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Evaluation of Microleakage of a New Generation Nano-Ionomer in Class II Restoration of Primary Molars

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Abstract**—**Objective: This *in vitro* study was carried out to assess the microleakage properties of nano-filled glass ionomer in comparison to resin-reinforced glass ionomers. Material and Methods: 40 deciduous molar teeth were included in this study. Class-II cavity was prepared in a standard form for all the specimens. The teeth were randomly distributed into two groups (20 per group) according to the restorative material used either nano-glass ionomer or Photac Fill glass ionomer restoration. All specimens were thermocycled for 1000 cycles between 5 and 55 °C. After that, the teeth were immersed in 2% methylene blue dye then sectioned and evaluated under a stereomicroscope. Microleakage was assessed using linear dye penetration and on a scale from zero to five. Results: Two way ANOVA test revealed a statistically significant lower degree of microleakage in both occlusal and gingival restorations (0.4±0.2), (0.9±0.1) for nano-filled glass ionomer group in comparison to resin modified glass ionomer (2.3±0.7), (2.4±0.5). No statistical difference was found between gingival and occlusal leakage regarding the effect of the measured site. Conclusion: Nano-filled glass ionomer shows superior sealing ability which enables this type of restoration to be used in minimum invasive treatment.

Keywords**—**Microleakage, nano-ionomer, resin-reinforced glass ionomer, proximal cavity preparation.

I. Introduction

CONVENTIONAL treatment of deep carious lesion is based on the aggressive approach of complete caries removal. However, complete removal of carious dentine does not adhere to today's challenges of maximum preservation. The changes towards minimal invasive and maximum preservation focus on indirect pulp therapy techniques. Thus, proper sealing of the cavity is essential for arresting the activity of bacterial biofilm. Literature has shown that large number of failures in indirect pulp therapy occurs due to inadequate final seal [1]. Proper sealing not only inhibits the nutrient supply but also creates proper environment for remineralization [2].

Microleakage permits the bacteria and tiny molecules to go through the gap between the restoration and the cavity walls [3]. It is the most common problem that causes failure of almost all restorative materials since it is the main cause of secondary caries and pulpal irritation [4]. Accordingly, there is an interest toward finding a restorative material which has better chemical and physical properties, thus decreasing microleakage and reducing the development of dental caries at the restoration margins and resultant pulpal irritation [3], [5].

Resin-modified glass ionomer is recommended for pediatric patients due to its excellent sealing ability and marginal adaptation [6], [7]. The presence of photo-initiator systems in the formula of resin-modified glass ionomer together with the light curing system allowed a better controlling of the work and setting time, which are particularly important when used in pediatric dentistry approach [8]. It also has the advantage of fluoride releasing properties, rapid development of strength and more resistance to early moisture contamination. It has improved tensile, compressive strength and elastic modulus, when compared with conventional glass ionomer [9].

In 2007 Ketac Nano (3M ESPE) was introduced to the markets by the name of nano-ionomer. This product combined the advantage of resin-modified light-cure glass ionomer cement (RMGIC) and bonded nanofiller particles. It is known to exhibit improved esthetics while retaining the beneficial qualities like fluoride release [10]. Incorporation of nanotechnology enhances the physical properties like wear resistance, polishability, esthetics, abrasion resistance, strength and optical properties [11], [12].

The nano-sized-glass ionomer showed better adaptation to the hard tooth structure than other restorative materials as it promotes more microleakage resistance [13]. It has been termed as "tissue-specific direct tooth repair" and it is recommended for all types of cavity preparation in the primary tooth [14].

In occlusal and cervical cavities, the marginal seal can generally be preserved around cavity preparations as cavosurface margins are restricted to enamel due to its inorganic nature. This is not the case in proximal cavities where the cavosurface margins are facing two surfaces; enamel and dentin/cementum; this increases the difficulty in placement of the restorative materials [15]. The anatomy of primary teeth included constricted neck, broad-gingivally located contact areas and marked decrease in the thickness of enamel and dentine in the proximal area, this may explain the difficulty in achieving adhesion in this area and increase the tendency of microleakage [16], [17].

There is limited data about the microleakage in class II cavities; so, the aim of this study was to evaluate the microleakage properties of nano-filled glass ionomer (KetacTM Nano light-curing Glass Ionomer Restorative) in

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comparison to resin-reinforced glass ionomers (photak fill Quik Aplicap) in class II cavities of deciduous teeth.

