The effect of dentin disinfectants on shear bond strength of resin-modified glass-ionomer materials

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Abstract

The purpose of this study was to investigate the effect of dentinal disinfection with a 2% chlorhexidine or a 0.11% I₂-KI/CuSO₄ solution on the shear bond strength of three resin-modified glass-ionomer cements: Fuji II LC, Photac-Fil, and Vitremer. The occlusal surfaces of extracted human teeth were flattened to dentin. Specimens were randomly assigned to one of nine treatment groups (n = 12). For each glass-ionomer material, there was a control group and two treatment groups in which the dentin was treated with either a 2% chlorhexidine or a 0.11% I₂-KI/CuSO₄ solution before the dentin was treated with the recommended dentin conditioner prior to glass-ionomer bonding. Specimens were stored for 1 day in water, thermocycled, and tested in shear until failure. The chlorhexidine solution did not significantly affect the shear bond strengths of any of the cements, but the I₂-KI/CuSO₄ solution significantly lowered the bond strengths of Vitremer and Fuji II LC compared to the controls. (Quintessence Int 1997;28:545-551.)

Clinical relevance

The use of cavity disinfectants must be approached cautiously when the preparation will be restored with resin-modified glass-ionomer cements. A 2% chlorhexidine solution did not affect bond strengths of the tested cements, but a 0.11% I₂-KI/CuSO₄ solution significantly lowered the bond strengths of two of the three cements.

Introduction

Glass-ionomer cements were first introduced to the profession in 1971 by Wilson and Kent.¹ Since that time, dentistry has seen the material evolve from the original glass-ionomer cement to the resin-modified formulations with both light- and chemical-cure systems. Because of its many desirable properties, this versatile material has dramatically increased the dentist’s ability to meet the restorative needs of patients. These desirable properties include fluoride release, antimicrobial activity, a coefficient of thermal expansion similar to that of tooth structure, and a physicochemical bond with tooth structure providing excellent sealing ability.²,³ These qualities make glass-ionomer cements an excellent restorative material for patients who are caries-active or have high caries risk factors.

Presently, there are no universally accepted objective tests to ensure complete removal of all bacterially infected dentin during cavity preparation. Traditionally, the effectiveness of caries removal has been a subjective judgment based on the color and texture of dentin in the cavity preparation, which may or may not accurately reflect the actual bacteria status.⁴-⁶ If there is residual bacteria in the cavity preparation, it can...
multiply from within the smear layer, even in the presence of a good seal from the oral cavity. This can be a source of bacterial toxins, which can diffuse to the pulp and cause inflammation or a recurrence of the caries process.

Therefore, it is possible that what is clinically recorded as secondary or recurrent caries, associated with margins or beneath an existing restoration, can be the result of infected dentin left during the initial cavity preparation-residual caries. It has been well documented in the literature that secondary caries has consistently been the most common reason for replacement of amalgam restorations and one of the major reasons for replacement of resin composite restorations. Recently, Mjö"e found that almost half of all failed glass-ionomer cement restorations were replaced because of the diagnosis of secondary caries.

A clinical example that demonstrates this problem is shown in Figs 1 to 3. The carious lesion was excavated in the conventional manner with rotary and hand instrumentation prior to restoration with a resin-modified glass-ionomer material. Was the preparation (Fig 2) sterile or still infected prior to restoration? Caries-disclosing solutions, consisting of either a 0.5% basic fuschin or a 1.0% acid red dye, have been proposed as an objective method for determining the bacterial status of dentin. However, there is growing skepticism about the accuracy of these dyes in reflecting the true bacterial condition of dentin.

A possible solution to the problem of residual bacteria left in the initial cavity preparation would be the use of antibacterial washes. Oral disinfectants based on an I₂-KI/CuSO₄ formula and chlorhexidine have been shown to be highly effective on teeth. However to date, there is no information on how these agents may affect the bond of glass-ionomer materials to dentin. The purpose of this study was to investigate the effect of an I₂-KI/CuSO₄-based disinfectant (ORA-5, McHenry Labs) and a 2% chlorhexidine-based disinfectant (Bisco Cavity Cleanser, Bisco Dental) on the shear bond strength of resin-modified glass-ionomer restoratives to dentin.

