Effect of Nano-Coating on Microleakage of Different Capsulated Glass Ionomer Restoration in Primary Teeth: An *In Vitro* Study

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Abstract

Aim: The aim of this *in vitro* study was to assess and compare the effect of the nano-coating on microleakage of different capsulated conventional glass ionomer cement (CGIC), resin-modified glass ionomer cement (RMGIC) and hybrid glass ionomer cement in primary molars.

Materials and Methods: A total of 36 primary molars samples were divided into three groups. Group 1 - teeth restored with capsulated RMGIC (Fuji II LC) without nano-coating. Group 2 - teeth restored with capsulated CGIC (Fuji IX) with nano-coating. Group 3 - teeth restored with capsulated hybrid glass ionomer (Equia Forte) with nano-coating. Microleakage was tested using immersed the teeth in 2% methylene blue dye penetration for 24 hours after the thermocycler and measured at x40 magnification under the stereomicroscope.

Results: The results of this *in vitro* study showed that coating with nano-coating showed a reduction in microleakage in hybrid glass ionomer (Equia Forte) and more microleakage in non-coating RMGIC (Fuji II LC) but also more microleakage in coating CGIC (Fuji IX), which was statistically significant. CGIC with nano-coating and RMGIC without coating showed highest microleakage followed by hybrid glass ionomer (Equia Forte) with coating.

Conclusion: Significant reduction in microleakage was seen in Equia Forte (hybrid glass ionomer) with nano-coating and the coating should use with all types glass ionomer.

Key word: *Conventional glass ionomer cement, G-Coat Plus, microleakage, primary molars, resin-modified glass ionomer cement, thermocycling.*

Introduction

Dental caries is the foremost common chronic disease in childhood. Around the world, the commitment of dental caries to the burden of oral infections is around ten times higher than that of periodontal infection and the other common oral condition. In dentistry, dental caries is the major reason for loss of the teeth, representing a major challenge for oral health. [(1)]. The work of a pediatric dental practitioner treating children is two-fold, we must put quality work for our patients and we must be experts at managing our patient's involvement. We must be able to work with speed and precision. This may only be possible in case we have materials that can hand easily and provide reliable results. One such restoration is glass ionomer cement capsule (GIC) [(2)]. Glass ionomer has been utilized as a dental restoration since its presentation in 1972. With its presentation as a restorative material, there were a few restrictions to the material [(3)]. Since their presentation, glass ionomers have advanced and have been progressed colossally. Today's glass ionomers are simpler to handle by capsule, have superior wear resistance, and have superior esthetics than the first GIC [(4)]. Glass ionomers have numerous preferences as a restorative material. These incorporate, but are not constrained to the capacity to bond chemically to dentin and enamel, biocompatibility, favorable thermal extension, diminished dampness affectability, and the capacity to discharge fluoride, and after that act as a fluoride store. Resin-modified GIC (RMGIC) has resin monomers, like HEMA or Bis-GMA consolidated in its composition, making it a dual-cured cement having higher flexural, compressive, and pliable qualities than ordinary GICs [(5)].

EQUIA (GC, America) may be a new glass ionomer restorative framework. It may be a combination of a self-adhesive, chemically cured, exceedingly filled GIC (Fuji IX GP Additional, GC) and a self-adhesive, light cured, filled resin surface sealant (G Coat Furthermore, GC). The producers of EQUIA claim that the fabric has expanded break durability, flexural quality, and flexural weariness resistance which are required in Class V restorations [(6)].

