Microleakage of a new improved glass ionomer restorative material in primary and permanent teeth

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Abstract

Purpose: The objective of this study was to assess the microleakage of the new conventional glass ionomer, Fuji IXgp™ in comparison to another conventional glass ionomer (Fuji II™), a resin modified glass ionomer (Vitremer™) and a composite resin (TPH™) in primary and permanent teeth.

Methods: Twenty-five extracted human premolars and 13 primary molars were used. Preparations were made on the center of the buccal and lingual aspects of the premolars (Group A) and the mesio buccal and disto buccal surface as well as the mesio lingual and disto lingual surface of the primary molars (Group B). Each group was randomly divided into five subgroups of 10 specimens each and restored with a different material following the manufacturer's recommendations. Restorations were subjected to thermocycling followed by microleakage evaluation using 50% silver nitrate and computerized image analysis.

Results: Two factor analysis of variance revealed a significant main effect of material ($P<0.001$), a trend toward a main effect of tooth type ($P=0.082$) and a significant interaction term $P=0.016$. Materials were a source of difference, so a one-way ANOVA test was used for both primary and permanent teeth together and for each individual group of teeth. Differences were further examined with a multi-variate analysis using the Scheffe' test for both groups of teeth and each individual group of teeth. Each group of teeth restored with the same material was then analyzed with an Independent Samples t-test which showed that conventional glass ionomer (Fuji II™) had more leakage than all other groups ($P<0.01$). In addition TPH™ showed more microleakage in primary teeth ($P<0.02$) and Fuji II™ showed more microleakage in permanent teeth ($P<0.02$).

Conclusions: Fuji IXgp™ behaved similarly to the composite (TPH™) and to the resin modified glass ionomer (Vitremer™). This is a promising result for this material that is targeted for application in conjunction with the Atraumatic Restorative Technique and minimal intervention treatments.*(Pediatr Dent 24:23-28, 2002)*

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The strategy of care using chemically cured, intermediate restorative materials in countries where children do not have access to optimal care has been named Atraumatic Restorative Treatment (ART). This Atraumatic Restorative Treatment (ART) consists of an elementary technique based on caries removal using hand instruments only, combined with the use of a glass ionomer restorative material with adhesive characteristics.[1,2] The newer materials such as Fuji IXgp™ (GC Corporation, Tokyo, Japan) are suggested for this dental health strategy. In addition, concepts of minimally invasive restorative care argue for use of such materials in certain caries control situations. Obviously, the physical properties and the microleakage must be tested to prove adequacy for such use.

Microleakage is the most common cause of failure of almost all restorative materials since it is a major contributing factor to secondary caries and pulpal irritation.[3-5] Accordingly, there is an interest in finding a restorative material which has better bond characteristics, thus minimizing microleakage and reducing the potential for caries development at the tooth surface interface and resultant pulpal irritation.

The development of glass ionomer materials has been the subject of several studies due to the many advantages they provide. A classification of three different types of glass ionomers has evolved: glass ionomer cement, glass ionomer hybrid materials and polyacid modified composite resin.[6] The major advantages of glass ionomers include chemical adhesion to dentin and enamel, fluoride release, high tissue tolerance, and pulpal biocompatibility. However, lack of strength, abrasion resistance and poor esthetics have limited glass ionomer use by most practitioners. Today, the new generation of glass ionomers, sometimes called intermediate restorative materials, may be able to provide better esthetics, stronger bond and long-term results lasting years rather than months, largely due to smaller mean particles sizes which increases the viscosity of the material.[7] Therefore, the intermediate restorative material, Fuji IXgp™, may offer some benefits to dental patients, especially children. Fuji IXgp™ contains fluoride, adheres to tooth structure without the need of an additional bonding system, has adequate strength and can be finished and polished in one visit. To be of benefit to children, this material would not necessarily need to last as long as an amalgam but instead be capable of lasting throughout the period that primary teeth are functional.