II. Material and method

A. Selection and Preparation of Teeth

40 freshly extracted caries-free second primary molar teeth were selected for this study. Residual tissues were removed by brush; the teeth were cleaned with a rubber cup and slurry of pumice, and investigated under a stereomicroscope at 20X for surface cracks or developmental defects. After that, the teeth were stored in distilled water at room temperature.

B. Cavity Preparation

Standard class-II cavity preparations were prepared by one operator using a high-speed handpiece under air-water spray using # 330 fissure burs (Diatech Dental AG, Heerbrugg, Switzerland). Measurement of the cavity preparations were standardized using metallic scale and calibrated periodontal probe. All cavosurface margins were beveled (approximately 1 mm) using the same bur. New burs were used after every ten preparations. For the purpose of standardization, all the specimens were prepared by one hand operator as following: The occlusal part of the preparation measured 3 mm in depth and 2 mm in buccolingual width, and the proximal margins were placed 1 mm above the cementoenamel junction (CEJ). The depth of the box from cavosurface margin to the axial wall was 3 mm and the buccolingual width was 3.0 mm.

Following cavity preparation, the root apices and the furcation regions were sealed with wax in all teeth in order to prevent dye penetration through the pulp chamber.

C. Samples Preparation

The teeth were randomly selected and assigned to one of the two experimental groups according to the restoration type (20 per group). Group I: Using Nano glass ionomer restoration (Ketac^{TM} Nano light-curing Glass Ionomer Restorative. 3M ESPE), Group II: Using resin modified glass ionomer restoration (Photac Fil Quik Aplicap. 3M ESPE). All restorative procedures were carried out in accordance with the manufacturers' instructions and cured by the same light-curing unit (POLYlux II, KaVoDental Gmbh, KG, and Germany)

In group I: Ketac Nano Primer was painted within the cavity preparation and over the cavosurface margins. Excess primer was washed out using dry air. Then the primer was allowed to cure using light cure beam for 10 seconds. Ketac Nano shade A3 was applied following manufacturer's instructions. The restoration was light cured for 20 seconds followed by finishing and polishing using slow-speed medium and fine diamond burs, aluminum oxide and discs.

In group II: Photac Fil quick applicap shade A3 was mixed for 10 seconds at 4300 rpm high frequency in a Kerr Automix computerized mixing system, and applied following manufacturer's instructions then the restoration was light cured for 20 seconds. Finishing and polishing were done as in group I. Following storage in distilled water at 37 ºC for one week, the specimens were thermocycled for 1000 cycles. Dwell times were 30 s. in each water bath (BILGE, Turkey) with a lag time 10 s. The low-temperature point was 5 ºC and the high-temperature point was 55 ºC.

D. Assessment of Microleakage

Two layers of nail polish were used to paint the surface of each tooth leaving 1 mm around the restoration margin free of painting then the teeth were immersed in a solution of 2% methylene blue dye (Supreme organization for drugs, Germany) for 24 hours at room temperature. Posteriorly, the teeth were removed from the dye solution, washed with water, and the samples were mounted into special holding device for sectioning.

The teeth were sectioned mesio-distal direction with a low speed diamond saw (Top Dent, Edenta Golden, Swiss) under water spray. The specimens were rinsed in running water and then dried with tissue paper.

The dye penetration along the cavity wall (including both occlusal and gingival margins) was assessed with a measuring Stereomicroscope (Nikon Eclips E600, Tokyo, Japan) at 45× magnification in which the image of the restoration was captured and transferred to a computer equipped with the image analysis software program (Image J 1.43U, National Institute of Health, USA), marginal leakage can be measured by determination of the depth of dye penetration. Six degrees of leakage were used, utilizing a standardized system suggested by [18] and modified by [19].

- Degree 0: No penetration of dye
- Degree 1: Penetration of dye along the occlusal or gingival wall limited to the enamel
- Degree 2: Penetration of dye along the entire length of the occlusal or gingival wall but not along the pulpal wall
- Degree 3: Penetration of dye along the pulpal wall
- Degree 4: Diffusion of the dye into the dentin under the pulpal wall
- Degree 5: Penetration of dye through the dentin into the pulp chamber.

Every section was rated separately for the occlusal and cervical margins. The examination of the teeth was done by two investigators independently. If they get different scores, discussion took place till agreement.

E. Statistical Data Analysis

The microleakage value for each group, and subgroup was calculated as mean ± SD. Data analysis was performed in several steps. For numerical values, two way ANOVA was done for comparing variables (materials and site) affecting mean values.

