

Comparison of the Solubility of Conventional Luting Cements with that of the Polyacid Modified Composite Luting Cement and Resin-modified Glass Ionomer Cement

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ABSTRACT

Introduction: This study was planned to find the solubility of the conventional luting cements in comparison with that of the polyacid-modified composite luting cement and recently introduced resin-modified glass ionomer cement (RMGIC) with exposure to water at early stages of mixing.

Materials and methods: An *in vitro* study of the solubility of the following five commercially available luting cements, viz., glass ionomer cement (GIC) (Fuji I, GC), zinc phosphate (Elite 100, GC), polyacid-modified resin cement (PMCR) (Principle, Dentsply), polycarboxylate cement (PC) (Poly - F, Dentsply), RMGIC (Vitremer, 3M), was conducted. For each of these groups of cements, three resin holders were prepared containing two circular cavities of 5 mm diameter and 2 mm depth. All the cements to be studied were mixed in 30 seconds and then placed in the prepared cavities in the resin cement holder for 30 seconds.

Results: From all of the observed luting cements, PMCR cement had shown the lowest mean loss of substance at all immersion times and RMGIC showed the highest mean loss of substance

at all immersion times in water from 2 to 8 minutes. The solubility of cements decreased by 38% for GIC, 33% for ZnPO₄, 50% for PMCR, 29% for PC, and 17% for RMGIC.

Conclusion: The PMCR cement (Principle-Dentsply) had shown lowest solubility to water at the given time intervals of immersion. This was followed by PC, zinc phosphate, and GIC to various time intervals of immersion.

Keywords: Dental cements, Glass ionomer cement, Luting cements.

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INTRODUCTION

In dentistry, dental cements are widely used. Dental cements have wide range of clinical uses in dental treatments. They can be used as temporary filling material, base material, or as a luting agent. Also, various types of cements have been developed for use on endodontic and orthodontic purposes.¹

Luting cements can be permanent or temporary, depending on cements' physical properties and the planned longevity of the restoration. Still, it is argued in literature that there is no ideal cement developed answering all purposes. Therefore, different cements are required for comprehensive patient management, and thus, it is not always easy to make the best choice.¹⁻³

The definition of "luting" is "use of a flowable substance to seal the joints and thereby cement two surfaces together." In previous years, in dentistry, the term cement was used for a powder liquid material, which after mixing to a creamy consistency sets to become a hard mass and

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used clinically for restoring the teeth. For a long period of time, cements have been used for luting purposes. Also the various properties of cements differ from each other and the use of particular type of cement depends on biological and functional demands of the certain clinical situation.¹⁻³

The currently used word "luting" is derived from a Latin word "Lutum," which means mud. Dental luting cements provide a connection between the prepared tooth and restoration, bonding them together with the help of some form of surface attachment – mechanical, micro-mechanical, chemical, or combination. Luting materials may be definitive or provisional depending on their physical properties and planned longevity of the restoration.⁴

Nowadays, different types of cements are used for the purpose of temporary and permanent cementation of the indirect restorations. These cements have different mechanical and biological characteristics, among which the most important property is resistance against decomposition and degradation and stability in the oral environment. Deterioration of restorations can result from decomposition of the cements and can also cause secondary caries.⁶ The solubility of these restorative materials may directly affect their selection criteria. Materials designed for the same clinical purpose differ in their behavior with respect to long-time aging in water.⁵

Early cement exposure to moisture or saliva during setting of dental cement can alter most of its properties like solubility, resulting in microleakage and may affect durability of the restoration. Luting cements can undergo early dissolution when exposed to saliva or moisture immediately after initial hardening. Moisture control is therefore necessary during setting of the dental cements. Despite the positive aspects of glass ionomer cements (GICs) that have been used in dentistry since the 1970s till the present day, in order to improve some of their qualities and eliminate the disadvantages, resin-modified glass ionomer cements (RMGICs) were developed in the late 1980s by adding resin to GICs.^{1,6}

Polyacid-modified composite resins (PMCRs) were defined at the end of 1990s as a composite of (compomer) composite resin (comp) and glass ionomer (omer). Physical qualities of compomers are closer to composite resins.¹

This particular study was done to comparatively study the solubility of the conventional luting cements with that of the polyacid-modified composite luting cement and recently introduced RMGIC with exposure to water at early stages of mixing.

