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An in-vitro comparative evaluation of microleakage between giomer, compomer, composite and resin-modified GIC

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ABSTRACT

Introduction: The marginal ingress of oral fluids and bacteria between the tooth – restoration interface is termed as microleakage or marginal leakage. The ability to maintain an unfailing margin improves the durability of a restoration to a large extend.
Aim: Aim of this study was to evaluate microleakage of a Giomer, Hybrid composite, Compomer and Resin Modified Glass Ionomer Cement (RMGIC) along the enamel and cemental margins of class V cavities.
Materials and Methods: This in-vitro study was performed on 80 human maxillary and mandibular premolars which were extracted for orthodontic reasons. Class V cavities were prepared on the buccal surfaces of teeth centered on the Cemento Enamel Junction (CEJ). Teeth were divided into four groups of 20 each and restored with RMGIC, Giomer, Compomer and Hybrid composite and were subjected to thermocycling. Teeth were then immersed in 0.5% Methylene blue dye for 24 hours. They were sectioned longitudinally from the middle of cavity into mesial and distal parts. The sections were observed under stereomicroscope(SM) to evaluate microleakage at both enamel and cemental margins. Depth of dye penetration was measured using a scoring system.
Statistical Analysis: The data was analysed using the one-way ANOVA (Analysis of variance) test. The result is considered statistically significant if the 'p' value obtained is <0.05 level of significance. The inter group comparisons were made using Duncan's Multiple Range Test. The comparison between the enamel and cemental margins within each material were also done, using the Mann Whitney U Test.
Results: The microleakage values of Giomer, Compomer and Hybrid Composite do not differ significantly from each other at the enamel margins while the microleakage of RMGIC is significantly higher than the other three materials ($p < 0.001$). At the cemental margins, the microleakage values of Giomer and RMGIC were not significantly different from each other but significantly higher than Compomer and Hybrid Composite ($p<0.05$).
Conclusion: At the enamel margins, giomer, compomer and hybrid composite showed comparable microleakage values which were significantly lower than RMGIC. At the cemental margins, compomer and hybrid composite showed significantly lower microleakage values compared to giomer and RMGIC. All materials exhibited greater microleakage at the cemental margins than at the enamel margins.

1. Introduction

Microleakage is defined as the chemically undetectable passage of bacteria, fluids, molecules or ions between the cavity walls and restorative materials. This leakage may be clinically undetectable but is a major factor influencing the long-term success of restorations in Class V cavities, as margins of such restorations are generally located in dentin/cementum.[1,2]

A major advancement in the current practice of dentistry is the restoration of lost dental tissue with tooth coloured

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adhesive materials. Earlier amalgam and gold restorative materials were used to restore Class V cavities but became obsolete mainly because of their esthetic shortcomings. Resin based materials form the major part of the currently used tooth coloured restoratives and the commonly used ones are composites, compomers and resin modified glass ionomers.[3]

Since the introduction of silicates in the 1950s and conventional glass ionomers in the 1960s, research and development in dental materials and restorative dentistry have been geared towards fluoride release. Glass Ionomer Cements (GICs) have undergone many modifications since its invention by Wilson and Kent.[4] Hybrid materials combining the technologies of glass ionomers and resin composites were introduced to overcome the problems of conventional GICs such as moisture sensitivity, low initial mechanical properties and inferior surface finish and translucency; and at the same time maintain their clinical advantages such as fluoride release and adhesiveness.

