EGYPTIAN
DENTAL JOURNAL

Vol. 62, 9:19, January, 2016

I.S.S.N 0070-9484

EDJ
EGYPTIAN DENTAL JOURNAL

WWW.EDA-EGYPT.ORG

MARGINAL MICROLEAKAGE OF FIVE DIFFERENT GLASS IONOMER RESTORATIONS IN PRIMARY TEETH WITH OR WITHOUT POLISHING

Ghada Mohamed Mahmoud Aly*; Nehal Refaat Kabel** *and* Dawlat Mostafa Ahmed***

ABSTRACT

Aims and Objectives: The purpose of this *in vitro* study was to investigate the effect of polishing on the microleakage of five different Glass Ionomer restorative materials.

Materials and Methods: Class V cavities were prepared at the labial surfaces of 50 freshly extracted primary anterior teeth. The prepared teeth were randomly divided into five groups and restored with Equia Fort, photac fil, Ketac molar, riva self cure and Fuji IX. each group was further subdivided into two subgroups (polished and not polished) of 5 teeth each. Finishing and polishing of the polished group was done using the Sof-Lex polishing system. Furthermore, all the restorations were subjected to dye penetration testing.

Results: EQUIA specimens showed the least microleakage which was significantly better than the rest of groups. Maximum microleakage scores were observed in specimens of groups III and V (ketac molar and fuji IX). There was no significant difference between polished and non polished specimens of each group.

Conclusions: Generally, resin modified glass ionomer cements produced more favorable results than conventional glass ionomer in terms of microleakage, with the exception of EQUIA, exhibiting excellent results. Also, polishing of glass ionomer restorations has no effect on marginal microleakage.

KEYWORDS: Glass ionomer, Microleakage, Resin modified glass ionomer

INTRODUCTION

Dentistry had always thrived to achieve biocompatible restorations that do not compromise the pulp, attain chemical retention to dental tissue, and also has anticaries properties. One of the significant contributions has been the development of glass ionomer restorative materials.

In general, glass ionomer cements are classified into three main categories: conventional, metal-reinforced and resin-modified.[1-3] Conventional

* Lecturer of Pediatric Dentistry. Modern Science and Arts University. Cairo, Egypt.
** Lecturer of Pediatric Dentistry. Misr University for Sience and Technology. Cairo, Egypt.
*** Lecturer of Dental Biomaterials. Alexandria University. Alexandria, Egypt

glass ionomer cements were first introduced in 1972 by Wilson and Kent[4] .They are derived from aqueous polyalkenoic acid such as polyacrylic acid and a glass component that is usually a fluoroaluminosilicate. When the powder and liquid are mixed together, an acid-base reaction occurs. As the metallic polyalkenoate salt begins to precipitate, gelation begins and proceeds until the cement sets hard. [1]

Glass ionomer cements are believed to possess several advantages over resin material. These include good adhesion to tooth enamel and dentine, long-term fluoride release and less toxic to dental pulp. They also have potential to inhibit caries and exhibit antibacterial activity generally by a low setting pH.[5] These acid-base reaction cements can be regarded as bioactive and therapeutic.[6] Bonding between the cement and dental hard tissues is achieved through an ionic exchange at the interface[7] .Polyalkenoate chains enter the molecular surface of dental apatite, replacing phosphate ions. Calcium ions are displaced equally with the phosphate ions so as to maintain electrical equilibrium. [1] This leads to the development of an ion-enriched layer of cement that is firmly attached to the tooth . [7]

As early as 1977, it was suggested that glass ionomer cements could offer particular advantages as restorative materials in the primary dentition because of their ability to release fluoride and to adhere to dental hard tissues. [8] And because they require a short time to fill the cavity, glass ionomer cements present an additional advantage when treating young children. [9]

But these cements are brittle and their flexural and compressive strengths are much weaker than those of amalgam. To improve the physical properties of the material, metal particle reinforced GIC or cermet cements were developed. They have the advantage of greater flexural strength, less occlusal wear, improved radioopacity and faster setting reaction [10] . Conventional glass ionomer cement was again modified and resin glass ionomer cement which sets by the spectrum of visible light came into existence. These materials have the advantages of longer working time, less sensitivity to water during setting and were more convenient to use [11]

Recently, several faster setting, high-viscosity conventional glass ionomer cements have become available. Called viscous or condensable glass ionomer cements by some authors,[12] these restorative materials were originally developed in the early 1990s for use with the atraumatic restorative treatment in some developing countries. [13] These materials set faster and are of higher viscosity because of finer glass particles, anhydrous polyacrylic acids of high molecular weight and a high powder-to-liquid mixing ratio.[12-13] The setting reaction is the same as the acid-base reaction typical of conventional glass ionomer cements. In 1992, resin-modified glass ionomer cements were developed that could be light cured. In these materials, the fundamental acid-base reaction is supplemented by a second resin polymerization usually initiated by a light-curing process.[2-3] In their simplest form, they are glass ionomer cements that contain a small quantity of a water-soluble, polymerizable resin component. More complex materials have been developed by modifying the polyalkenoic acid with side chains that could polymerize by light-curing mechanisms in the presence of photo initiators, but they remain glass ionomer cements by their ability to set by means of the acid-base reaction.[2]

The permanent teeth contain more inorganic content as compared to the primary teeth, leading to the strong bond which in turn might have lead to the decrease in microleakage. According to Hirayama[14] who revealed that peritubular dentin of primary teeth is 2–5 times thicker than that of permanent teeth, with thicker peritubular dentin, there is relatively less intertubular dentin. And since intertubular dentin is the major area where bond occurs, primary teeth provide lesser bonding as compared to the permanent teeth leading to increase in microleakage.