As a result of these qualities, GIC is perfect for the uncooperative child as well as the "high caries risk" children [(7)]. One of the most disadvantages of the filling materials is the microleakage around a tooth, which can be seen as recoloring around the edges of the filling, postoperative sensitivity, secondary caries, pulpal pathology or pulpal rot and the moment being decreased bond quality of the restorative cement driving to fractional or add up to disappointment of the filling itself. According to Nakabayashi and Pashley, in 1998 microleakage is characterized as the section of liquids and substances through minimal holes on the interface of the filling and teeth [(8)]. Within the glass ionomer cements (GICs), water plays an vital part within the setting. Water is capable for the transport of calcium and aluminum cations, which can respond with the polyacid to make a polyacrylate framework. Joining of water with glass ionomers is related with increment within the translucency of the GIC. The freely bound water can be misplaced from the surface by drying up. This causes an unattractive chalky appearance as infinitesimal breaks create within the drying surface and leads to microleakage. Moreover, the nearness of moisture can lead to retention of water and hygroscopic setting extension. To avoid this, it is critical to secure the cement by covering it with an fitting varnish or petroleum jelly [(9)]. Another advantage of utilizing such surface defenders is that they fill little surface voids and absconds and may offer assistance to protect the first color of the restorations by diminishing the take-up of stains [(10)]. The 21st century is the period of nanotechnology. Nanofillers make strides the wear resistance of coating operator, in this way giving more defensive coating over CGIGs. As of late, G-Coat Additionally and Equia coat a nanofilled, self-adhesive, light-cured defensive coating has been presented for ordinary GIC, RMGIC, composite resin, and compomer. Past studies have affirmed that when connected, the consistently scattered film thickness of G-Coat Additionally gives higher wear resistance, reinforces the rebuilding, and gives exceedingly gloss appearance [(11)]. Therefore, the present study was undertaken to investigate the effect of G-Coat plus (nanofilled, self-adhesive, lightcured protective coating) on microleakage of conventional GIC and RMGIC in primary molars.

Materials and Methods

Sample's selection & mounting:

Thirty-six extracted primary molar teeth for orthodontic purposes or because of still over time will select for the study collected for no more than 3 months inspected beneath magnifying lens to avoid any samples with (cracks, Hypoplastic or hypocalcified teeth), as well as the teeth with caries including more than one-fourth of the occlusal surface, will removed from the study. All the teeth were collected from dental specialized centers in Baghdad or from dental private clinics. The teeth belong to child patients.

The teeth were cleaned with hand-scaler then polished by pumice and rubber cups in handpiece low speed and stored at room temperature in distilled water [(12)].

Covered the roots of teeth by a layer of sheet wax short of the cervical line to work as the soft tissue and act as separating medium between the tooth and silicon. A base of silicon is mounted so that it covers the roots of the teeth short of the cemento-enamel junction and the mounting was in plastic molds.

Samples distribution:

The teeth were randomly distributed and numbered according to the filling materials used into three groups each contain twelfth samples as follows:

- **Group 1:** restored with non-coating Fuji II LC capsulated glass ionomer cement.
- **Group 2:** restored with coating Fuji IX capsulated glass ionomer cement.
- **Group 3:** restored with coating Equia forte capsulated glass ionomer cement.

Cavity preparation and restoration:

In order to standardize cavity preparations for all the teeth,used a modified dental surveyor. Turbine (high speed handpiece) attached to the movable arm of the surveyor in a way put the long axis of the bur in perpendicular to the long axis of the tooth during the preparation. used diamonds depth cutter 2 mm-Crown Prepration bur was used and the bur was replaced after four teeth preparations.

The teeth received class V cavity width 4mm, length 2mm and depth 2mm prepared on the buccal surface of each tooth with no mechanical retention used diamonds depth cutter 2 mm-Crown Prepration bur under air – Water cooling peraration.

The depth and width of the cavity was checked by digital caliper and periodontal probe [12].

After cavity prepared the teeth were rinsed and dried, and moist cotton pellet was placed in the cavity to prevent complete dehydration of the tooth, cavity conditioning was carried out using 20% acrylic acid (GC, Tokyo-Japan) for 10 s by micro brushes and rubbing movements. Then, cavity was rinsed using water spray for 15 s, after that, a piece of cotton was placed in the cavity and gently dried for 5 s using air spray; then, the cotton was removed to prevent complete dehydration [13, 14].

After cavity prepation and cavity conditioner applied to the 36-primary molar.

was restored with glass ionomer cement capsule powder and liquid in capsule according to manufacture,mixed in amalgamator 10 second and restore the cavity to full depth 2mm to cavosurface line angle of cavity after chemical setting take 6 min to group 2 (Fuji IX-GC, Tokyo - Japan) and group 3 (Equia forte-GC, Tokyo - Japan) but group 1 (Fuji II-GC, Tokyo - Japan) according to manufacture used curing with light cure 20 seconds, then finish and polish the filling with enhance polish bur during finish use internal water hand piece then applied layer of G-Goat plus (GC, Tokyo - Japan) it is Nano-fill protecting layer above the filling to group 2 (Fuji IX), and use Equia coat (GC, Tokyo - Japan) it is Nano-fill also to group 3 (Equia forte) then curing with light cure 20 seconds.