One way ANOVA test was done to detect significance between subgroups. Considering scoring system, Chi square test was done to determine the subgroups significance. Statistical analysis was performed using Graphpad In-Stat statistics software for Windows. P values $\leq$ 0.05 are considered to be statistically significant in all tests.

III. Results

This study was classified as a case-control study in which two types of teeth restorations were compared to each other.

Group I (nano-filled glass ionomer) and Group II (resin modified glass ionomer) were compared regarding marginal leakage on recently extracted primary teeth.

The data of microleakage in the occlusal and gingival part in both groups have been summarized in Table I.

Two way ANOVA test reveals that:

1- Regarding the effect of material: It is clear that, nano-filled glass ionomer group showed statistically lower degree of microleakage in both occlusal and gingival restorations (0.4±0.2), (0.9±0.1) than resin modified glass ionomer (2.3±0.7), (2.4±0.5).
2- Regarding the effect of measuring site: There was no statistical difference between gingival and occlusal leakage site.

One way ANOVA test was done to compare between the four subgroups, where a significant difference between the subgroups was revealed. The highest mean value was recorded in gingival site of Group II (2.4±0.5) following by occlusal site of group II (2.3±0.7) and gingival site of group I (0.9±0.1) while occlusal site of group I recorded the lowest mean value (0.4±0.2).

TABLE I
LEAKAGE RESULTS FOR BOTH GROUPS AT DIFFERENT MEASUREMENT SITES

	Group I		GroupII		
	Occlusal	Gingival	Occlusal	Gingival	Statistics
Score 0	60	10	30	20	<0.0001*
Score 1	40	90	0	40	
Score 2	0	0	40	0	
Score 3	0	0	0	20	
Score 4	0	0	0	0	
Score 5	0	0	30	20	
Mean±SD	0.4±0.2	0.9±0.1	2.3±0.7	2.4±0.5	0.0038*

* significant (p<0.05)

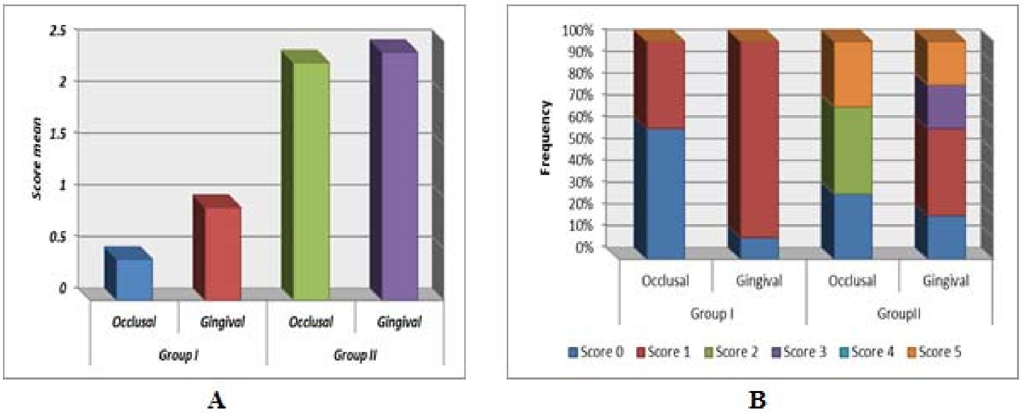

Fig. 1 (A) Mean values of leakage scores for both groups at different measurement site (B) Leakage scores for both groups at different measurement sites

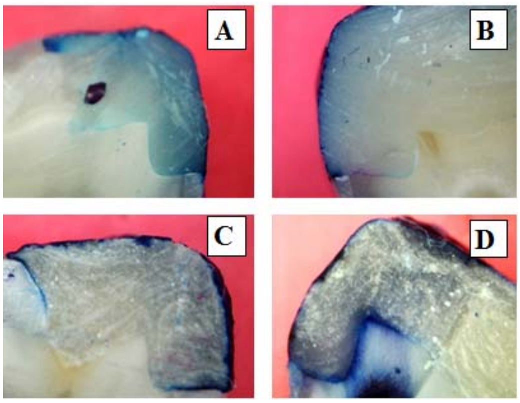

Fig. 2 (A) Microscopic image of dye penetration showing score 0 microleakage (B) score I microleakage (C) score II microleakage (D) score V microleakage.

IV. DISCUSSION

Many changes happened in the field of dentistry in the last decade. In recent years, preventive methods, minimally invasive methods and longevity of restorations have gained special attention in pediatric dentistry [20], [21].