The purpose of this *in vitro* study is to assess the microleakage of a new material, Fuji IXgp™, in comparison to a conventional glass ionomer (Fuji™ II, GC Corporation, Tokyo, Japan), a resin modified glass ionomer (Vitremer™, 3M, St Paul, MN) and a composite resin (TPH™, Caulk, Mildford, De). In addition, this study will compare the degree of microleakage between primary and permanent teeth when using these four materials.

Methods

Sample preparation

Extracted human permanent (Group A) and primary (Group B) teeth were collected and stored in 0.2% sodium azide. A saucer-shaped cavity, 3.0 mm in diameter and 1.0 mm deep [depth of a #2 round bur=1mm; width of a #8 round bur=3mm], was prepared on the center of the buccal and lingual surfaces of the premolars. On primary molars, cavities were prepared on the mesio buccal and disto buccal surface, as well as on the mesio lingual and disto lingual surface (Fig 1). A high-speed handpiece with water spray was used with a # 2 carbide round bur to obtain the depth of the preparation and to provide consistency, then a large # 8 round bur was used to increase the width of the preparation. The dimensions were determined to keep the preparations in enamel.

Permanent and primary teeth were randomly divided into five subgroups of 10 teeth specimens each, each subgroup was marked with a dot marking system in the coronal and cervical part of the preparation to distinguish among subgroups (Fig 1). These dots cannot be seen under the microscope while observing the restoration, thus maintaining unbiased scoring of leakage. Each subgroup was restored with a different restorative material randomly assigned; Subgroup I the new conventional glass ionomer (Fuji IXgp™); Subgroup II a conventional glass ionomer (Fuji II™); Subgroup III a resin-modified glass ionomer (Vitremer™); Subgroup IV a composite resin (TPH™) and Subgroup V the new conventional glass ionomer (Fuji IXgp™) without the conditioner.

Before material placement, the preparations were cleaned with a rubber cup and a slurry of pumice powder. The restorative materials mentioned above were placed following manufacturers' instructions. After placement of the restorations, all teeth were stored in distilled water for 24 hours. The teeth were then subjected to 500 thermocycles at a temperature range of 4 °C and 55 °C and a dwell time of 30 sec.

Microleakage testing

The teeth were placed in a 50% aqueous solution of silver nitrate for two hours in darkness.[8] After two hours, the teeth were rinsed with distilled water and placed in a radiographic developer for eight hours under fluorescent light to precipitate the silver nitrate. This causes the silver nitrate to turn black, allowing visualization of the penetration pattern of the silver ions along the enamel-restoration interface.

Microleakage measurement

Each permanent tooth was sectioned twice, first vertically through the center of the tooth and then longitudinally, in a bucco-lingual direction through the center of the restorative material, with a diamond wheel saw (South Bay Technology, model 1650, Los Angeles, Calif) mounted with a diamond wafering blade (4≤ grit 320, Mager Scientific, Inc, Co-152). Each primary molar was sectioned three times with a diamond wheel saw mounted with a diamond wafering blade. The first section was sectioned vertically through the center of the tooth, then horizontally through the center of the tooth and then longitudinally, in a bucco-lingual direction, through the center of the restorative

