown to result in some more dentin remaining suitable for RMGIC bonding. Moreover, the adaptation of GIC to tooth surface could be improved by removal of smear layers.[25] Despite its insignificance from controls in our study, the lowest glucose leakage was observed in Group I treated with polyacrylic acid. Taken together, the adhesions between RMGIC and dentin surfaces treated with 10% polyacrylic acid might be better than those treated with TCA.

The dentin in our controls was left with no surface treatment, causing their calcium to be undecalcified, covered with some smear layer, and preserved for the RMGIC bonding.[30] A smear layer has been reported to limit the adhesion of restorative materials to dentin.[31] A removal of smear layers has then been recommended, prior to a restorative procedure. Because of its non-homogeneity and potential dislodgement from the tooth surface, the smear layers have been slowly disintegrated and dissolved under a leaking restoration or by bacterial acids. These may permit some bacterial colonization.[32] Time limitations in this study may cause an insufficiency in the findings of a significant difference of the glucose microleakage between Group I and controls. Therefore, a longer thermocycling time should be conducted and the marginal adaptation of RMGIC should be evaluated using a different quantitative microleakage method[33] in a further study.

Conclusions

Dentin pre-treatment by 90% TCA associated with RMGIC resulted in a greater

amount of glucose leakage than that by 10% polyacrylic acid. When using TCA, the amount of glucose leakage was depended on the durations of treatment time. No difference in the glucose leakage test was found with the pre-treatment by 10% polyacrylic acid or by no dentin conditioner.

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Declaration of Interest

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