Clinical observation has led to the conclusion that GICs both reduce the tendency to demineralization and enhance the remineralization of enamel and dentine that has been subjected to caries attack.[15] The coefficient of thermal expansion of GIC is similar to that of tooth structure, but their capacity to prevent microleakage is disputed.[16-17]

The coefficient of thermal expansion of conventional glass ionomer cements is close to that of dental hard tissues and has been cited as a significant reason for the good margin adaptation of glass ionomer restorations.[4] Even though the shear bond strength of glass ionomer cements does not approach that of the latest dentin bonding agent, glass ionomer restorations placed in cervical cavities are very durable.[4] Nevertheless, microleakage still occurs at margins. An in vitro study has shown that conventional glass ionomer cements were less reliable in sealing enamel margins than composite-resin.[18]

They also failed to eliminate dye penetration at the gingival margins.[18-20] Although resin-modified glass ionomer cements show higher bond strength to dental hard tissues than conventional materials, they exhibit variable results in microleakage tests.[21-23] Not all of them display significantly less leakage against enamel and dentin than their conventional counterparts.This may be partly because their coefficient of thermal expansion is higher than conventional materials, though still much less than composite-resins. Controversy also exists as to whether the slight polymerization shrinkage is significant enough to disrupt the margin seal. [2-3]

Microleakage allows oral microorganisms and chemical substances to migrate through the tooth-restoration interface.[24] Bacteria, fluids, molecules, or ions can pass through this gap between the restoration and the cavity wall, Microleakage is thought to be responsible for hypersensitivity, secondary caries, pulpal pathosis, and failure of restorations.[25-26] Besides pulpal irritation and secondary caries, microleakage also results in marginal discoloration.

Possible reasons for microleakage at the restoration margin are cavity configuration (C-factor), dentinal tubule orientation to the cervical wall (CEJ), organic content of dentine substrate and movement of dentinal tubular fluids, incomplete alteration or removal of smear layer, physical characteristics of the restorative material, (filler loading, volumetric expansion, and modulus of elasticity), inadequate margin adaptation of restorative material, and instrumentation, and finishing and polishing effects.

It is generally accepted that a smooth surface has a beneficial effect on the esthetic quality and longevity of the restoration, as well as on its biocompatibility with the oral tissues. Furthermore, the benefits of a smooth restoration are: [27-28]

1. Minimal irritation of soft and hard tissues
2. Stimulates natural tooth surface esthetics
3. Less likely to trap food debris and plaque
4. Reduced potential for corrosion
5. More hygienic.

Since good marginal seal can reduce the marginal leakage which is the precursor of secondary caries, marginal deterioration, postoperative sensitivity and pulpal pathology [29]. Investigation of micro leakage at the margins would contribute to better assessment of material.

Hence, the present in vitro study was undertaken to evaluate the micro leakage of recently available glass ionomer cements used as restorations in primary teeth and the effect of polishing on their microleakage.

MATERIAL AND METHODS

This study was performed on fifty recently extracted primary incisors. They were selected to be free of caries, abrasion, attrition, fluorosis, or other enamel defects. After extraction, the teeth were stored in normal saline at room temperature till the study was conducted. After retrieving from the normal saline, class V cavities were prepared on the labial surface of each tooth. Cavities were prepared with standardized dimensions of height of 2 mm, width of 4 mm, and depth of 2 mm. (Fig 1) Care was taken that cavity margins were surrounded by enamel. The cavity was prepared with # 330 carbide bur on a high-speed hand piece with water spray(30) , the length of bur was used as guide for cavity depth. Each bur was replaced after five preparations.

Teeth were randomly divided into five equal groups and restored with five different types of glass ionomer based restorative materials; (Fig 2) EQUIA Forte*, photac fill**, ketac molar***, riva self cure ****, and Fuji IX GC Extra ***** (groups I to V respectively) The restorative materials were used according to their manufacturers' recommendations. The groups were further randomly subdivided into 10 equal subgroups (a&b), in which specimens of subgroups Ia, IIa, IIIa, IVa and Va were polished with soflix discs , while subgroups Ib, IIb, IIIb, IVb and Vb were not polished.

The specimens were stored in the normal saline at the room temperature for 24 h, they were then subjected to 250 cycles of thermocycling between 5 ±2˚C to 60±2˚C with dwell time of 30 s in each water bath and 10 s interval between the baths. For this purpose, the custom made thermocycling machine in the Dental Biomaterials Department, Alexandria University was used (Fig 3).