MATERIALS AND METHODS

An *in vitro* study of the solubility of the following five commercially available luting cements, viz. GIC (Fuji I, GC), zinc phosphate (Elite 100, GC), polyacid-modified resin cement (Principle, Dentsply), polycarboxylate (Poly - F, Dentsply), RMGIC (Vitremmer, 3M), was conducted.

For the purpose of assessing the water solubility, these cements were grouped as follows (Table 1):

- Group I – GIC (glass ionomer cement)
- Group II – ZnPO₄ (zinc phosphate cement)
- Group III – PMCR (polyacid-modified composite resin cement)
- Group IV – PC (polycarboxylate cement)
- Group V – RMGIC (resin-modified glass ionomer cement) (Table 1)

PREPARATION OF SAMPLES

For each of these groups of cements, three resin holders were made with two circular cavities of 5 mm diameter and 2 mm depth. The cements were mixed in accordance with the manufacturer's recommendation or also done by weighing powder or drops of liquid. The powder to liquid ratios of each cement is given in Table 1.

All the cements were mixed within 30 seconds and placed in the prepared cavities in the resin cement holder for 30 seconds. The surfaces were flattened, and excess cement was removed with spatula or dry cotton pellet.

Table 1: Powder to liquid ratios of the five cements used as per manufacturers recommendations

Groups	Product name	Producer	Composition	Scoops P:L	P/L ratio
I	Fuji – I	GC	P – Calcium Fluoroaluminosilicate Glass L – Conc. Aqueous Solution of Polyacrylic Acid	1:2	1.8 gm/1 gm
II	Elite 100	GC	P: 10% MgO. ZnO.90% L: 67% Phosphoric Acid Buffered 33% H ₂ O with Al & Zn	3:3	1.45 gm/0.5 mL
III	Principle	Dentsply	P: Strontium aluminofluorosilicate glass aerosil initiator components L: Macromonomer (M-IA.BSA) Aminopenta (AP) DGDMA, Inhibitor & Initiator Components	2:2	25 gm/0.12 gm
IV	Poly - F	Dentsply	P: ZnO, MgO, Bismuth, Al L: Polyacrylic acid	1:3	1 gm/0.5 gm
V	Vitremmer Luting Cement	3M Corp.	P: Fluoroaluminosilicate glass, Poly HEMA (Resin) L: Aqueous solution of modified polyalkenoic acid	3:3	1.6 gm/1 gm

TESTING OF SAMPLES FOR SOLUBILITY

After 2, 5, and 8 minutes of storage time, the specimens were immersed in 50 mL of distilled water in a beaker with the exposed area pointed upward.

The weight of the empty beaker was previously established by using a digital balance (Sartorius Analytical) with a measuring accuracy of 0.1 mg. The bottle was carefully rinsed and dried for 2 hours before weighing and then cooled in desiccators for 20 minutes. Beakers were stored for 3 hours at 37°C, and thereafter, the cement holders were removed from the water with a little vibration of the beaker.

The beakers were then stored at 130°C in furnace for 2 hours to allow evaporation of water. They were then cooled in desiccators and weighed again as above. The total amount of substance dissolved was calculated by subtracting the established weight of the beaker. Five specimens were used for each of the cement at each immersion storage sample. The mean weight loss per square centimeter was determined. The total exposed area of each specimen was recorded ($r = 2.5$ mm), and the exposed surface was doubled as each cement holder had two cavities.