Method and materials

One hundred eighty noncarious extracted human molars were stored in normal saline with 0.2% sodium azide (antibacterial agent) until ready for use. The teeth were scraped of any residual tissue tags and thoroughly

Fig 1 Carious lesion on the lingual aspect of a mandibular first molar.

Fig 2 Finished cavity preparation. Is it sterile or still infected with residual bacteria?

Fig 3 Resin-modified glass-ionomer restoration.
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I rinsed under running tap water for 15 minutes to remove any residual sodium azide. The occlusal surfaces were flattened to obtain a dentinal bonding surface. An Isomet sectional saw (Beuhler) was used for the first cut, followed by an Exact grinder/polisher machine (Exact) using 600-grit sandpaper. The teeth were placed in orthoacrylic contained in a split Teflon mold to form a base and to secure the roots.

The teeth were assigned to nine treatment groups, with 12 restorations per group, as follows:

Group 1. Vitremer control, V(C) (3M Dental)
Group 2. Vitremer (chlorhexidine), V(CHX)
Group 3. Vitremer (I₂-KI/CuSO₄), V(I)
Group 4. Photac-Fil control, PF(C) (ESPE)
Group 5. Photac-Fil (chlorhexidine), PF(CHX)
Group 6. Photac-Fil (I₂-KI/CuSO₄), PF(I)
Group 7. Fuji II LC control, F(C) (GC America)
Group 8. Fuji II LC (chlorhexidine), F(CHX)
Group 9. Fuji II LC (I₂-KI/CuSO₄), F(I)

For the control groups, the resin-modified glass-ionomer cements were applied according to the manufacturer's instructions. In the Vitremer control group, the primer was applied to the dentinal surface for 30 seconds, air dried (no rinse), and light cured for 20 seconds. In the Photac-Fil and Fuji II LC control groups, the dentin was treated with a polyacrylic acid solution for 10 seconds, rinsed for 30 seconds, and air dried but not desiccated.

Immediately, a 2 x 4-mm mold cut from a pipette was sticky waxed to the surface to create a consistent surface area for bonding. The resin-modified glass-ionomer cements were mixed and condensed into the mold to a depth of 2 mm and cured with an Optilux 400 visible light curing unit (Demetron Research). Curing efficacy was verified at the start of each bonding session by using a radiometer to measure light intensity. The material was light cured for 60 seconds from all sides to ensure complete polymerization.

For the chlorhexidine and I₂-KI/CuSO₄ treatment groups, the disinfectant solution was applied to the dentin for 30 seconds and air dried for 15 seconds. This was followed by the application of the polyacrylic acid or primer solutions and then placement of the resin-modified glass-ionomer cements in accordance with the manufacturer's instructions.

Immediately after curing, specimens were placed in 37°C distilled water for 24 hours and then thermocycled 1,000 times between 5°C and 55°C with a dwell time of 30 seconds. Specimens were placed into a positioning jig and tested in shear with an Instron Testing Machine used at a crosshead speed of 0.5 cm/min. The shear bond strengths of the specimens were calculated and expressed in MPa.

Fracture analysis of the bonded dentinal surface was performed under x10 power with a binocular microscope. Fractures were classified as adhesive (greater than 75% of the failure was between tooth and restorative material), cohesive (greater than 75% of the failure was within the restorative material), or a mixture of the two.

To help elucidate the possible effect that the dentin disinfectants may have had on the resin-modified glass-ionomers at the glass-ionomer-dentin interface (which was recorded as bond strengths of the various treatment groups), selected debonded dentinal surfaces, representing the most common fracture pattern observed on light microscopic evaluation for that treatment group, were desiccated, sputter coated with gold, and examined under scanning electron microscope at an acceleration voltage of 30 kV.