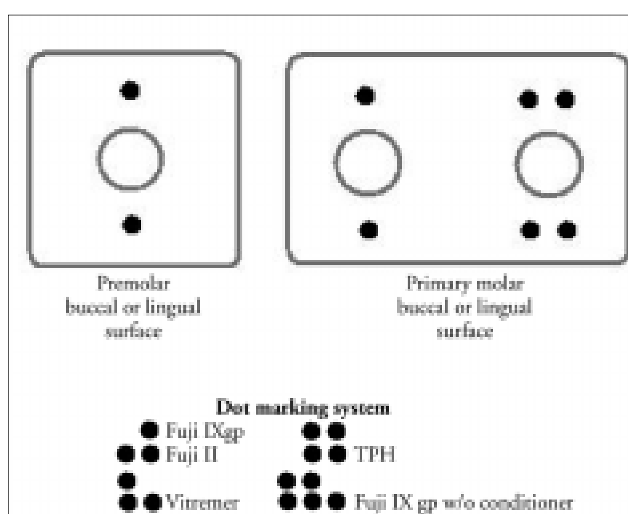

Fig 1. Diagram showing cavity preparation in the premolars on the center of the buccal and lingual surfaces. Cavity preparation on the primary molars on the mesial and distal of the buccal and lingual surfaces.

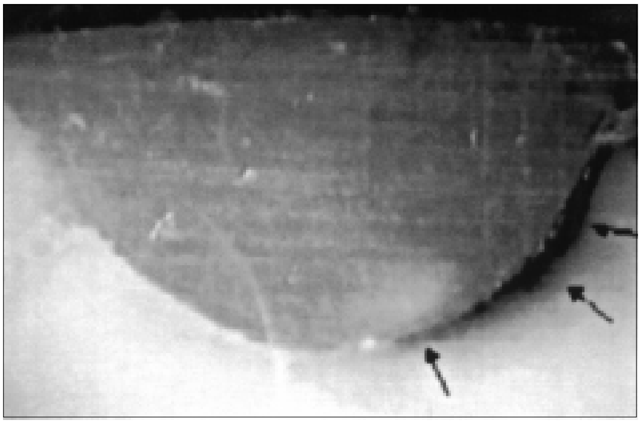

Fig 2. Primary tooth specimen showing penetration of the tracer along part of the gingival wall (TPH™)

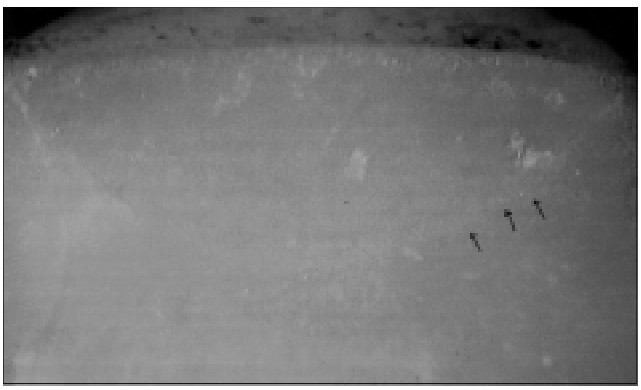

Fig 3. Permanent tooth specimen showing no tracer penetration (TPH™)

material. Thus, each restoration was sectioned into two equal parts for scoring of leakage at the tooth-material interface.

The microleakage was observed under a dissecting microscope at magnifications of 30 x (Figs 2-3). A computer linked to the dissecting microscope via a javilin ultrachip CCTV video camera (Javidin Electronics, model JE-7442, Los Angeles, CA) was used to capture the images. Measurements were made with the Image Pro Plus program version 1.3 for Windows. The curvi-linear extent of microleakage was measured in pixels along the enamel-restoration border on the occlusal and cervical aspects of each section. In addition, the full extent of the enamel-restoration border was measured (Fig 4). Measurements were made at random by the main examiner and re-measured by another examiner.

The results were recorded and then converted into percentage as a percentage of total tooth material-border; in addition, measurements were recorded as millimeters by using the scale bar of a millimeter ruler, under the microscope to convert image pixels to millimeters. Four samples from the permanent teeth group and five samples from the primary teeth group were discarded due to breakage during sectioning.

Data analysis

The mean and standard deviation was calculated for each group of specimens. Statistical Package for the Social Sciences (SPSS 7.5) for Windows was used for analysis. The data were subjected to a two factor analysis to determined differences between materials and teeth. A one-way ANOVA test was used for both primary and permanent teeth together and for each individual group of teeth to determine if significant differences existed among the groups. Differences were further examined with a multi-variate analysis using the Scheffe' test for both groups of teeth and each individual group of teeth. Each group of teeth restored with the same material was then analyzed with an Independent Samples t-test. Statistically significant differences among data were accepted if the probability level was equal to or less than 0.05.