Sample's storage and thermocycling of the samples:

All the specimens were then stored for 24 hours in normal saline, then use thermocycler device for thermocycling.

Thermocycling was carried out by soaking the teeth alternatively into (5-55 ±1~2Cº) water bath chambers with 30 seconds immersion time in each bath and 10 seconds transition time **(ISO/TS (E) 11405:2003;** [15, 16, 17, 18]. The thermocycling 500 cycle all the 12 specimens were thermocycled in the same time.

Sample's dye and microleakage measurement:

All the teeth were dried and two layers of nail varnish were applied to the teeth to cover the complete tooth surface except for 1mm around the restoration edges. The root apices of the teeth were sealed with adhere wax and after that submerged in 2% methylene blue color for 24 hours. The teeth had been washed beneath running water and dried.

The samples were blocked with clear epoxy resin; this was done by fabrication of a mold using a specially fabricated plastic molds with dimensions (3-2-1) cm.

Cut longitudinally in the center of the teeth into two pieces using microtome by disk thickness of 0.01mm cutting at high speed and water coolant. The cut halved the tooth bucco-lingually. The cut was made parallel to the long axis of the samples.

The presence of microleakage was affirmed by the visualization of a blue line of the color at the tooth-restoration interface for the occlusal and the cervical dye entrance by visualization by two spectators utilizing stereomicroscope at magnification 40X [19].

The extent of microleakage was evaluated and recorded according to the depth of dye penetration scores given by two way:-

1-Each prepare section will investigation using a sterio microscope (Kruss-Germany) with video output device [20].

Use software (Optika Vision Lite) to measure dye penetration between Glass ionomer filling and tooth in millimeter.

2-The scoring was done as described by Khera and Chan [21].

0 = (No micro-leakage).

1 = Dye penetrating is to the lesser than and up to one half of the depth of the prepared cavity.

2 = Dye penetrating is to more than one-half of the depth of the prepared cavity but not up to the angle of the axial and occlusal or gingival wall.

3 = Dye penetrating up to the angle of the axial and occlusal or gingival wall but not have the axial wall.

4 = Dye penetration have the axial wall.

Pilot study:

After doing pilot study for 5 samples, intercalibration absolute agreement for microleakage (mmm) and its score using Intraclass correlation coefficient (ICC) and weighted Kappa is 0.8 and 0.85 respectively.

Statistical Analysis

Using Statistical Package for social Science **(SPSS version 21, Chicago, IL, USA)**, Descriptive statistics is Frequencies and percentage for nominal variables, minimum, maximum, mean, and standard deviation (SD) for quantitative variable, while median and mean rank for qualitative variable and cluster chart bars. Inferential statistics are Weighted kappa, Intra Class Correlation Coefficient (ICC) Levene test, One Way Analysis of Variance (One Way ANOVA) with Dunnett's T3 posthoc test and finally Kruskal-Wallis test with Multiple Wilcoxon Sum rank and Mann-Whitney U tests adjusted by Dunn-Bonferroni method.

Results

Test of Normality:

The table 1 indicates that micro leakage variable is normally distributed among groups by using Shapiro-Wilk test ($p > 0.05$) so the parametric tests (One way Analysis of Variance "ANOVA".

Measure of microleakage in millimeter penetration of dye:

Results in table 2 demonstrate that microleakage is higher in Capsulated FUJI IX followed by Capsulated FUJI II while the lowest is in the EQUIA FORTE with significant results among them further multiple pair wise comparisons using Dunnett's T3 post hoc test indicates that there is no significant finding between both capsulated of FUJI IX and FUJI II while each one of them is statistically significant with EQUIA FORTE (Figure 1).