Data were analyzed statistically with an analysis of variance and Student-Newmann-Keuls comparison tests at a significant level of P < .05.

Results

Shear bond strengths in MPa (mean ± SD) for the nine test groups are shown in Fig 4. The values were F(C) 12.9 ± 1.7, F(CHX) 11.6 ± 2.7, and F(I) 10.7 ± 2.3; PF(C) 1.5 ± 1.3, PF(CHX) 2.4 ± 1.3, and PF(I) 2.1 ± 2.0; V(C) 9.2 ± 1.4, V(CHX) 9.9 ± 2.0, and V(I) 6.4 ± 2.0. Compared to the controls, the shear bond strengths of the three materials were not affected by the use of the chlorhexidine dentin disinfectant. However, the use of the 0.11% I₂-KI/CuSO₄ solution produced significantly lower bond strengths in Vitremer and Fuji II LC.

Light microscopic surface analysis of the debonded dentin specimens revealed mostly cohesive fractures in the F(C), F(CHX), F(I), V(C), and V(CHX) groups, adhesive-cohesive fractures in the V(I) group, and mostly adhesive fractures in all of the PF groups.

Scanning electron microscopic analysis of representative debonded specimens supported the light microscopic observations. Dentinal smear layers that were treated only with polyacrylic acid were similar in appearance to smear layers that were treated with chlorhexidine prior to the use of polyacrylic acid (Fig 5). However, there was a distinct difference in the appearance of the polyacrylic acid-treated dentin and...
Significant difference at $P < 0.05$ within group.

**Fig 4** Shear bond strengths of the nine test groups.

**Fig 5** Dentin after smear layer treatment with polyacrylic acid. Dentin with smear layers treated with chlorhexidine prior to polyacrylic acid treatment had similar appearances. (Split-screen image; original magnification $\times 750$ at a 55-degree angle; the shaded area on the left is magnified $\times 4$ on the right.)

**Fig 6** Dentin treated with $I_2$-KI/CuSO$_4$ prior to smear layer removal with polyacrylic acid. (Split-screen image; original magnification $\times 750$ at a 55-degree angle; the shaded area on the left is magnified $\times 4$ on the right.)

The appearance of the dentin treated with the $I_2$-KI/CuSO$_4$ solution prior to smear layer removal (Fig 6). The $I_2$-KI/CuSO$_4$ solution may have hindered the complete removal of the smear layer because the dentin in Fig 6 does not appear to be as clean as the dentin in Fig 5.

The dentinal surface after the application of the Vitremer primer is shown in Fig 7. Chlorhexidine- and $I_2$-KI/CuSO$_4$-treated specimens had similar-looking Vitremer-primed surfaces. The cavity disinfectants appeared to have no effect on the primer.

A definitive coating was present on the debonded dentinal surfaces of the V(C), V(CHX), F(C), F(CHX), and F(1) groups. A representative specimen of all of these groups is shown in Fig 8. This was suggestive of a cohesive fracture within the resin-modified glass-ionomer material.

Examination of the fractured dentinal surfaces for all Photac-Fil groups revealed significant exposure of dentinal tubules, indicating the failures were adhesive (Fig 9).

An example of a fractured dentinal surface from the Vitremer (1) specimens is shown in Fig 10. This represents a mixed fracture, in which areas of both cement and dentin are present.
Discussion

The results of this study indicated that cavity disinfectants can have variable results on the bond strength of resin-modified glass-ionomer cements to dentin. The 2% chlorhexidine wash did not significantly affect the bond strengths of any of the glass-ionomer cements tested. However, the I$_2$-KI/CuSO$_4$ solution produced a significant decrease in bond strength for Vitremer and Fuji II LC. Meiers and Shook$^{24}$ in a similar study that examined the effect of these two disinfectants on dentin bonding agents, discovered these washes could significantly affect the shear bond strength of resin composite, depending on the bonding agent’s method of smear layer removal.