One of the major problems faced by the pediatric dentists is the restoration of carious teeth in children, as the children have lower biting forces and deciduous teeth have limited lifespan. Glass ionomer cements is commonly used in primary dentition, the use of this material offering an advantage in the primary dentition as it has the ability of releasing fluoride and to adhere to dental hard tissues [22].

Short-term clinical studies have shown that Class II glass ionomer restorations in deciduous molars have significantly lower performance than other materials [22] [23]. With the increased interest in using nanomaterials in dentistry, a nano-ionomer is now available in the markets. And because of its superior properties, it may increase the success rate of glass ionomer in class II restoration of deciduous teeth [24].

The aim of this study was to evaluate and compare microleakage properties of two most commonly used glass ionomers worldwide, nano-filled glass ionomer (KetacTM Nano light-curing Glass Ionomer Restorative) and resin-reinforced glass ionomers (photak fill Quik Aplicap) in class II primary molars.

Microleakage is considered as one of the main problems that most of the dentists faced. To increase the clinical success rate of any restorative material, the microleakage at the tooth/ restoration interface must be in its lower limit [21]. Different methods are used to evaluate the microleakage of restoration, including silver nitrate, air pressure, bacteria, radioactive isotopes, organic dyes, calcium hydroxide technique and scanning electron microscope (SEM).

Dye penetration is considered as a successful method because of its easy penetration into the flaws and crevices of the test object. Some of the organic dyes used include basic fuchsin, methylene blue, eosin, aniline blue, crystal violet and erythrosin B [25]. In this study, we used the methylene blue solution because it can penetrate better than other solutions due to its size that is smaller than the smallest bacteria. On the other hand, it is inexpensive and easy in handling [26]. De Almeida et al. [27] stated that the dye permits an easy visualization of the sample cavity and excellent contrast with the surrounding environment.

Thermocycling is a widely used method to simulate oral conditions in dental research particularly when testing the performance of adhesive materials. This method aims to subject the restored teeth to extreme temperatures similar to that happened in the oral cavity. The variable temperature produces thermal stresses in the adhesive joint at the tooth/ restoration interface, which may lead to fatigue in the joint with subsequent microleakage [21]. However, there is no standard for thermocycling methodology in microleakage studies, the literature shows that there is a wide range in temperature extremes, transfer times between baths and dwell times [26], [28], [29]. Thus, this permits contradictory discussions and leads to variation in the laboratory tests. In the present study, all the samples were thermo-cycled in cold and hot bath within the range of 5-55°C, with a dwell time of 30 sec to simulate the oral environment. The same has been recommended earlier [21], [30], [31].

The result of this study showed that, nano-filled glass ionomer group showed statistically lower degree of microleakage in both occlusal and gingival restorations (0.4±0.2), (0.9±0.1) than resin modified glass ionomer (2.3±0.7), (2.4±0.5). Regarding the dye penetration score, the difference between the subgroups was statistically significant. The highest microleakage was recorded at the gingival margin of group II (2.4±0.5) while the lowest microleakage was recorded at the occlusal margin of group I (0.4±0.2), Comparison of leakage at the occlusal and gingival margins revealed no significant difference. A similar result has also been reported previously by Puckett et al. [32].

In this study, nano-filled glass ionomer showed lower microleakage scores at the occlusal and gingival margin, this finding was in agreement with some studies which mention that the nano-ionomer demonstrated less microleakage [13], [33]-[35]. This may be explained by the use of nano-primer, this primer allows modification of the smear layer, increasing the wetness of the tooth surface, maximizing the water uptake of the cement and thus improving the adhesion properties of Ketac Nano-restorative [21]. In nano-ionomer, the superior adaptation to the tooth surface may refer to the nano-size of the glass ionomer particles which increases its surface area and enhances the flowability of the material. Also incremental layer technique, which is used in placement of nano-filled resin-modified glass ionomer, may have resulted in better adaptation leading to reduced microleakage [35], [36]. However, leakage of resin modified glass ionomer could be due to rigid framework and less capability of elastic deformation at the initial stage of polymerization [35]. As the resin component of resin-modified glass ionomer is responsible for the polymerization shrinkage of light-cured glass ionomers, it could adversely affect marginal adaptation [37]. Prati et al. [38] stated that in RMGIC, un-removal of the smear layer can act as a weak point leading to cohesive failure during polymerization shrinkage and episodes of thermal expansion and contraction which can affect the bond between RMGIC and dentin.

V. Conclusion

Nano-filled glass ionomer provides margins show least leakage in comparison to resin-modified glass ionomer. So it is recommended to use nano-filled glass ionomer in class II cavities of primary molars

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