To assess microleakage in the restorations, samples were dried superficially with absorbent paper and sealed with 2 coats of nail varnish, leaving a 1 mm window around the cavity restoration margins. The apical region of each tooth was also sealed with epoxy glue to prevent dye penetration.(31) The teeth were then stored in 1% methylene blue for 24 h. (Fig 4) After 24 h, the samples were removed from the dye and washed thoroughly with the slurry of pumice to remove the superficial dye. The teeth were then sectioned longitudinally through the centre of the restoration in bucco-lingual plane using a diamond disc under water spray. Providing 1.5 mm thickness cuts per tooth

The area of the restoration was captured by a CCD digital camera (DP10, Olympus, Japan) mounted on Zoom stereo microscope****** (Fig 5) at a magnification 70x. Digital images were then transferred to a computer system.

Microleakage was assessed also by scoring the degree of linear dye penetration in the tooth / restoration interface. The degree of dye penetration was identified according to Silveira de Ara´ujo et al.(32)

- Score 0-no dye penetration
- Score 1-penetration involving half the occlusal/gingival wall
- Score 2-penetration involving more than half the occlusal/gingival wall
- Score 3-penetration involving up to the axial wall

Both sections of each restoration were scored and the section with the greatest amount of microleakage was recorded as the score of that restoration. Microleakage scores were recorded for the gingival margins. All recorded data were tabulated and statistically analyzed.

---

* GC corporation.76-1 Hasunuma-cho,Itabashi-ku,Tokyo 174-8585, Japan.
** 3M Deutschland GmbH Dental products. Carl-Schurz-Str.1.41453Neuss-Germany
*** 3M ESPE Dental Products, St.Paul. U.S.A.
**** Riva self cure . SDI Limited……………Australia
***** GC corporation.76-1 Hasunuma-cho,Itabashi-ku,Tokyo 174-8585, Japan
****** Olympus SZ-PT-Japan

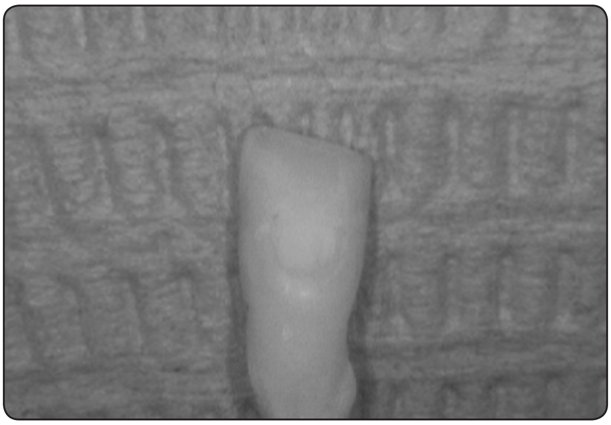

Fig. (1) Standardized class V cavity prepared in a primary incisor.

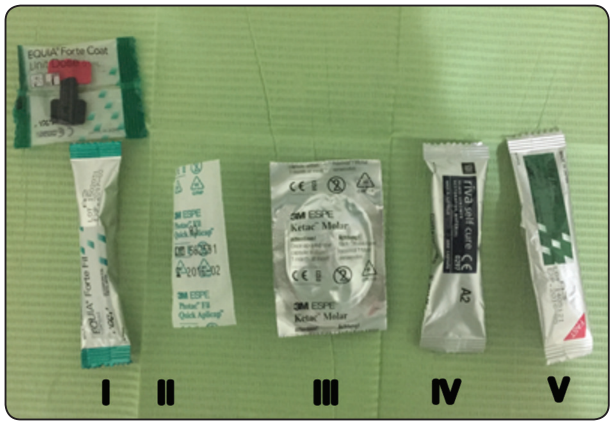

Fig. (2) The five tested glass ionomer restorative materials; I(EQUIA forte), II (Photac fil), III(Ketac Molar), IV (riva self cure) &V(Fuji IX).

Fig. (3) A custom made Thermocycling machine

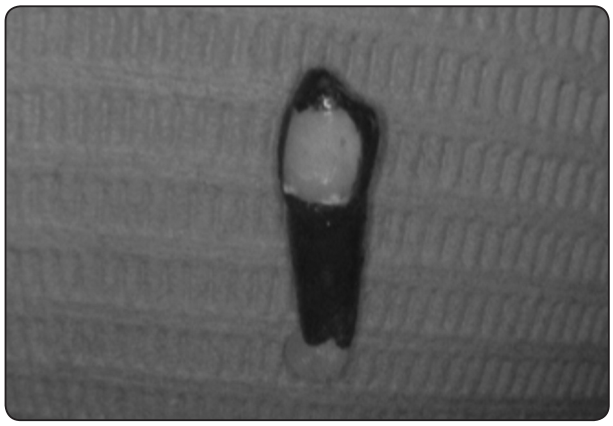

Fig. (4) A specimen coated with nail varnish before immersion in dye.

Fig. (5) The stereomicroscope.