Measure of microleakage in score for dye penetration:

Findings in table 3 show that microleakage score is higher in Capsulated FUJI IX followed by Capsulated FUJI II while the lowest is in the EQUIA FORTE with significant results among them further multiple pair wise comparisons using multiple wilcoxon sum rank test indicates that there is no significant finding between both capsulated of FUJI IX and FUJI II while each one of them is statistically significant with EQUIA FORTE (Figure 2).

Distribution of scores among groups:

Results in table 4 shows that score 0 occurs in EQUIA FORTE only, score one mostly occurs in Caps. Fuji II followed by Caps. Fuji IX while lowest in EQUIA FORTE, score 2 finds in caps. FUJI IX followed by Caps.Fuji II, lastly score 3 finds only in Caps. Fuji IX (Figure 3).

Table 1: Tests of Normality of micro leakage area among groups

Types	Shapiro-Wilk			
	Statistic	**df**	**P value**	
Caps. Fuji II	0.867	12	0.0599	NS
Caps. Fuji IX	0.870	12	0.0654	
EQUIA FORTE	0.872	12	0.0693	

Table 2: Descriptive and statistical test of Micro leakage among groups using One Way ANOVA and Dunnett T3 post hoc test.

Types	N	Min.	Max.	Mean	±SD	F	P value	Groups		MD	P value
Caps. Fuji II	12	0.476	1.900	0.9487	0.5393	13.297	0.000*	Caps. Fuji II	Caps. Fuji IX	-0.1231	0.9040
Caps. Fuji IX	12	0.534	1.943	1.0718	0.4502			Caps. Fuji II	EQUIA FORTE	0.7169	0.0022*
EQUIA FORTE	12	.000	0.567	0.2318	0.2522			Caps. Fuji IX	EQUIA FORTE	0.8400	0.0001*

Levene statistics=3.962, p value=0.029 (*), df=2, *.=significant at $p<0.05$, MD=mean difference.

Table 3: Descriptive and statistical test of Micro leakage score among groups using Kruskal-Wallis and Multiple Wilcoxon sum rank test adjusted by Dunn-Bonferonni method.

Types	N	Min.	Max.	Median	Mean rank	Chi square	P value	Groups		MRD	P value
Cap. Fuji II	12	1	2	1.00	21.125	14.187	0.001*	Fuji II	Fuji IX	-2.750	1.00
Cap. Fuji IX	12	1	3	1.00	23.875			Fuji II	EQUIA FORTE	-10.625	0.014*
EQUIA FORTE	12	0	1	0.50	10.500			Fuji IX	EQUIA FORTE	-13.375	0.001*

Df=2, MRD=mean rank difference.

Table 4: Distribution of scores among groups.

Types		Frequency	Percent
Caps. Fuji II	1	9	75.00
	2	3	25.00
Caps. Fuji IX	1	7	58.33
	2	4	33.33
	3	1	8.33
EQUIA FORTE	0	6	50.00
	1	6	50.00

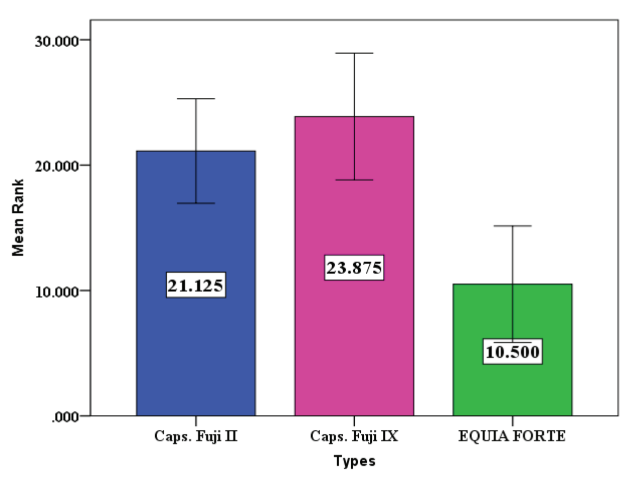

Figure 1: Micro leakage among group.