In 1989, Antonucci and Stansburyn developed the first resin modified glass ionomers by incorporating a resin component, HEMA, in the polyacrylic acid component. In 1993, polyacid modified resin composites or compomers where introduced. The difference between compomers and composites is that the compomers contain acidic functional group that can participate in an acid/base glass ionomer reaction following polymerization of the resin molecule. They have minimal fluoride release and are not fluoride rechargeable.[5]

Recently another improvement was made in fluoride releasing materials – the "giomer". Giomers are hybrids between glass ionomers and resin composites. Giomers are directed to have an increased wear resistance, shade conformity, increased radiopacity, improved light diffusion and fluorescence like resin composites along with high fluoride release and rechargability similar to GIC. Giomers uses pre-reacted glass filler technology where pre-reaction of fluroaluminosilicate glass fillers with polyacrylic acid forms a stable phase referred as "wet siliceous hydrogel" which is then freeze dried, milled, silane treated and ground to form PRG fillers. It was found that giomers did not show the gel transition phase characteristic of glass ionomer cements; however, the glass ionomer phase, which is responsible for fluoride release is readily available in PRG particles.[6,7]

2. Aim

Aim of the present in-vitro study was to compare and evaluate microleakage of a Giomer, Compomer, Hybrid composite and RMGIC, along the enamel and cemental margins of class V cavities and to compare the microleakage between the enamel and cemental margins of each material.

3. Materials and Methods

This study was conducted at Government Dental College, Thiruvananthapuram, Kerala, India. This study included 80 freshly extracted human mandibular or maxillary premolars, extracted for orthodontic reasons. Teeth were divided into four groups of 20 each. Teeth were randomly selected with respect to the inclusion and exclusion criteria and were distributed into four experimental groups. Teeth with previous restorations, cracks, decay, fracture, abrasion or structural deformities were excluded from the study.Teeth were cleaned with ultrasonic scaler and disinfected with 0.5% chloramine for 24 hours and stored in distilled water at room temperature. Class V cavities were prepared on the buccal surface of teeth using 008-diamond bur (Diatech Dental AG) with air/water spray. Preparations were centered on the cemento-enamel junction and were approximately 1.5 mm deep, 3 mm in height and 3.5 mm in width. No bevel was prepared for the enamel margins thus maintaining 90 – degree cavosurface angles at all cavity margins. All the cavity preparations and restorations were performed by the same operator to eliminate inter operator variability. After cavity preparations, the teeth in each group were assigned numbers and were randomly divided into four experimental Groups (I, II, III and IV). Teeth in Group I were restored using Giomer (Beautifil A3 shade; Shofu Inc. Kyoto Japan) after priming and bonding with a self-etch primer and bonding agent (FL – BOND, Shofu Inc. Kyoto Japan). In group II, the teeth were restored using Compomer (Dyract A3 shade; De Trey, Dentsply) after etching with 37% phosphoric acid and bonding with a fifth generation bonding system (Prime and Bond® NT, Dentsply). Teeth in group III were restored with a Hybrid Composite (Spectrum TPH, shade A3; De Trey, Dentsply) using the same bonding system and protocol as in the second group. In group IV, the teeth were restored with RMGIC (Fuji II LC Improved, Shade A3, GC Corp: Tokyo, Japan) as per manufacturer's instructions. Cavities were restored in incremental technique and finishing and polishing were done after 24 hours using extra fine diamond points (Mani, Japan) and SofLex disks (3M ESPE, USA).

3.1. Microleakage testing

The specimens were stored in 100% relative humidity at 37°C for 24 hours and then subjected to thermocycling for 500 cycles in a thermocycling machine (HAAKE; Thermoelectron Corporation) with two baths at $5 \pm 2^{o}C$ and $55 \pm 2^{o}C$ with a dwell time of 30 seconds and a dry cycle at temperature $22 \pm 2^{o}C$ with a dwell time of 30 seconds in between the two baths. The root apices were then sealed with cyanoacrylate and two coats of nail varnish were applied to the entire tooth surface to within 1.0 mm of the restoration to limit dye penetration to cavity margins. The coated teeth were then immersed in 0.5% solution of methylene blue dye for 24 hours at room temperature. The stained teeth were embedded in clear acrylic auto polymerizing resin using split stainless steel moulds. A Buehler Isomet (Buehler Ltd, Evanston, IL, USA) low speed diamond saw was used to section the tooth block, such that buccolingual sections through the centre of the restoration were obtained. Two sections were obtained from each block and the section with greater dye penetration reading was considered as the leakage score of the particular tooth sample. Dye penetrations at the occlusal and gingival margins were examined and photographed using a stereomicroscope (LEICA MZ6, Vashaw Scientific Inc.) at 20X magnification. A scoring system for measurement of microleakage was followed strictly for all samples. The degree of microleakage along the incisal and cervical margins were determined using the following scoring system [Figures 1, 2, 3, 4 and 5].