The solubility of cement is calculated as follows:

$$W_1 = \text{Weight of the resin}$$

$$W_2 = W_1 + \text{weight of the cement}$$

$W_3 = \text{Weight of empty beakers}$

$W_4 = W_3 + \text{weight of the cement residue}$

$(W^x) W_4 - W_3 = \text{Amount of cement dissolved mg/cm}^2$

The diameter of the resin cavity = 5 mm = 0.5 cm (d)

The radius of the resin cavity hole = 2.5 mm = 0.25 cm (r)

Weight difference in mg (1 gm = 1000 mg)

$$\text{Weight loss per unit area} = \frac{\text{Weight loss}}{\text{Total area}}$$

$$\begin{aligned} \text{Area of the two resin cavities} &= 2 \times \pi r^2 \\ &= 2 \times 3.14 \times (0.25 \text{ cm})^2 \\ &= 0.3925 \text{ cm}^2 \end{aligned}$$

Weight loss per unit area

$$= \frac{\text{Weight loss}}{\text{Total area}} \times \text{mg}$$

$$= \frac{W^x \text{ mg}}{0.3925 \text{ cm}^2} = \frac{W^x}{0.393}$$

RESULTS

The results are presented in Tables 2 to 5. Table 2 shows the solubility of the five cement samples at various time intervals of immersion in water, indicating a decrease in solubility by increase in the time until immersion from start of mixing.

Table 3 shows the mean values and the standard deviations of the solubility of samples at various time

Table 2: Solubility of the five cement samples at various time intervals of immersion in water

Groups		I	II	III	IV	V
Time interval	Trials	GIC (mg/cm ²)	ZnPO (mg/cm ²)	PMCR (mg/cm ²)	PC (mg/cm ²)	RMGI (mg/cm ²)
2 minutes	1	11.4649	8.1528	5.8598	5.8047	15.0318
	2	11.2101	7.3053	4.0764	5.9615	14.872
	3	11.8701	7.0955	4.5859	5.7951	15.253
	4	10.9605	7.5858	5.9601	6.0150	14.4649
	5	11.14	7.535	5.1264	5.8825	14.564
5 minutes	1	7.64311	5.1337	3.0573	4.1200	12.2092
	2	7.6433	5.0764	2.0382	4.32	12.2290
	3	6.1146	5.6407	2.2929	3.980	12.3124
	4	6.5650	4.2629	2.5859	4.23	11.7961
	5	7.125	5.123	2.7214	4.21	12.254
8 minutes	1	3.3121	3.0242	1.0191	2.8025	9.4458
	2	3.3321	3.0573	1.7834	2.6215	9.1719
	3	3.3121	3.1668	1.8500	2.7154	9.9363
	4	3.0311	2.8025	1.2061	2.770	10.3644
	5	3.3210	3.0854	1.5425	2.7450	9.854

Table 3: Mean values and SD of the solubility of samples at various time intervals of immersion in water

Groups	I		II		III		IV		V	
Time intervals	GIC		ZnPO ₄		PMCR		PC		RMGIC	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
2 minutes	11.33	0.35	7.53	0.40	5.12	0.81	5.91	0.09	14.64	0.32
5 minutes	7.02	0.67	5.05	0.50	2.54	0.39	4.17	0.13	12.16	0.21
8 minutes	3.26	0.13	3.03	0.14	1.48	0.36	2.71	0.08	9.76	0.46

SD: Standard deviation

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Table 4: Significance of solubility of cement samples at various time intervals within each of the five groups

Groups	Mean	Time intervals	2	5	8	F	p
GIC	3.2617	2		*	*	411.2381	VHS
	7.0181	5			*		
	11.3291	8					
ZnPO ₄	3.273	2		*	*	181.4242	VHS
	5.0473	5			*		
	7.5349	8					
PMCR	1.4796	2		*	*	56.0042	VHS
	2.5396	5			*		
	5.1223	8					
PC	2.7309	2		*	*	1288.3648	VHS
	4.1720	5			*		
	5.8990	8					
RMGIC	9.7553	2		*	*	252.6757	VHS
	12.1601	5			*		
	14.6351	8					

*Significant reduction in solubility at various time intervals within each of the five groups

VHS: Very highly significant, p = 0.0000

$$F = \frac{\text{Mean sum of squares between the groups}}{\text{Mean errors sum of squares}}$$

This table indicates that the reduction in solubility is significant at 2 vs 5 minutes

2 vs 8 minutes for all the 5 groups

5 vs 8 minutes

intervals of immersion in water. From all of the observed luting cements, PMCR cement had lowest mean loss of substance measured at immersion times, while RMGIC had highest mean loss of substance at all immersion times in water from 2 to 8 minutes.