Results

Primary teeth showed a mean microleakage of 24% when restored with Fuji IXgp™, 45% when restored with Fuji™ II, 9% when restored with Vitremer™, 16% when restored with TPH™ and 42% when restored with Fuji IXgp™ without conditioner (Table 1 and Fig 5).

Permanent teeth showed a mean microleakage of 29% when restored with Fuji IXgp™, 76% when restored with Fuji™ II, 13% when restored with Vitremer™, 6% when restored with TPH™ and 46% when restored with Fuji IXgp™ without conditioner (Table 1 and Fig 5).

When all materials in both groups were compared, teeth showed a mean microleakage of 26% when restored with Fuji IXgp™, 60% when restored with Fuji™ II, 11% when restored with Vitremer™, 11% when restored with TPH™ and 44% when restored with Fuji IXgp™ without conditioner.

Two-factor analysis of variance (ANOVA) revealed a significant main effect of material ($P<0.001$) and a trend toward a main effect of tooth type ($P=0.082$) showing greater microleakage in permanent teeth than in primary teeth. In addition, a significant interaction ($P=0.016$) was shown. Further testing was required as a significant difference ($P<0.05$) was found among the analytical units involved (tooth type, restorative materials type).

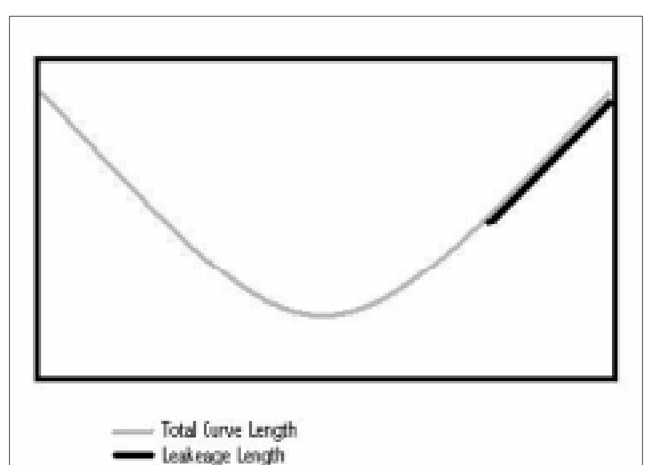

Fig 4. Diagram showing microleakage measurement

Table 1. Tooth-Material Interface Leakage in Permanent and Primary Teeth (Mean and SD of Percent Leakage)

	Group A permanent teeth Mean± SD	Group B primary teeth Mean±SD	Groups A and B combined Mean±SD
Fuji IX gp™	29.0±19.65	24.16±16.10	26.45±17.06
	n=10	n=9	
Fuji II™	76.0±12.25*a	44.9±34.67**b	59.63±29.55
	n=10	n=9	
Vitremer™	12.75±8.82	8.55±4.24**b	10.52±6.7
	n=9	n=8	
TPH™	5.6±8.47	16.22±9.62	10.63±10.05
	n=9	n=10	
Fuji IX gp™ w/o condit.	45.66 ± 14.39	41.5 ± 28.21	43.7 ± 20.74
	n=8	n=9	

*a= significantly different from all other materials in permanent teeth ($P \leq 0.001$); **b= significantly different from one another in primary teeth ($P \leq 0.02$)

Materials were a source of difference, so a one-way ANOVA test was used for both primary and permanent teeth together and each individual group of teeth. Differences were further examined with a multi-variate analysis using the Scheffe' test for both groups of teeth and each individual group of teeth. Even though tooth types were not found to be different, each group of teeth restored with the same material was analyzed with an independent samples t-test. Microleakage was observed more in primary teeth than in permanent when teeth where restored with TPH™ ($P<0.02$) and also observed more in permanent teeth than in primary when teeth where restored with Fuji II™ ($P<0.02$).