Score 0 – no leakage cervically/incisally.

Score 0.5 – leakage half the length of cervical/incisal wall.

Score 1.0 – leakage extending along the full length of cervical/incisal wall.

Score 1.5 – leakage along the full length of cervical/incisal wall and extending towards the incisal/cervical wall respectively, occupying half the length of the walls.

Score 2.0 – leakage along the full length of incisal and cervical wall and extending through the dentinal tubules into the pulp chamber.

Fig. 1: Score- 0 at both enamel and cemental margins

3.2. *Statistical analysis*

The depth of dye penetration along the incisal and cervical margins towards the pulpal wall was measured using the visual scoring system. The statistical analysis of data was done using the one-way ANOVA (Analysis of variance) test. The inter group comparisons were made using Duncan's Multiple Range Test. A p-value of <0.05 is

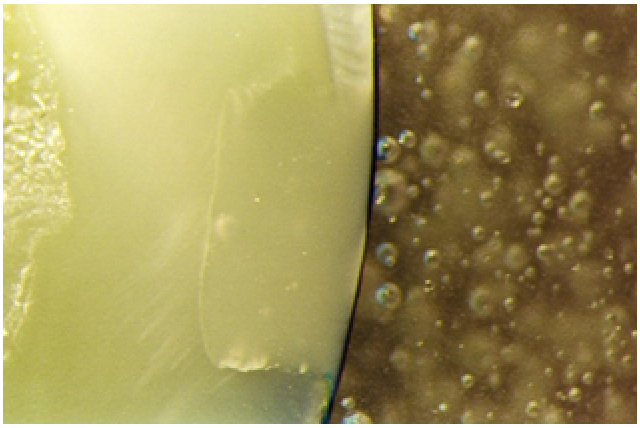

Fig. 2: Score- 0 at enamel margin and 0.5 at cemental margin

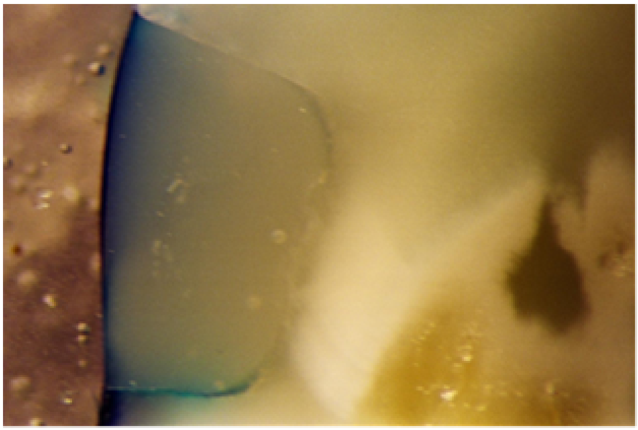

Fig. 3: Score- 0 at enamel margin and 0.5 at cemental margin

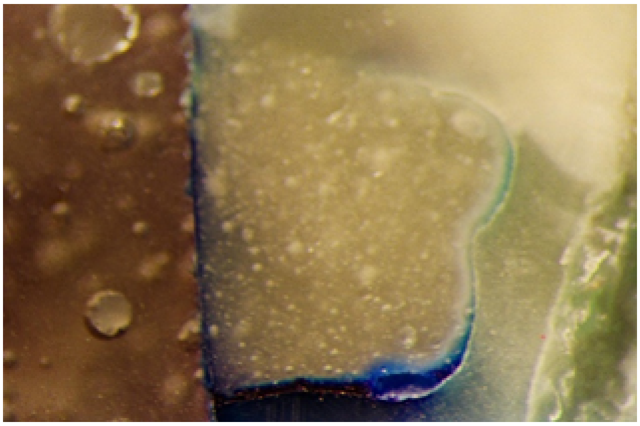

Fig. 4: Score 0 at enamel margin and 1.5 at cemental margin

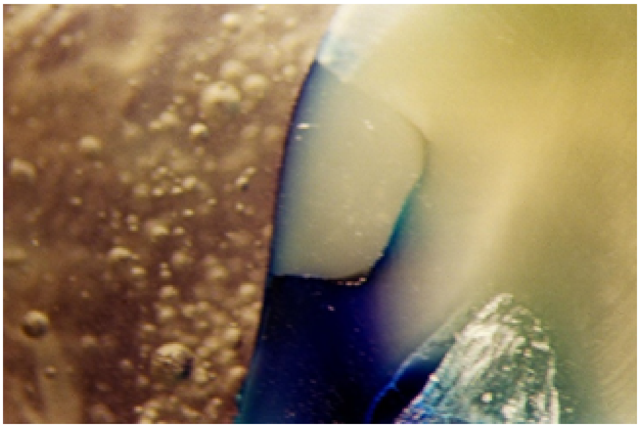

Fig. 5: Score 0 at enamel margin and 2 at cemental margin

taken as statistically significant. The enamel microleakage was evaluated separately from cemental microleakage. The comparison between the enamel and cemental margins within each material were also done, using the Mann Whitney U Test.

4. Results

The microleakage values of Group I, II and III do not differ significantly from each other at the enamel margins while the microleakage of Group IV is significantly higher than the other three materials ($p<0.001$) [Figure 2]. At the cemental margins, the microleakage values of the Group II and Group III do not differ significantly from each other and were significantly lower compared to Group I and Group IV and the values of Groups I and