Original Research

A Confocal Microscopic Evaluation of the Dehydration Effect on Conventional, Resin Reinforced Powder/Liquid and Paste to Paste Glass Ionomer Luting Cements

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Abstract:
Background: The purpose of this study was to evaluate the effect of dehydration of resin-modified glass ionomer powder/liquid system, resin-modified glass ionomer paste/paste luting cements in three different quantities and to compare them with a conventional glass ionomer luting cement using confocal laser scanning microscope.
Materials and Methods: A conventional glass ionomer (Group I), a resin modified powder/liquid system (Group II), and a resin-modified paste/paste system (Group III) were selected for the study. In Group III, there were three subgroups based on the quantity of material dispensed. 50 premolar teeth were selected and randomly divided among the groups with 10 samples in each. The teeth were ground flat to expose a flat occlusal dentin. A device was made to standardize the thickness of cement placed on the teeth. The teeth were stored in distilled water for 24 h and then longitudinally sectioned to examine the tooth dentin interface under a confocal microscope. The specimens were allowed to dehydrate under the microscope for different time intervals. The width of the crack after dehydration near the dentinal interface was measured at definite intervals in all the groups and analyzed statistically using Student's *t*-test.
Results: Conventional glass ionomer cement showed the maximum width of the crack followed by resin modified paste/paste system during the dehydration period. Resin modified powder/liquid system did not show cohesive failure.
Conclusions: Conventional glass ionomer luting cement is more susceptible to cohesive failure when subjected to dehydration compared to resin-modified glass ionomer paste/paste luting cement. Among the luting cements, resin-modified glass ionomer powder/liquid system showed the best results when subjected to dehydration.

Key Words: Confocal microscopy, dehydration, glass ionomer, luting cements

Introduction

Glass Ionomer cement introduced by Wilson and Kent in 1972 was initially used as a substitute for silicate cement, for anterior esthetics.[1] Zinc phosphate cement has long been the material of choice for luting permanent cast restoration because of its good manipulative properties and relatively high strength. However, this material relies on mechanical interlocking for its retentive effects.[2] The quest for improved alternative cementing material that can form a physiochemical bond to the tooth structure led to the development of glass ionomer luting cement in 1977.[3] It has showed considerable promise as a means of reducing secondary caries by its fluoride release. Other favorable traits include significantly less disintegration *in vivo*, a film thickness comparable to that of zinc phosphate and biocompatibility.[4]

The conventional glass ionomer cement, however, is susceptible to moisture contamination and dehydration in the early stages. Resin modified glass ionomer cement shows less early water sensitivity and their tensile strength and flexural strength exceeds the conventional glass ionomer.[5,6] However, they remain susceptible to water loss and exhibit crack formation when subjected to dehydration stress.[7]

The glass ionomer is also highly sensitive to power/liquid ratio and the material cannot be under proportioned or over proportioned. Premeasured glass ionomer in the form of capsule was introduced to obtain a correct ratio of powder and liquid, but it also could not solve the problem of wastage.

A later introduced, paste to paste system was provided with a dispenser to ensure dispensing the required amount of material without altering the proportion. The low film thickness of 3 μ also permits stress-free seating of restoration and reduce the chances of high occlusion.

Confocal laser scanning microscope (CLSM) enables to view subsurface features of tooth/cement interface under normal environmental conditions without disrupting the interface morphology.[8] This is especially useful to study the interaction of glass ionomer cement with the tooth surface, which is very sensitive to dehydration.[9]

This study compared the effect of dehydration in a conventional glass ionomer luting cement, resin reinforced powder/liquid system, and resin reinforced paste/paste system after 0 min, 15 min, 30 min, 60 min by examining the cement/dentin interface in a CLSM.