There were significant differences among the materials used. A one-way analysis (ANOVA) test comparing all materials in both groups showed that a significant difference exists ($P<0.05$). A multi-variate analysis using the Scheffe' test showed: A) The mean microleakage rate for Fuji II™ was significantly greater than the values obtained for Fuji IX gp™, Vitremer™ and TPH™ respectively and B) The mean microleakage rate for Fuji IX gp™ without conditioner was significantly greater than the values obtained for Vitremer™ and TPH™.

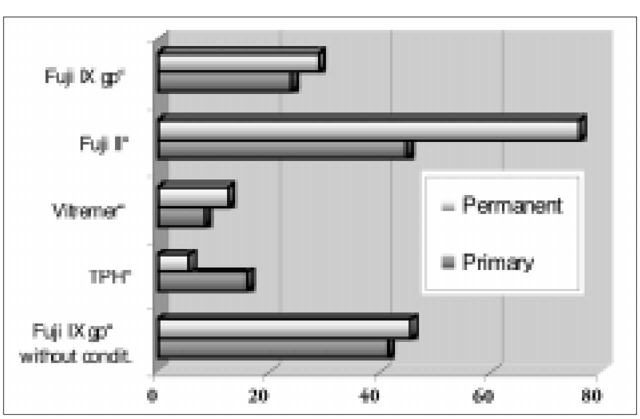

Fig 5. Mean % microleakage in primary and permanent teeth

Discussion

The maintenance of a marginal seal over a long period of time is extremely important for avoiding or at least decreasing clinical problems such as the discoloration of margins due to microleakage and secondary caries.

When the materials were compared, differences were clearly shown. Conventional glass ionomer (Fuji II™) showed more leakage than all other groups. However, Fuji IXgp™, the improved conventional glass ionomer, behaved similarly to the composite resin and to the resin modified glass ionomer (Vitremer) when conditioning was used.

The results of this study are in agreement with the basic findings of Hallet et al,[9] 1989, Hallet and Garcia-Godoy,[10] 1993, Erdilek et al,[11] 1997, Wilder et al, [12] 2000 and indicate that cavities filled with resin modified glass ionomers had significantly less leakage than similar cavities filled with conventional glass ionomer cements. It has been shown that composite resins and resin-modified glass ionomer cements provide a better seal than glass ionomer cements. Some previous investigations did not find similar results (Douglas et al,[13] 1992, Crim GA,[14]1993, Brackett,[15]et al 1995, Puckett[16] et al, 1995, Salama, et al[17]). The methods followed by the authors who obtained different results was based on the use of colored agents to demonstrate leakage. This technique is highly sensitive and the assessment of results requires standardization.

In addition, this form of assessment was usually associated with the assignment of a numerical scoring system of increasing degrees of leakage and this assessment is somewhat subjective. Furthermore, the protocols used for thermocycling were significantly diverse. The chemical tracers technique used in this study in conjunction with computer imaging gives a more quantifiable microleakage assessment. The computer program allows the exact measurement of the curvilinear extend of the leakage stain with a measurement unit, the pixel, which then can be converted to a percentage. This is of great advantage, eliminating the traditional scoring system that made microleakage studies more subjective.

Some limitations of this study include the lack of an in vivo environment. In vitro studies do not reflect all the variables present in a patient mouth. In addition, to preserve the integrity of samples and to avoid the loss of samples, it is suggested to mount the teeth in epoxy resin prior to sectioning.

This is one of the few comparisons of microleakage rates between permanent and primary teeth. It is important to bring this to the attention of the manufacturers of dental materials who concentrate most efforts in the development of materials intended for permanent teeth.