Table 4 shows the significance of solubility of cement samples at various time intervals within each of the five groups, as obtained from the “one-way analysis test.” For all the five groups, reduction in solubility, which was significant, was present at 2 minutes vs 5 minutes and 2 minutes vs 9 minutes and 5 minutes vs 8 minutes.

Table 5 shows the significance of solubility of cement samples at particular time intervals between the groups. Intercomparison result was calculated from Bonferroni t-test. The solubility of cements decreased by 38% for GIC, 33% for ZnPO₄, 50% for PMCR, 29% for PC, and 17% for RMGI. When the specimens were immersed in water 5 minutes after mixing, the difference in solubility between 2 and 5 minutes was most marked for PMCR cement (50%). The % decrease in solubility at 5 minutes immersion time was 45% for GIC, 40% for ZnPO₄, 41.7% for PMCR, 35% for PC, and 28% for RMGI cement. The amount of solubility of cements ranging from 2 to 8 minutes measured from start of mixing was found to be 71.2% for GIC followed by PMCR by 71.1%, 59.8% for ZnPO₄, 53.7% for PC, 433.3% for RMGIC (Graph 1).

Table 5: Significance of solubility of cement samples at various time intervals between the various groups

Time intervals	Mean	Groups	A	B	C	D	E	P	F
2 minutes	5.1223	I		*	*	*		382.6362	VHS
	5.8990	II			*	*			
	7.5349	III							
	11.3291	IV							
	14.6351	V	*	*	*	*			
5 minutes	2.5396	I		*	*	*		376.7962	VHS
	4.1720	II			*	*			
	5.0473	III							
	7.0181	IV			*				
	12.1601	V	*	*	*	*			
8 minutes	1.4796	I			*			696.8323	VHS
	2.7309	II			*				
	3.0273	III							
	3.2617	IV							
	9.7553	V	*	*	*	*			

*Significant reduction in solubility between the various groups with respect to time.

VHS: Very highly significant; p = 0.0000

$$F = \frac{\text{Mean sum of squares between the groups}}{\text{Mean errors sum of squares}}$$

This table indicates that the reduction in solubility is significant.

At 2 minutes – Group I vs groups II, III, and IV

Group II vs groups III and IV

Group V vs groups I, II, III, IV

At 5 minutes – Group I vs groups II, III, IV

Group II vs groups III, IV

Group IV vs group III

Group V vs groups I, II, III, IV

At 8 minutes – Group I vs group III

Group II vs group III

Group IV vs group III

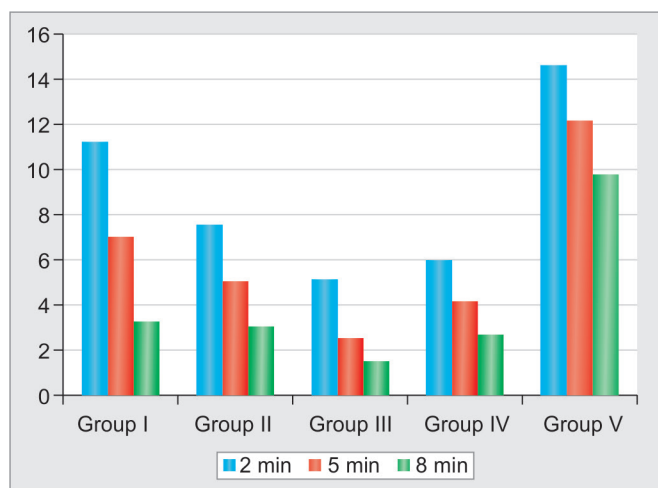
Group V vs groups I, II, III, IV

DISCUSSION

In case of luting cements, solubility is an important feature in assessing the clinical durability. Therefore, *in vitro* solubility of luting cements has been widely evaluated. Solubility can cause degradation of the cement, resulting in debonding of the restoration and leading to recurrent decay.^{7,8}