Materials and Methods

Freshly extracted non-carious 50 human maxillary premolars that were extracted for orthodontic treatment in the age group 10-18 years were selected as samples. The samples were stored in saline and later cleaned ultrasonically. The superficial occlusal dentin was exposed by using a slow speed diamond disc under the water spray. The surface was prepared flat and polished with 600 grit silicon carbide paper for placement of glass ionomer cement. The dentin surface was conditioned with 10% polyacrylic acid (G.C. conditioner) for a period of 20 s and rinsed with distilled water for 20 s. The samples were divided into three groups based on the type of glass ionomer cement used and in Group III there were three subgroups based on the amount of material dispensed from the cartridge (Table 1).

In Group I and Group II the cements were mixed as per the manufactures instructions. In Group III A, Group III B, Group III C, the material was dispensed from the cartridge with a dispenser. Three lines were marked on the lever for the 3 subgroups, one in the most forward position, one in the middle, and one in the rear position to obtain least, moderate, and large quantity of material, respectively. Rhodamine B that has an excitation wavelength for 514 nm was used in the study to visualize the cement matrix. The cement was placed on the dentin surface in the respective groups to a dimension of 4 mm diameter and 2 mm height using a mold. A single coat of Fuji coat LC was applied and light cured for 10 s for all 50 samples. The cement was allowed to mature in distilled water for a period of 24 h and the samples were later sectioned longitudinally to examine the cement/dentin interface under CLSM after 0 min, 15 min, 30 min, 60 min of dehydration in all the groups.

Results

The width of the crack after dehydration near the dentinal interface at 0 min, 15 min, 30 min and 60 min were measured in microns. Group II material did not show gap formation. In Group I, Group III A, Group III B, and Group III C changes were visible (Tables 2 and 3). An independent Student's *t*-test

was done to test the mean values between the groups and also within each group at various time duration (Table 4). When $P < 0.05$ the, difference between the groups was considered significant. Graphical illustration of the width of the crack is tabulated in Graphs 1 and 2.

Table 2: Width of the crack in microns (μ) in Group I.			
Sample number	15 min	30 min	60 min
1	1.2	2.9	4.5
2	1.3	3.0	4.4
3	1.2	3.0	4.3
4	1.0	3.1	4.4
5	1.2	3.0	4.5
6	1.0	3.2	4.3
7	1.1	3.1	4.2
8	1.1	3.0	4.2
9	1.2	3.0	4.3
10	1.1.	3.1	4.3

Table 3: Width of the crack in microns (μ) in subgroups of Group III.				
Sample	Sub group	15 min	30 min	60 min
1	A	0.4	1.1	2
	B	0.4	1	2.2
	C	0.3	1.1	2
2	A	0.6	1.2	2
	B	0.6	1	2.3
	C	0.3	1	1.9
3	A	0.4	1	2
	B	0.4	1.1	2.2
	C	0.4	1.1	2
4	A	0.4	1.1	2
	B	0.4	1.1	2.2
	C	0.3	1	2
5	A	0.5	1.1	2
	B	0.5	1	2.3
	C	0.3	1.1	2
6	A	0.6	1	2
	B	0.5	1	2.1
	C	0.4	1	2
7	A	0.5	1.2	2
	B	0.4	1.1	2.1
	C	0.3	1.1	2.1
8	A	0.5	1	2.1
	B	0.6	1.1	2.1
	C	0.4	1	1.9
9	A	0.5	1.1	2
	B	0.4	1.2	2.2
	C	0.4	1.1	2.1
10	A	0.4	1	2
	B	0.5	1.1	2.2
	C	0.3	1.0	2.0

Table 1: Three groups based on the type of glass ionomer cement used and three subgroups in Group III based on the amount of material dispensed from the cartridge.		
Groups	Material	Samples
Group 1	Conventional glass ionomer (GC Fuji 1)	10
Group II	Resin reinforced glass ionomer powder/liquid system (GC Fuji PLUS)	10
Group III A	Resin reinforced glass ionomer paste/paste system (GC Fuji CEM) Least quantity	10
Group III B	Resin reinforced glass ionomer paste/paste system (GC Fuji CEM) Moderate quantity	10
Group III C	Resin reinforced glass ionomer paste/paste system (GC Fuji CEM) Large quantity	10