RESULTS

This study was carried out on 50 human clinically sound primary incisors. Class V cavities were prepared in the cervical third of each tooth on the buccal or lingual surface surrounded by enamel. The prepared teeth were classified into five equal groups, 10 specimens each, according to the type of restoration used. Assessment of microleakage scores was done.

Table (1) shows the comparative analysis of microleakage scores for the tested restorative materials. All the specimens in group I showed zero microleakage (Fig6), which was significantly better results when compared to the rest of the groups ($p<0.001$)

As for group II; 30% of the specimens showed score 2 (Fig 7), and 70% showed score 3, with dye penetration to the axial wall. The difference was significant only when compared with group I.

It is clear that specimens of both group III and V showed the maximum microleakage , with 100% and 80% of specimens exhibiting dye penetration to the axial wall (score 3)in group III and V respectively. (Fig 8&9)

Regarding group IV, the specimens showed variable degrees of microleakage, with seven specimens showing score 2 (Fig 10), one specimen scored 1 and 2 specimens scored 3. The difference between this group and group II was not significant. However it shows significantly better results than both group III and V. (Table 1)

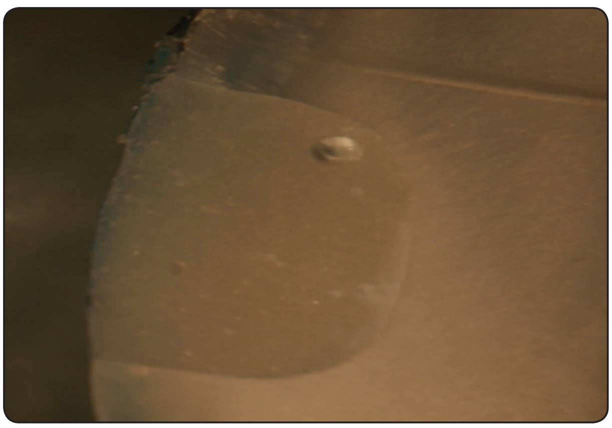

Fig. (6) A photomicrograph of EQUIA restoration (group I) showing score zero microleakage

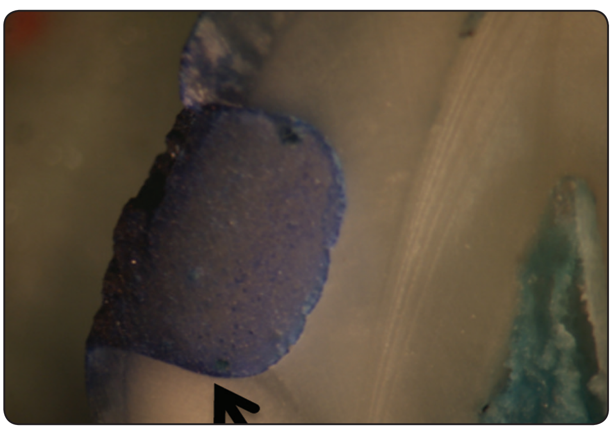

Fig. (7) A photomicrograph of Photac fil(group II) showing score score 2 microleakage

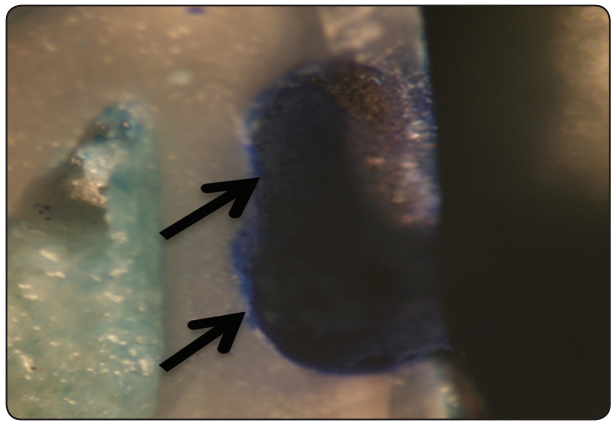

Fig. (8) A photomicrograph of Ketac Molar (group III) restoration showing score 3 microleakage

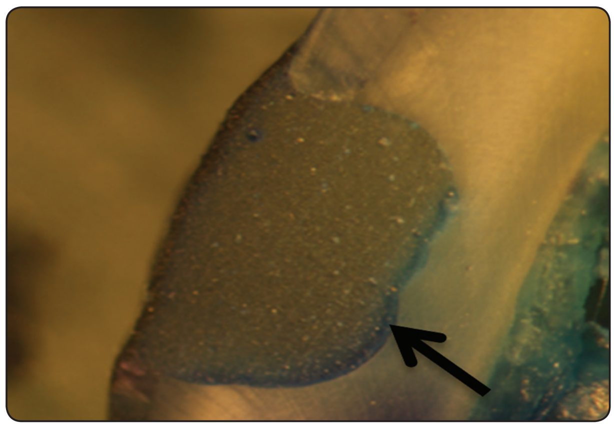

Fig. (9) A photomicrograph of Fuji IX(group V) restoration showing score 3 microleakage