Figure 2: Micro leakage score among group

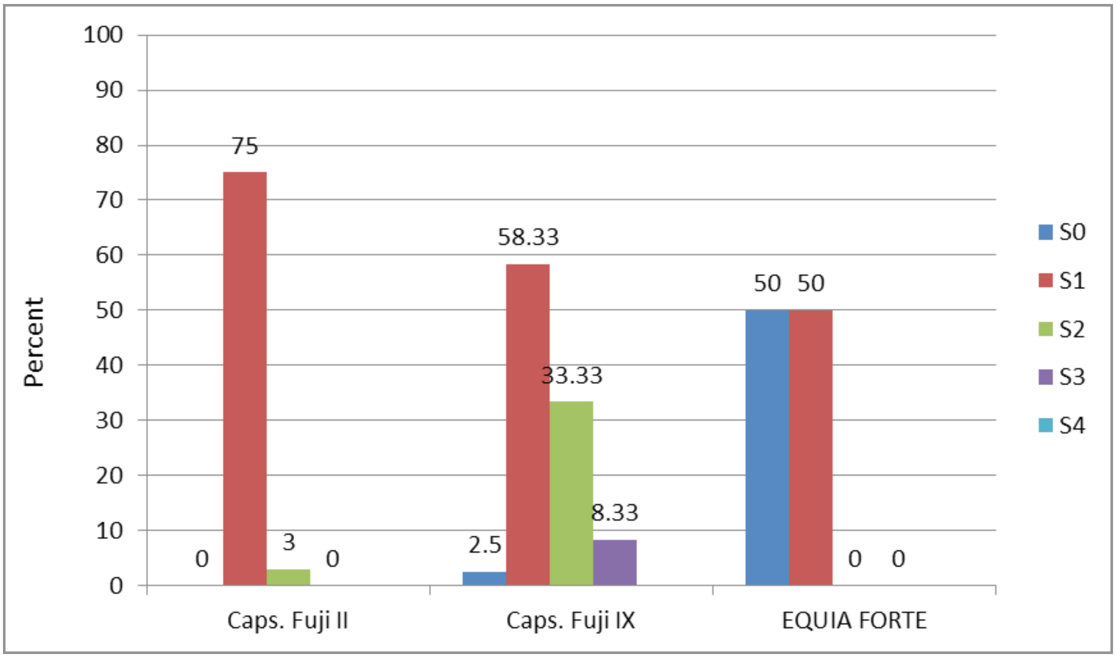

Figure 3: Distribution of scores among groups

Discussion

Enamel of deciduous teeth contains less calcium and phosphorus than permanent teeth; additionally, Deciduous teeth have more sensitive of enamel rods with more density. The Dentinal tubule numbers in deciduous teeth are more than permanent teeth. All of these variables can cause higher microleakage score in deciduous compared with permanent teeth. [22].

Thermocycling has been utilized in this study to mimic oral conditions. This prepare may highlight the mismatch in thermal extension between the restoration and tooth structure, coming about in numerous volumetric changes amid temperature changes and causing weakness of the adhesive joint with consequent microleakage. This is often in understanding with other investigates, which expressed that, thermo-cycling as intra-oral temperature varieties and subjecting the restorations on the tooth to temperature extremes consistent with oral cavity [23, 24].

Glass ionomers (GIC) have been used as a restorative material since of their capacity to chemically bond to tooth structure and discharge fluoride. They are broadly utilized in dentistry for restoration, as a luting and liner or base. GICs are most sensitive restorative materials to the moisture during the early stages to placement. [25].

Water plays a key part within the development of GIC. Drying out and water defilement amid the starting setting stages can compromise the physical properties of restoration [11].

According to Gemalmaz *et al*. (1998), when GIC restorations were contaminated with moisture, their mechanical quality diminished and the surface of the material disintegrated or wore quickly. The ability of (GIC) to minimize the degree of microleakage at the tooth or restoration interface is an important factor in clinical success. In the studies microleakage can happen due to disintegration of the tooth-restoration interface, contrasts between thermal expansion coefficients of the restorative material – tooth tissue or polymerization shrinkage, causing recoloring, recurrent caries, and restoration failure. [26].

To overcome the downsides of GIC from moisture defilement and drying up amid starting setting arrange, it has continuously been suggested that GICs must be covered quickly after put (GIC)with a water-proof surface coating [9].

Studies have suggested protection of the surface amid the starting setting of GIC with different surface coating agents such as cocoa butter, waterproof varnish, and also nail varnish [11].