Table 4: Descriptive statistics.						
Groups	15 min (μ)		30 min (μ)		60 min (μ)	
	Mean	SD	Mean	SD	Mean	SD
Group 1	1.14	0.096	3.04	0.084	4.35	0.107
Group III A	0.48	0.078	1.08	0.078	2.01	0.031
Groups III B	0.47	0.082	1.07	0.067	2.19	0.076
Group III C	0.34	0.051	1.05	0.052	2.01	0.85

SD: Standard deviation

From the above results following have been concluded:

- No specimens showed crack formation at the beginning of the experiment.
- Group II specimens did not show any crack formation even at the end of 60 min.
- Group I specimens showed the maximum width of the crack at the end of 60 min.
- The width of the crack increased gradually starting from the beginning of the experiment up to 60 min in Group I, Group III A, Group III B, and Group III C and there was statistical significant difference in all the groups.
- At 15 min and 30 min, Group I specimens showed the maximum width of crack, followed by Group III A, Group III B, and III C. Group 1 > III A > III B >III C.
- At 60 min Group I specimens showed the maximum width of the crack followed by Group III B. There was statistical significance among all the groups except between Group III A and Group III C. Group I > III B > III A = III C.

Discussion

Glass ionomer cement is a water based cement and the acid-base reaction between aluminosilicate glass powder and polyacrylic acid occurs only in the presence of water.[10] The water fo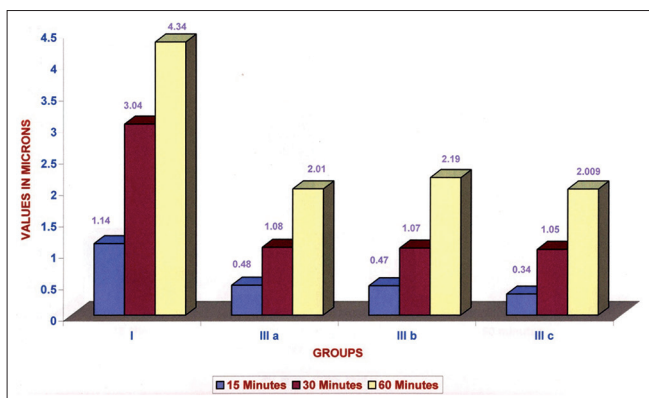rmed as a result of the acid base reaction, initially lies free in the matrix, and the cement remain susceptible to water loss at this stage. This water is called the loosely bound water. Later this loosely bound water becomes tightly bound water by incorporating water molecules into the aluminum ion to form stable aluminum polyacrylate salt.[11]

When glass ionomer cement was allowed to dehydrate the silaceous hydrogel around the glass core was subjected to shear stress and crack tend to occur cohesively in the cement.[12] The thickness of the silaceous hydrogel ranges from 150 to 300 μm for conventional glass ionomer cement and resin-modified glass ionomer cement showed thinner hydrogel ranging between 100 and 150 μm.[13] The presence of thicker hydrogel widened the crack in conventional glass ionomer cement compared to resin-modified glass ionomer cement. Complete maturing and resistance to water loss is not available for at least 2 weeks for fast setting cements and up to 6 months for slow setting conventional cements.[14]

The Group I specimens (conventional glass ionomer) showed the maximum width of the crack, when it was subjected to dehydration under the microscope throughout the 60 min dehydration period (Figures 1 and 2). The crack was cohesive and occurred close to the interface leaving a thin layer of glass ionomer cement attached to the dentin. The crack was also not uniform throughout and was interrupted in between by
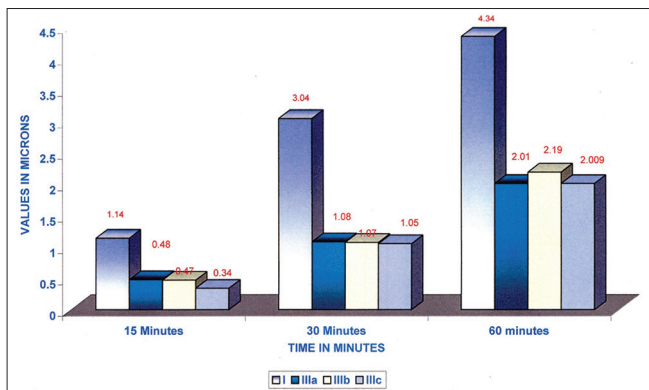
Graph 1: Comparison of the width of the crack between the groups at different time intervals.