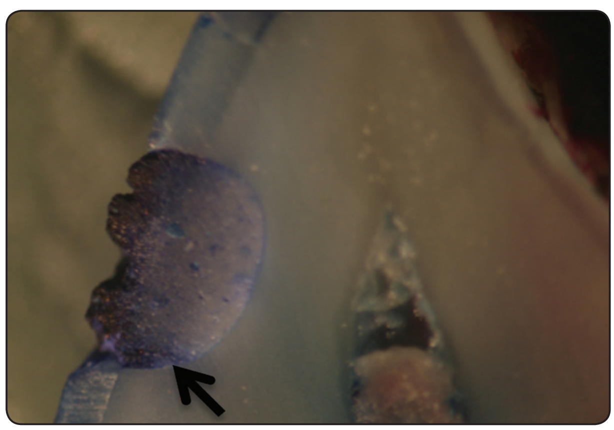

Fig. (10) A photomicrograph of riva self cure (group IV) restoration showing score 2 microleakage

TABLE (1) Comparison of marginal microleakage between the five studied groups.

	Group I	Group II	Group III	Group IV	Group V	$^{MC}p_1$
Score						
0	10 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (10.0%)	<0.001*
1	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (10.0%)	1 (10.0%)	
2	0 (0.0%)	3 (30.0%)	0 (0.0%)	7 (70.0%)	0 (0.0%)	
3	0 (0.0%)	7 (70.0%)	10 (100.0%)	2 (20.0%)	8 (80.0%)	
Sig. bet. grps	II, III, IV, V	I	I, IV	I, III,V	I,IV	

Qualitative data were described using number and percent and was compared using Monte Carlo

p value for Monte Carlo for comparing between different studied groups

Sig. bet. groups was done using Chi square test, Monte Carlo

****: Statistically significant at p ≤ 0.05***

Regarding the effect of polishing on microleakage, table II describes comparison between subgroups a&b both subgroups of each group recorded nearly similar results with no significant difference noted (p=1)

TABLE (II) Comparison between the studied groups and subgroups according to marginal microleakage.

	Group I	Group II	Group III	Group IV	Group V
Subgroup a/ score					
0	5 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (20.0%)
1	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (20.0%)	0 (0.0%)
2	0 (0.0%)	2 (40.0%)	0 (0.0%)	3 (60.0%)	0 (0.0%)
3	0 (0.0%)	3 (60.0%)	5 (100.0%)	1 (20.0%)	4 (80.0%)
Subgroup b/ score					
0	5 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
1	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (20.0%)
2	0 (0.0%)	1 (20.0%)	0 (0.0%)	4 (80.0%)	0 (0.0%)
3	0 (0.0%)	4 (80.0%)	5 (100.0%)	1 (20.0%)	4 (80.0%)
p_2	-	$^{FE}p=1.000$	-	$^{MC}p=1.000$	$^{MC}p=1.000$

Qualitative data were described using number and percent and was compared using Monte Carlo

p_1: p value for Monte Carlo for comparing between different studied groups

p_2: p value for Monte Carlo or Fisher Exact for comparing between subgroups in each group

Sig. bet. grps was done using Chi square test, Monte Carlo or Fisher Exact

****: Statistically significant at p ≤ 0.05***

DISCUSSION

A major goal of restorative dentistry is achieving proper adhesion between restorative materials and the cavity walls resulting in good marginal sealing, less microleakage and longer life of the restoration. Since no material is exempted from microleakage [33], its information is useful for comparative assessment of different materials. The present study was carried out to assess the difference in microleakage of five restorative materials (EQUIA Forte, Fuji IX GC Extra, ketac molar, riva self cure, or photac fill) having a good potential for use in pediatric dentistry.

The microleakage assessment was done by an *in vitro* method because *in vitro* tests remain an indispensable method for initial screening of dental materials and *in vitro* microleakage tests may set a theoretical maximal amount of leakage that could be present *in vivo*. [34-35]Furthermore, *in vitro* microleakage studies are relatively easy to perform and effective in differentiating the quality of various materials in terms of their microleakage resisting potentials as compared to *in vivo* studies.[36]

Class V preparations were used to study the behavior of the tested restorative materials in a high C-Factor design and to rule out any influence of occlusal loading on microleakage. [37]

Furthermore, cervical lesions have always been a restorative challenge. The complex morphology of Class V cavities with margins partly in enamel and partly in dentin presents a challenging scenario for the restorative material. The primary problem associated with the restoration of this kind of cavity is leakage at the gingival margin located in dentin. [38]

Thermocycling has been used in this study to simulate oral conditions.. This process may highlight the mismatch in thermal expansion between the restoration and tooth structure, resulting in different volumetric changes during temperature changes and causing fatigue of the adhesive joint with subsequent microleakage. This is in agreement with other researches [39-40] which stated that, thermo-cycling mimic intra-oral temperature variations and subjecting the restorations on the tooth to temperature extremes compatible with oral cavity.