IV were not significantly different from each other ($p<0.05$)Figure 3]. The mean enamel and cemental microleakage within each material were compared using Mann Whitney U Test. The analysis of the values shows that the cemental margins show significantly greater microleakage compared to enamel margins for all the four materials($p<0.001$) [Figure 4]

5. Discussion

Marginal seal of a dental restorative material is its capacity to adapt well to the tooth structure and hence prevent the development of secondary caries and destruction of tooth structure. Microleakage is used as a measure by which clinicians and researchers can predict the performance of a restorative material. Microleakage between cavity wall and restorative material is one of the main causes of post-operative sensitivity, recurrent caries and pulpal pathosis.[1,8] Restoration of Class V cavities which are usually located in cervical area of the tooth, presents a special challenge to the clinician.[9] The coronal margins of these Class V cavities are in enamel while the gingival margin is usually located in cementum or dentin. Despite several improvements in adhesive systems, the adaptation and bonding of these adhesive systems to cementum and dentin is less predictable. The cyclic flexure of tooth in the cervical areas along with polymerization shrinkage of adhesive material may also lead to loss of marginal adaptation.[9–12]

In-vitro evaluation tests are done to predict the clinical performance of the restorations.[2] Various methods for detection of marginal adaptation of restorative material include dye and bacterial leakage studies, chemical and radioactive tracers and Scanning Electron Microscopy (SEM).[12] Bond failure between the tooth and restoration interface are commonly assessed with microleakage dye penetration tests.[1,2] The dye leakage technique of detecting the microleakage is an acceptable technique of studying microleakage[13] eventhough it has some limitations in the method of assessment.