From the results of the data obtained, it can be seen that the PMCR Cement (Principle-Dentsply) had least solubility time intervals. The reason can be that the principle cement is of resin cement more than GIC. Previous studies by Yoshida et al⁹ in 1998 on resin cements have shown similar results with very little solubility after exposure to moisture.

Leaching or solubility of dental cement has an impact on both its biocompatibility and structural stability. The rate of dissolution can be affected by the conditions of the test used. Various other factors can include time of dissolution, specimen shape and thickness, concentration of



Graph 1: Comparison of mean solubility of various cements at different immersion times

Percentage reduction of solubility from 2 to 8 minutes:

Group I – 71.2% Group III – 71.1% Group V – 33.33%
Group II – 59.8% Group IV – 53.7%

the solute in the dissolution medium, pH of the medium, and powder/liquid ratio of cement.

The chemical structure of the solutions used for various *in vitro* tests is also important because it simulates the complexity of the oral environment. The *in vitro* tests used are only static solubility tests as they do not simulate the pH and temperature changes of the oral cavity. Clinical conditions can vary, even within the same person, making it virtually impossible to reproduce a natural environment.⁵

Another ideal cement in terms of decreased solubility was PC (Poly-F-Dentsply). However, although *in vitro* studies of PCs show less solubility, clinical studies have shown that PCs degrade rapidly in the oral environment.^{10,11}

When compared with conventional cements in previous studies, the early sensitivity to dehydration and moist, and resistance to solubility of RMGIC are reported to be better than those of GICs. The solubility of various adhesive cements is important in terms of clinical applications. As the solubility of the dental cements increases, aesthetic, marginal integration, and mechanical problems can arise. The solubility of the dental cements indirectly has an effect on the overall success rate of the dental restorations being done.^{12,13}

A number of resin-based cements are now becoming available as direct filling resins with modified properties, like the acid-etch technique for bonding resins to enamel and molecules with effect of organic or inorganic acid bond to conditioned dentin.¹¹

The century-old zinc phosphate cement was ranked third as far as its solubility was concerned and it was found less soluble than glass ionomers in our *in vitro* study. This finding is in agreement with the previous

studies of Oilo¹⁴ and Williamson,¹⁵ who found the essentiality of GIC protection a short time after cementation, because they had shown to disintegrate fast in contact with moisture.

Adequate care must be taken against water after cementation, as glass ionomer has higher solubility than zinc phosphate.

Lastly, the highest solubility was shown by RMGIC as they had a resin hydroxy ethylmethacrylate (HEMA). This is hydrophilic in nature and there is more water sorption. Subsequently, plasticity and also hygroscopic expansion can result. This type of behavior is similar to a synthetic hydrogel. Although initial water sorption may compensate for polymerization shrinkage stresses, continual water sorption has deleterious effects.¹⁶

All the five luting cements had shown reduction in solubility during the time interval from start of mixing and immersion to the water.

With reference to the percentage decrease in solubility from 2 to 8 minutes, the present study had shown that RMGIC had shown least decrease in solubility, which can be due to the presence of HEMA resin.

Though *in vitro* researches have limited clinical importance, it will not show the stability of the set cement in oral cavity; they are essential for sorting out the quality of various types of cement.

CONCLUSION

The PMCR cement (Principle-Dentsply) had shown the least solubility to water at different time intervals of immersion. This was followed by PC, zinc phosphate, and GIC, while RMGIC had shown the highest solubility and the GIC had shown a greater percentage of decrease in solubility according to the increased time of immersion in water. Therefore, the present study concludes that GIC and RMGIC require moisture protection after mixing during the early period.

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