In this study, the dye leakage method was used because it is a simple, inexpensive, fast technique and does not require the use of complex laboratory equipment.[41]

The results of the present study revealed that there was statistically significant difference between the five groups ($P<0.001$).(Table I)

Group I specimens (EQUIA) exhibited the least microleakage The use of the light cured coat with EQUIA could have provided better seal, since it is believed microleakage could be minimized by avoiding dehydration [42] The EQUIA Restorative system combines a highviscosity glass ionomer cement (EQUIA Fil) with a highly filled light curing resin coating (EQUIA Coat). This technology integrates the main advantages of the high-viscosity GIC (self-adhesion, bulk application, improved mechanical properties) with a protective barrier in the early maturation phase. [43-45]

While group I specimens exhibited the least microleakage scores, they were followed by specimens of Group IV (Riva self cure) . The scores of the present study were similar to those reported by Abdulateef et al [46] . Better scores were reported with Riva self cure by Bortoletto et al [47] and Ghasemi et al [48]. However, preetching with 10% polyacrylic acid for 30 s was used in both studies which could have improved the adaptation of the material by removing unwanted residue and altering its wetting capacity.

The results of the present study also shows that photac fill specimens (group II) exhibited less microleakage than both ketac molar (group III) and Fuji IX (group V). Several researches[49-51] have previously reported similar findings in which less microleakage was reported with resin modified glass ionomer as compared to conventional glass ionomer. The results of this study are also in agreement with the basic findings of Hallet et al,[52] 1989, Hallet and Garcia-Godoy, [53] 1993, Erdilek et al, 1997[54] , and Wilder et al, 2000 [55] .

These results could be attributed to the better adaptation of RMGIs to tooth structure. This restorative material bonds by chemical interaction with tooth structures, based on an ionic binding of multiple carboxylic groups of polyalkenoic acid with calcium, which is abundantly available in hard tooth structures.(56-57) also, this material provides micro-mechanical interlocking which is achieved by infiltration of the organic tags of RMGI components into a partially de-mineralized dentin surface. Therefore, a sub-micron hybrid layer is formed, similar to the one produced by 'mild' self-etching adhesives.(58)

On the other hand, Better results had been reported with FujiIX in the oral cavity. One possible explanation is the difference between in vivo and in vitro conditions. In the oral cavity, dehydration of Fuji IX is controlled by the presence of tubular fluid in dentin. Continuous outward flow of fluids form freshly cut dentin increases the wetting of dentin and improves hydrated gel phase during solidification and allows self-repairing process.(42) Hence, the material maintains its bulk volume through internal microcracks. With water sorption, the cracks close to repair cohesive strength, and the dimensional stability of glass ionomer cement is maintained, resulting in excellent adaptation with tooth structure. In in vitro condition, absence of water and lower cohesive strength can alter the properties of glass ionomer cement, which may have resulted in leakage in the present study.(59)

The results of the present study also showed no significant effect of polishing on the marginal microleakage of the restorations. Similar to these results, Sengupta et al(60) studied the effect of polishing on silorane composite, conventional glass ionomer cement and resin modified glass ionomer cement . While the results showed some positive effect of polishing on silorane composite, there was no significant difference between polished and non polished glass ionomer restorations in terms of microleakage.

CONCLUSION

- Within the limitations of this study, only the EQUIA was free from microleakage and dye penetration. All the other four materials showed more microleakage, with resin modified glass ionomer exhibiting more favorable results than conventional glass ionomer material tested.
- Final polishing of glass ionomer restorations has no effect on marginal microleakage

RECOMMENDATIONS

The use of a protective barrier on the surface of glass ionomer can help reduce the marginal microleakage of those materials.

REFERENCES

1. Mount G. Making the most of glass ionomer cements. Dent Update 1991; 18:276-9.
2. Sidhu SK, Watson TF. Resin-modified glass ionomer materials. A status report for the American Journal of Dentistry. Am J Dent 1995; 8:59-67.
3. Burgess J, Norling B, Summit J. Resin ionomer restorative materials: the new generation. J Esthet Dent 1994; 6:207-15.
4. Wilson AD, Kent BE. A new translucent cement for dentistry. The glass ionomer cement. Br Dent J 1972; 132:133-5.
5. O'Brien T, Shoja-Assadi F, Lea SC, Burke FJ, Palin WM. Extrinsic energy sources affect hardness through depth during set of glass ionomer cement. J Dent 2010;38:490–5.
6. Delme KI, Deman PJ, Nammour S, De Moor RJ. Microleakage of class V glass ionomer restorations after conventional and Er: YAG laser preparation. Photomed Laser Surg2006;24:715–22.
7. Wilson AD, Prosser HJ, Powis DM. Mechanism of adhesion of polyelectrolyte cements to hydroxyapatite. J Dent Res 1983; 62:590-2.
8. McLean JW, Wilson AD. The clinical development of glass ionomer cement. II. Some clinical applications. Aust Dent J 1977; 22:120-7.
9. Hickel R, Voss A. A comparison of glass cermet cement and amalgam restorations in primary molars. ASDC J Dent Child 1990; 57:184-8.

10. Hirschfeld, Z., Frenkel, A., Zyskind, D., Fuks, A. Marginal leakage of class II glass ionomer composite resin restorations: An in vitro study. J. Prosthet. Dent. 1992;67: 148–53.