Earl *et al*. (1989) have appeared that quick covering of immature (GIC) with a light-cured resin bonding is the foremost viable strategy of restricting movement of the water across to the surface [11].

According to Tyagi., et al, (2020)[26] the amount of soluble framework is greatest amid the early stages of GIC formation and the foremost sensitive period is the primary six minutes after mixing. Any contamination by moisture amid this stage can cause the loss of soluble network and diminish its physical properties, thus the GIC ought to be ensured from extra water contamination amid the starting stages to avoid disintegration of particles though once it sets.

In this study found Fuji IX (conventional GIC) with coating and Fuji II (RMGIC) without coating have high microleakage and not significant different between them but equia fort with coating have not and less microleakage.

In previous studies founds Fuji II LC (resin modified glass ionomer) without coating less microleakage than Fuji IX (conventional glass ionomer) without coating because resin-modified GIC (RMGIC) has resin monomers, like HEMA or Bis-GMA incorporated in its composition, making it higher flexural, compressive, and tensile strengths than conventional GICs [27, 28, 29] thus in this study the coating give improve to the Fuji IX become the same degree of microleakage to the Fuji II LC without coating.

According to Chuang, et al. (2001)[30], resin-modified glass ionomer cements (RMGIC) were developed to replace conventional GICs. RMGICs are materials that set concurrently via a dominant acid-base reaction and auxiliary photopolymerization. With the addition of resin monomer (2-hydroxyethyl methacrylate [HEMA]), and light-polymerized initiators, RMGICs are polymerized immediately after visible light irradiation. Compared with conventional analogs, RMGICs have been characterized as having a longer working time, a rapid set, improved appearance and translucency, and higher early strength. However, RMGICs retain some properties of their conventional counterparts. Additional resin monomer and supplementary photopolymerization have not significantly reduced the susceptibility of RMGICs to dehydration problems. Thus, the maintenance of water balance in the modified cements is important, resin-modified glass ionomers can be finished immediately, they remain moisture sensitive , the results suggest that resin adhesive should be used as a surface protection to reduce margin microleakage of resin-modified glass ionomer restorations, Their results indicated that RMGICs should be protected from water for at least 1 hour after cement mixing. In contrast, most manufacturers' instructions indicate that RMGICs can be used with or without surface protection.

Whereas the most elevated scores were in Fuji II LC. This may well be come about from polymerization shrinkage that happens in light cured tar adjusted glass ionomer cements. Polymerization shrinkage creates inside 5 minutes after curing and proceeds for another 24 hours. This shrinkage brought about in withdrawal stress which can break the adhesive interface and make the gaps in the margin [12, 31].

The display study shown that there was significant contrast in microleakage between three groups i.e. EQUIA specialty appeared lesser leakage. The advantage of GC EQUIA Strong point is an inventive restorative framework based on a new glass hybrid innovation, which has more voluminous glass fillers of EQUIA Specialty Fil were supplemented by smaller, exceedingly receptive fillers that reinforce the restoration. In combination with the EQUIA Strong point coat, a composite coating the flexural strength increments by 17% and flexural energy by nearly 30%. EQUIA Specialty Coat enters the surface porosities, hence increasing the quality of the generally EQUIA filling and diminishes the microleakage around the restoration [32].

Conclusion

According to this study an in vitro study conclusion into:

1- Conventional glass ionomer (GC-Fuji ix) with nano-coating (GC G-Coat plus) have high microleakage equal to resin modified glass ionomer (GC-Fuji II LC) without coating.

2- Nano-Coating (GC-Equia coat) with resin modified glass ionomer (GC-EQUIA FORTE) have very low microleakage.

3- Maximum score in Fuji IX with coating then in Fuji II LC without coating but minimum score in Equia Forte with coating.

4- Thus, prefer use Nano-Coating with RMGIC to minimum microleakage.

5- Nano-Coating nanofilled resin-coating provides a high hydrophilicity combined with an extremely low viscosity, thus accounts for a perfect seal to GIC also provide color stability to cement and glossy appearance and bond chemically to tooth structure.

Declarations

Conflict of Interest the authors declare that there are no potential conflicts of interest related to the study.

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Ethical Clearance: This research has exemption as it a routine treatment (no new materials were used).

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