Thermocycling is the in vitro process of subjecting the restoration on the tooth to temperature extremes compatible with the oral cavity. This simulates introduction of hot and cold extremes in the oral cavity and shows the relationship between coefficient of thermal expansion between the tooth and restorative material.[14] In the present study experimental teeth were subjected to thermocycling, similar to other microleakage studies.[9–11,15]

None of the tested materials were able to completely resist microleakage at either incisal or cervical aspects. The gingival margins of all the four restorative materials exhibited significantly greater leakage than the occlusal margins. This finding is in accordance with the previously reported studies on microleakage of RMGICs[16] and resin based composites.[17–19] The increased cemental microleakage can be attributed to various factors like cavity configuration (C-factor), organic content of the dentin substrate and movement of tubular fluids, incomplete alteration/ removal of smear layer by acidic primers (self-etch systems), inefficient infiltration/penetration of primer components into the mineralized collagen fibrillar network, polymerization contraction of the resin composite, physical characteristics of restoration material (filler loading, volumetric expansion, modulus of elasticity), polymerisation source-photoinitiator incompatibilities and instrumentation and finishing/polishing effects[18,20–25]

The microleakage of the RMGIC (Fuji II) was greater than the compomer, the hybrid composite and the giomer used in the study. The cemental microleakage was comparable to that of giomer but was significantly higher than composite and compomer. This is in accordance with the previous studies by Minakuchi et al[26] and Oda et al.[27] Morabito et al[28] found that compomers showed the best mechanical and esthetic properties combined with a good marginal seal compared to RMGICs. On the contrary de Magalhaes CS et al[29] concluded that the microleakage performance of glass-ionomer-resin composite hybrid materials were similar to those of a conventional glass-ionomer and a bonded resin composite system. The texture

Table 1: One-way ANOVA comparing enamel microleakage of test materials

Material	Mean*Enamel Microleakage	+ SD	F value	P value
Group I	0.175^{a}	0.373	14.176	< 0.001
Group II	0.053^{a}	0.158		
Group III	0.175^{a}	0.437		
Group IV	0.825^{b}	0.568		

a, b – Means with same superscript do not differ each other (Duncan's Multiple Range Test) * Mean of 20 observations per material

Table 2: One way ANOVA comparing cemental microleakage of test materials

Material	Mean* Cemental Microleakage	± SD	F value	P value
Group I	1.175^{b}	0.634	13.867	< 0.05
Group II	0.578^{a}	0.607		
Group III	0.875^{a}	0.509		
Group IV	1.200^{b}	0.641		

a, b – Means with same superscript do not differ each other (Duncan's Multiple Range Test)* Mean of 20 observations per material

Table 3: Mean enamel & cemental micro-leakage within each material

Material	Mean Enamel Micro-leakage	Mean Cement Micro-leakage	U value*	P value
Group I	0.175 ± 0.373	1.175 ± 0.634	20.027	< 0.001
Group II	0.053 ± 0.158	0.578 ± 0.607	16.239	< 0.001
Group III	0.175 ± 0.437	0.875 ± 0.509	25.651	< 0.001
Group IV	0.825 ± 0.568	1.200 ± 0.641	11.354	< 0.001

* Mann Whitney U Test; P < 0.001 – Highly significant

of Fuji II LC appeared granulated with incorporation of air voids when viewed under the stereomicroscope, probably due to the manual mixing of the material required before placement. The porous nature of the material compared to other materials may also be an important factor that enhances potential for microleakage.

The microleakage values of the compomer and hybrid composite were comparable. This is in accordance with previous studies.[17,30] Kugel et al[31] has reported that Dyract had good marginal adaptation, when enamel was etched prior to its placement. Thus Dyract behaves more like a composite and less like a glass ionomer.[32] For both the compomer and composite materials in the study, the same bonding system i.e. Prime and Bond NT, which is a fifth generation bonding agent that relies on total etch technique was used This might have resulted in the similar microleakage behaviour of the two materials. A probable explanation for the comparatively better microleakage scores of the above two could be also due to the presence of nanofillers in the adhesive system that claims to improve bond strength with tooth structure and subsequently reduces microleakage. Tay et al[33] had suggested that the nanofillers added to certain one bottle adhesives may help to establish a uniform resin film that stabilizes the hybrid layer. Despite the considerable high bond strengths of composites to dentin using the latest generation of bonding agents, composite restorations with margins located in dentin still suffer microleakage mainly caused by dimensional changes of composite.[34,35]