11. Dutta, B.N., Gauba, K., Tiwari, A., Chawla, H.S.Silver amalgam versus resin modified glass ionomer cement class II restoration in primary molars. Twelve month clinical evaluation. J. Indian Soc. Prev. Dent. 2001; 19, 118–22.

12. Frankenberger R, Sindel J, Kramer N. Viscous glass-ionomer cements: a new alternative to amalgam in the primary dentition? Quintessence Int 1997; 28:667-76.

13. Berg JH. The continuum of restorative materials in pediatric dentistry — a review for the clinician. Pediatr Dent 1998; 20:93-100.

14. Hirayama, A. Experimental analytical electron microscopic studies on the quantitative analysis of elemental concentrations biological thin specimens and its application to dental sciences. Shikwa Gakuho1990; 90: 1036–91.

15. Inoue S, Van Meerbeek B, Abe Y, et al.Effect of remaining dentin thickness and the use of conditioner on micro-tensile bond strength of a glass ionomer adhesive. Dent Mater 2001;**17**:445–55.

16. Gordon M, Plasschaert AJ, Stark MM. Microleakage of several tooth-colored restorative materials in cervical cavities. A comparative study in vitro. Dent Mater 1986;2:228–31.

17. Cooley RL, Robbins JW. Glass ionomer microleakage in Class V restorations. Gen Dent1988;36:113–5.

18. Smith ED, Martin FE. Microleakage of glass ionomer/ composite resin restorations: a laboratory study. The influence of glass ionomer cement. Aust Dent J 1992; 37:23-30

19. Crim GA, Shay JS. Microleakage pattern of a resin-veneered glass-ionomer cavity liner. J Prosthet Dent 1987; 58:273-6.

20. Reid JS, Saunders WP, Sharkey SW, Williams CE. An in-vitro investigation of microleakage and gap size of glass ionomer/composite resin “sandwich” restorations in primary teeth. ASDC J Dent Child 1994; 61:255-9.

21. Morabito A, Defabianis P. The marginal seal of various restorative materials in primary molars. J Clin Pediatr Dent 1997; 22:51-4.

22. May KN Jr, Swift EJ Jr, Wilder AD Jr, Futrell SC. Effect of a surface sealant on microleakage of Class V restorations. Am J Dent 1996; 9:133-6.

23. Hallett KB, Garcia-Godoy F. Microleakage of resin-modified glass ionomer cement restorations: an in vitro study. Dent Mater 1993; 9:306-11.

24. Bauer JG, Henson JL. Microleakage: a measure of the performance of direct filling materials. Oper Dent 1984;9:2–9.

25. Franco EB, Lopes LG, Lia Mondelli RF, Da Silva E Souza Jr., and Lauris JRP, “Effect of the cavity configuration factor on the marginal microleakage of esthetic restorative materials,”American Journal of Dentistry2003;16(3): 211–4.

26. Simi B, Suprabha BS, “Evaluation of microleakage in posterior nanocomposite restorations with adhesive liners,” Journal of Conservative Dentistry2011;14(2):178–81.

27. Venturini D, Cenci MS, Demarco FF, Camacho GB, Powers JM. Effect of polishing techniques and time on surface roughness, hardness and microleakage of resin composite restorations. Oper Dent 2006;31:11-7.

28. Gale MS, Darvell BW, Cheung GS. Three-dimensional reconstruction of microleakage pattern using a sequential grinding technique. J Dent 1994;22:370-5

29. Prabhakar, AR, Madan M, Raju OS. The marginal seal of flowable composite, an injectable resin modified glass ionomer and compomer in primary molars – an in vitro study. J. Indian Soc. Pedo. Prev. Dent2003; 21 (2): 45–8.

30. Wadenya RO, Yego C, Mante FK. Marginal microleakage of alternative restorative treatment and conventional Glass ionomer restorations in extracted primary molars. J Dent Child 2010;77:32-5.

31. Juntavee A, Juntavee N, Peerapattana J, Nualkaew N, Sutthisawat S. Comparison of Marginal Microleakage of Glass Ionomer Restorations in Primary Molars Prepared by Chemomechanical Caries Removal (CMCR), Erbium: Yttrium Aluminum-Garnet (Er:YAG) Laser and Atraumatic Restorative Technique (ART). Int J Clin Pediatr Dent 2013;6(2):75-9.

32. Silveira de Ara´ujoCS, Incerti da Silva TI, Ogliari FA, Meireles SS, Piva E, Demarco FF. Microleakage of seven adhesive systems in enamel and dentin. Journal of Contemporary Dental Practice 2006;7(5):26–33.

33. Yap AU, Ang HQ, Chong KC. Influence of finishing time on marginal sealing ability of new generation composite bonding systems. J Oral Rehabil 1998;25:871-6

34. Yavuz I, Aydin H, Ulku R, Kaya S, Tumen C. A new method: Measurement of microleakage volume using human, dog and bovine permanent teeth. J Electron Biotechnol 2006;9:8-17.

35. Fabianelli A, Pollington S, Davidson C, Chrysanti M, Goracci C. The relevance of micro-leakage studies. Int Dent SA 2007;9:64-72.