Figure 1: Group I sample at 0 min (cement/dentin interface under confocal laser scanning microscope).

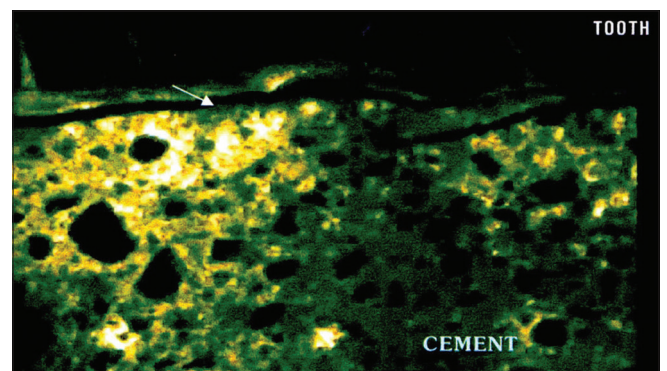**Graph 2:** Comparison of the width of the crack in each group at different time intervals.

Figure 2: Group 1 sample at 60 min (cement/dentin interface under confocal laser scanning microscope).

the glass particles. When the cement was dehydrated, it is the unbound water that is readily lost by evaporation. The ratio of bound to unbound water in conventional glass ionomer has been found to increase with time.[15,16]

The Group II specimens (resin reinforced powder/liquid system) did not show any crack formation throughout the dehydration procedure under the microscope (Figure 3). In this hybrid material part of the water content of the glass, polyalkenoate system is replaced by water soluble polymer or polymerizable resin.[17] The addition of HEMA into the liquid along with the catalyst permitted initial polymerization of resin to occur along with shower acid-base reaction. This offered protection to the cement against dehydration. The polymerization of HEMA also offered protection to the calcium polyacrylate chains against dissolution in water.[18] The addition of resin caused on the overall increase in fracture toughness of the material.

The Group III specimens (resin reinforced paste to paste system) developed a cohesive crack close to the interface upon dehydration of the specimen. The crack was observed at 15 min and gradually widened at 30 min and 60 min (Figures 4 and 5). However, the width of the crack was significantly less than that of the Group I specimens. Statistical significance was found at different quantities of mixing (Group III A, Group III B, Group III C), but they are not important because no single quantity was able to completely eliminate crack formation.
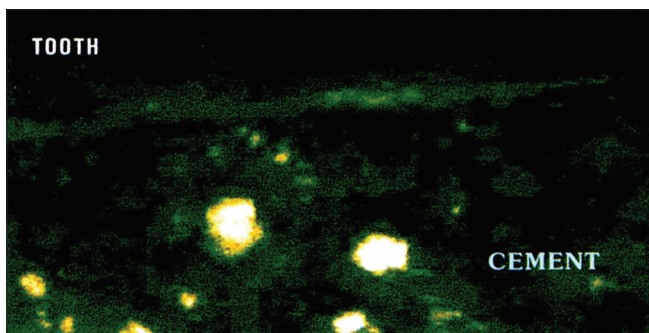

Figure 3: Group II sample at 60 min (cement/dentin interface under confocal laser scanning microscope).
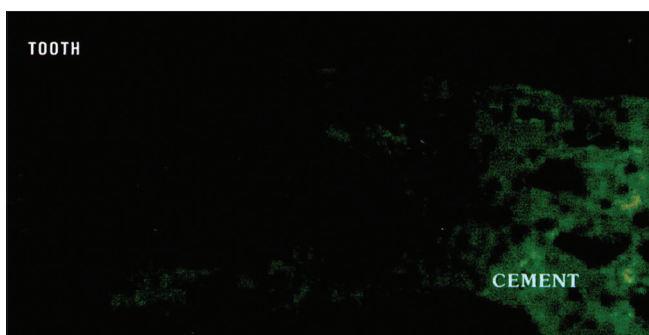

Figure 4: Group III C sample at 0 min (cement/dentin interface under confocal laser scanning microscope).