The reason that cavity disinfectants may affect the dentin bond of resin-modified glass-ionomers may be explained in the way that these cements attach to dentin. Traditional glass-ionomer cements bond primarily to the inorganic component (calcium) of tooth structure by a chelation reaction that is similar to the setting reaction of the material. This involves initial hydrogen bonding followed by the formation of metal ion bridges and is a true physicochemical bond. The
development of an ion exchange layer that is formed between the glass-ionomer material and the tooth is very important in the prevention of microleakage into the dentinal tubules. A smooth, clean surface with good wettability is needed to obtain good adhesion to the dentinal tubules. The polyacrylic acid removes the smear layer and surface contaminants at the same time as it alters the surface energy and exposes the mineralized tooth structure to the diffusion of the acid and the exchange of ions. Additionally, there has been some evidence that, with resin-modified glass-ionomer materials, a micromechanical interlocking of the resin component, forming a hybrid layer at the surface of the dentin, also plays a role in surface adhesion.

Scanning electron microscopic analysis of the dentinal interfaces indicated that the removal of the smear layer with polyacrylic acid was hindered when the I₂-KI/CuSO₄ solution was used, possibly explaining the decrease in bond strength. However, fractured dentinal interfaces of the control and Fuji II (I) specimens were similar in appearance, showing primarily cohesive failures. From these observations, it could be postulated that the I₂-KI/CuSO₄ solution interferes with either the setting reaction of the material close to the dentinal interface or the ability of the resin to penetrate and form a hybrid layer, resulting in a weaker material that would fracture cohesively at lower bond strengths in this affected layer.

The purpose of the primer in the application of the Vitremer material is to adequately wet the bonding surfaces to facilitate the adhesion of the glass-ionomer material. One possible reason for the decreased bond strengths of the Vitremer (I) specimens (mixed fractures) could be that the I₂-KI/CuSO₄ solution interferes with the ability of the primer to adequately wet the bonding surfaces. It could also be theorized that ions from the I₂-KI/CuSO₄ solution compete with the calcium of tooth structure for the carboxyl groups of the polyacid in the glass-ionomer material, thereby weakening the bond.

When specimens were restored with Photac-Fil after the dentinal surface was treated with the disinfectant, there was no significant difference in the bond strengths obtained. However, the mean bond strength of Photac-Fil was significantly lower than that of either of the other two resin-modified glass-ionomer cements tested in this study. This fact may have eliminated any chance of seeing a real effect from the cavity disinfectants. This low shear bond strength to dentin is consistent with the results obtained by Swift et al., who also found Photac-Fil to have significantly lower shear bond strength to dentin than other resin-modified glass-ionomer cements.

The desirability of sterilizing the cavity preparation with a cavity disinfectant during caries removal has to be weighed against the potential negative impact these washes may have on the restorative material chosen. If resin-modified glass-ionomer cements are the material of choice, then caution must be used in the selection of the cavity wash. Additionally, glass-ionomer materials have been shown in numerous in vitro studies to possess antibacterial properties of their own. Whether these data are indicative of how these materials may perform in vivo has yet to be determined. Therefore, the ultimate decision whether to use a cavity wash when these materials are employed is dependent on the clinician’s understanding of the oral environment in question and the literature supporting the materials being used.

Whether the bonding data from the use of cavity wash disinfectants on dentin translates to similar relationships for microleakage within materials is an interesting question that needs to be examined in the future.

Conclusion

The results of this study indicated that a 2% chlorhexidine cavity wash can be used without negatively affecting the shear bond strength of the resin-modified glass-ionomer materials, Vitremer, Fuji II LC, and Photac-Fil. However, the use of a I₂-KI/CuSO₄ disinfectant produced significant decreases in the shear bond strengths of Vitremer and Fuji II LC.

References