The giomer (Beautifil) used in the study showed microleakage values similar to composite and compomer at the enamel margins. The microleakage values at the cemental margins were significantly greater compared to composite and compomer. Eventhough the giomer showed less microleakage than light cured glass ionomer at the cemental margins, the difference was not statistically significant. Thus in the present study, the enamel microleakage of the giomer is similar to that of the compomer and composite and the cemental microleakage is comparable to that of RMGIC. This is in accordance with the previous studies by Fu et al.,[36] where they concluded that self-etching primers are unable to reduce cemental microleakage. The bonding system used with the giomer (Beautifil) is FL-Bond, which belongs to the category of self- etch primers. Depending on their pH, self-etch primers can be subdivided into weak, strong and intermediary strong self- etch systems.[22] FL Bond is based on "mild" self-etching system and it was reported that a self-etch procedure with "mild" self-etching primers may result in equal or reduced bonding effectiveness to enamel when compared to total etch.[37,38] According to the above results, it seems that failure to use a separate acid as a preliminary step in tooth enamel substrate may result in insufficient bond strength and sealing ability with enamel.[39] In contrary some authors have observed that prior application of phosphoric acid to etch dentin negatively affects dentin bonding of mild self-etch primers. This leads to over-etched dentin and incomplete infiltration of the resin monomer.[40] The FL-Bond contains

4-AET (4-Acryloxyethyltrimellitic acid), which can interact with the calcium cations of hydroxyapatite to form 4-AETCa, a relatively insoluble calcium salt that improves durability of adhesive system.[41] This can also be a reason for the comparable microleakage of giomer to that of compomer and composite at the enamel margins in the present study.

The bonding mechanism of mild self-etching adhesives to dentine is also based on hybridization, with the difference that only submicron hybrid layers are formed and resin tag formation is less pronounced.[42] Studies by Van Meerbeek & others[43] concluded that these adhesive systems typically result in a shallow hybrid layer (0–1 μm) and in non-demineralised sections they revealed only partially demineralised dentine, leaving collagen fibrils coated by hydroxyapatite crystals. Thus dentinal microleakage depends on the efficiency of their respective monomers in infiltrating the smear layers and producing resin tags and this can be one of the reasons for increased microleakage of giomer compared to composite and compomer. The strong self-etch adhesives have been documented as having an interfacial ultra-morphology at dentine resembling that produced typically by total-etch adhesives. Consequently, the mechanism of bonding of strong self-etch adhesives to dentine is more like that of total-etch adhesives.[22] Some authors suggested that the main cause of marginal deterioration of giomer restorations is hygroscopic expansion which is an intrinsic property of this restorative material.[44]

In summary, the results of our study indicated that none of the restorations where able to completely resist microleakage in class V restorations. Hybrid composites and compomers showed better sealing ability probably due the better bonding given by conventional etch and rinse adhesive. Improvements in the self –etch systems may have better future perspective, but further longitudinal clinical trials are still needed to evaluate their true performance.

6. Limitation

In this study, the hybrid layer morphology was not evaluated microscopically. So the specific nature of restoration failure (microleakage) for each adhesive system is unknown. The teeth were not subjected to any mechanical stress. Hence, future studies should also be conducted by subjecting these restorations to cyclic occlusal loading. The sealing ability of these restorative materials should also be examined through other complex methods like bacterial penetration and with the use of fluid transport model. The present study was done under in-vitro conditions; hence future studies should be focused to be conducted in-vivo conditions to evaluate the clinical behavior of the tested restorative materials.

7. Conclusion

Within the limitations of the present in-vitro study following conclusions can be drawn:

1. None of the restorative materials tested in the present study were able to totally prevent the microleakage on the cervical margin of the Class V cavities.
2. Hybrid composite, giomer and compomer showed lesser microleakage and better marginal adaptability when compared to RMGIC at the enamel margins while both giomer and RMGIC had greater microleakage at the cemental margins of class V restorations.

8. Source of Funding

None.

9. Conflict of Interest

The author declares no conflict of interest.

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