In this study, the dentinal interface was chosen to demonstrate the cohesive failure. By prior studies it had been shown that cohesive failure of the cement in the form of crack was associated with the dentin interface, which might be due to localized increase in strength of the glass ionomer close to the dentin by the strong ion-exchange layer.[18]

During cementation of crowns, some amount of cement gets exposed at the margins to the oral environment. Extended operative procedures and also in mouth breathers, the exposed margin of the cement will remain continuously in a state of dehydration.[7] As a result, cracks can develop and marginal leakage can occur at the crown margins. Dehydration of a specimen under the microscope is an effective means of applying stress and indicates some of the stresses that can be placed on the system during the extended operative procedure. Monitoring the interface for the crack at 0 min, 15 min, 30 min, and 60 min, permitted to observe whether there is widening of the crack over time.

The range and particle size distribution will have a bearing on the physical properties of each material.[14] Finer the particle size, the lesser will be the film thickness of the cement. Conventional glass ionomer cement (Group I) and resin-modified glass ionomer powder/liquid system (Group II) has an average filler particle size of 3.8 µm and a maximum of 15 µm. In case of resin-modified glass ionomer paste to paste system (Group III), the filler particle size is 1.8 µm and a maximum of 4 µm, which is significantly less than that of the Group I and Group II materials. In resin reinforced paste to paste system, the fine particle size has got a bearing on the development of crack. The lesser the particle size, more will be the acid-base reaction, and the amount of glass core filler in the cement will be less. This would have resulted in the crack formation, which was otherwise absent in powder/liquid system.

In this study, the use of unfilled resin did not provide protection to both water loss and water gain in all the groups. Furthermore, only the dentinal interface was examined for crack propagation. Further studies are required to examine the cohesive failure in other areas of the cement.
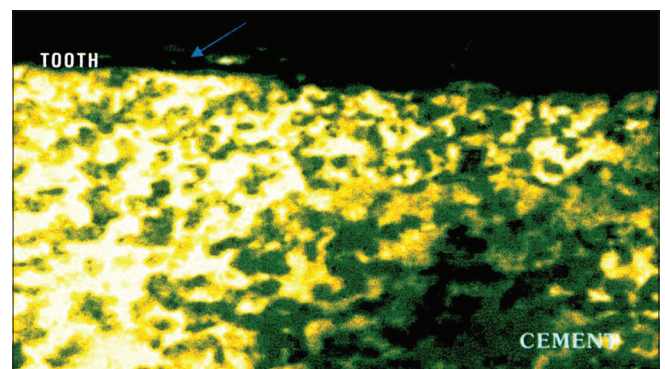

Figure 5: Group III C sample at 60 min (cement/dentin interface under confocal laser scanning microscope).

The use of bioactive materials like ceramir, which is a calcium aluminate luting cement, a luting cement that incorporates the principle of two cements, calcium aluminate, and glass ionomer cement will to a certain extent mitigate the deficiencies of conventional glass ionomer cement. However, the search for a perfect luting agent must go on.[19]

Conclusion

Within the limitations of the study, the following conclusions were drawn:

1. Conventional glass ionomer luting cement (Fuji 1) is more susceptible to cohesive failure when subjected to dehydration compared to resin-modified glass ionomer paste/paste luting cement (Fuji CEM).
2. Among the luting cements, resin-modified glass ionomer powder/liquid system (Fuji PLUS) showed the best results when subjected to dehydration.

Acknowledgment

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