These results suggest that leakage in primary and permanent teeth may well vary individually which each type of material, one showing greater primary tooth leakage, while another showing more permanent teeth leakage.

These results are promising for this new material (Fuji IXgp™) that is targeted for non-industrialized countries where conditions make dentistry unavailable to the majority of the population that live in rural areas. In many of these areas, electricity is not available and the application of this material in conjunction with the Atraumatic Restorative Technique (ART) might be an alternative to bring dentistry to an otherwise neglected population. The ART allows deeper layers of carious tooth structure to be left intact. The idea of leaving decayed tissue under a well sealed restoration is not new. A 10-year study by Mertz-Fairhust[18] and collaborators in 1998 demonstrated the ability of sealed restorations to arrest the progress of the caries lesion. Other studies using the ART have shown an acceptable clinical performance of the newer conventional glass ionomers.[19-23] However, long-term performance has not yet been evaluated.

In addition, improved glass ionomer materials may prove to be ideal for methods of minimally invasive caries management in the first world countries as well, since they combine ease of technique (by using hands instruments to remove only a portion of the decalcified tooth tissue) with high strength, chemical adhesion and fluoride release.

Conclusions

1. Cavities filled with a new generation of conventional glass ionomer cement (Fuji IXgp™) had significantly less leakage than similar cavities filled with conventional glass ionomer cement.
2. Cavities filled with resin-modified glass ionomer cement and composite resin had significantly less leakage than cavities filled with conventional glass ionomer cement.
3. The application of Fuji IXgp™, in conjunction with the ART, may be an excellent alternative to bring dentistry to the population in rural areas of non-industrialized countries as well as a conservative approach for the management of early childhood caries, because it can be used without the use of photo curing.

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Abstract of the Scientific Literature

Sealant Use and Placement Techniques Among Pediatric Dentists

The authors conducted a survey concerning the utilization of pit and fissure sealants among one-third of the American Academy of Pediatric Dentistry membership in private practice and all 52 pediatric dentistry departments in U.S. dental schools. Seventy percent of private practitioners (PP) and 90% of dental schools (DS) responded. Caries-free and "questionable" carious surfaces were sealed by 80% of respondents, incipient carious surfaces were sealed by only 20% of respondents and none sealed overt carious surfaces. The majority of respondents deemed cooperative patient behavior and completely erupted permanent teeth as necessary selection criteria for sealant placement. Retention rates after 3 years were 83% for PP and 71% for DS. Permanent molars were sealed by 100% of the respondents.

Placement techniques varied among the respondents indicating there are no standards for the placement of sealants by pediatric dentists. For example: 89% of PP and 85% of DS used cotton rolls/The Dri-Angle for isolation, while 33% of PP and DS used a rubber dam for isolation; surface cleansing varied extensively among the respondents, e.g., 54% of PP and 47% of DS used explorers, 45% of PP and 55% of DS used pumice/paste, 15% of PP and 23% of DS used a rotary cup/brush, and 13% of PP and 17% of DS used a toothrush; surface preparation among respondents ranged form doing nothing (13%) to the use of a slow-speed bur (16% of PP and 30% of DS), high-speed bur (53% of PP and 55% of DS) or air abrasion (18% of PP and 2% of DS).

Comments: Pit and fissure sealants were first introduced to dentistry by Cueto and Buonocore in 1967, and yet, only one-fifth of U.S. children between ages 5 and 17 years have one or more sealed permanent teeth! Historically, pediatric dentists have been at the forefront of preventive dentistry as advocates of fluoride for the prevention of smooth surface dental caries in children, and it is apparent that we also have assumed this same leadership position in the utilization of occlusal sealants. Evidence based standardization of placement protocols and selection criteria will be essential for optimal utilization of this important preventive measure. **JDR**

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Primosch RE, Barr ES. Sealant use and placement techniques among pediatric dentists. ***J Am Dent Assoc*** **132:1442-1451, 2001.**

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