36. Harper RH, Schnell RJ, Swartz ML, Phillips RW. *In vivo* measurements of thermal diffusion through restorations of various materials. J Prosthet Dent 1980;43:180-5

37. Crim GA, Swartz ML, Phillips RW. Comparison of four thermocycling techniques. J Prosthet Dent 1985;53:50-3.

38. Silveira de Araújo C, Incerti da Silva T, Ogliari FA, Meireles SS, Piva E, Demarco FF. Microleakage of seven adhesive systems in enamel and dentin. J Contemp Dent Prac 2006;7:26.

39. Wahab FK, Shaini FJ, Morgano SM. The effect of thermocycling on microleakage of several commercially available composite class V restorations in vitro. J Prosthet Dent 2003;90:168-74.

40. Gupta SK, Gupta J, Saraswathi V, Ballal V, Acharya SR. Comparative evaluation of microleakage in Class V cavities using various glass ionomer cements: An in vitro study. Journal of Interdisciplinary Dentistry 2012 ;2(3):164-9.

41. Alani AH, Toh CG. Detection of microleakage around dental restorations: A review. Oper Dent 1997;22:173-85.

42. Brackett W, Gunnin T, Johnson W, Elaine Conkin J. Microleakage of light cured glass ionomer restorative materials, Quintessence Int. 1995;26:583–5.

43. (B). Systematic review of clinical trials by Mickenautsch et al., European Journal of Paediatric Dentistry 2009; 10:41-6.

44. Oliveira et al. Systematic review of trials. Journal of Minimum Intervention in Dentistry 2010; 3: p23 - abstract 023.

45. Bagheri et al. Investigation of dental materials. American Journal of Dentistry 2010; 23:142-6.

46. Abdulateef D S, Khursheed DA, Mina MB. Microleakageof three different materials in cervical restorations with different cavity margin locations: a comparative in vitro study . Wudpecker Journal of Medical Sciences 2014;3(2):19 – 26. ISSN 2315-7240

47. Bortoletto CC , Miranda WGJr, L Motta LJ, Bussadori SK. Influence of acid etching on shear strength of different glass ionomer cements Braz J Oral Sci. 2013; 12(1):11-5.

48. Ghasemi A, Torabzadeh H, Mahdian M, Afkar M, Fazeli A, Baghban AA. Effect of bonding application time on the microleakage of Class V sandwich restorations Australian Dental Journal 2012; 57: 334–8.

49. Khoroushi M1, Karvandi TM, Kamali B, Mazaheri H. Marginal microleakage of resin-modified glass-ionomer and composite resin restorations: effect of using etch-and-rinse and self-etch adhesives. Indian J Dent Res. 2012;23(3):378-83.

50. Mali P, Deshpande S, Singh A. Microleakage of restorative materials: An in vitro study. J Indian Soc Pedod Prev Dent. 2006;24:1–9.

51. Castro A, Feigal RF. Microleakage of a new improved glass ionomer restorative material in primary and permanent teeth. Pediatr Dent 2002; 24(1):23-8.

52. Hallet KB, Garcia-Godoy F. Microleakage of resin modified glass ionomer cement restorations: an in vitro study. Dent Mater1989; 5(6):392-8.

53. Hallet KB, Garcia-Godoy F. Microleakage of resin modified glass ionomer cement restorations: an in vitro study. Dent Mater 1993;9:306-11.

54. Erdilek N, Ozata F, Septcioglu F. Microleakage of glass ionomer cement, composite resin and glass ionomer resin cement. J Clin Pediatr Dent1997; 21(4):311-4.

55. Wilder AD Jr, Swift EJ Jr, May KN Jr., Thompson JY, McDougal RA. Effect of finishing technique on the microleakage and surface texture of resin modified glass ionomer restorative materials. J Dent2000; 28(5):367-73.

56. Mitra SB, Lee CY, Bui HT, Tantbirojn D, Rusin RP. Long-term adhesion and mechanism of bonding of a paste-liquid resin-modified glass-ionomer. Dent Mater 2009; 25:459-66.

57. Van Dijken JW, Pallesen U. Long-term dentin retention of etch-and-rinse and self-etch adhesives and a resin-modified glass ionomer cement in non-carious cervical lesions. Dent Mater 2008;24:915-22.

58. Cardoso MV, Delmé KI, Mine A, Neves Ade A, Coutinho E, De Moor RJ, *et al*. Towards a better understanding of the adhesion mechanism of resin-modified glass-ionomers by bonding to differently prepared *dentin*. J Dent 2010;38:921-9.

59. Diwanji A, Dhar V, Arora R, Madhusudan A, Rathore SA. Comparative evaluation of microleakage of three restorative glass ionomer cements: An in vitro study. J Nat Sci Biol Med. 2014; 5(2): 373–7.

60. Sengupta A, Gupta A, Dagur R. Effect of polishing on the microleakage of three different restorative materials: An in vitro study. Journal of Indian Society of Pedodontics and Preventive Dentistry 2014 ;32(2) : 140-8