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Comparative Evaluation of Microleakage in Class V Cavities Restored with Various Restorative Materials Using CLSM - An in Vitro Study

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Abstract

Background: Microleakage is a major reason of restoration failure, leading to postoperative sensitivity and secondary caries. Modified glass ionomer cements are routinely used to minimize microleakage and postoperative sensitivity in class V cavities.

Aim: This study aims at the evaluation and comparison of microleakage in Class V cavity restorations done with Conventional, Resin modified (RMGIC), Zirconia reinforced and Ceramic reinforced glass ionomer cements.

Materials and Methods: A total of 56 maxillary premolars were collected and class V cavities had been made on the buccal surface, 1 mm just above the junction of cementum and enamel (CEJ). All cavities received surface pre-treatment in accordance with currently accepted protocol and had been categorized into 4 groups on the basis of material employed for restoration: Group-A (Conventional GIC), Group-B (RMGIC), Group-C (Zirconomer improved) and Group-D (Amalgomer CR). All samples underwent 500 cycles of thermocycling following finishing and polishing of restoration. Samples were cut bucco-lingually which was immersed in 0.5% Rhodamine B dye and microleakage was assessed using Confocal Laser Scanning Microscopy (CLSM).

Statistical Analysis: One-way ANOVA and Tukey's Post Hoc test was used for statistical analysis.

Results: Microleakage in Group B samples was significantly less ($p<0.05$) than Group C and D. Group A and B have shown no statistically significant difference between them.

Conclusion: All restorative materials tested showed microleakage to an extent. RMGIC demonstrated least microleakage whereas Amalgomer CR showed highest microleakage among four groups.

Keywords: Amalgomer CR, class V cavity, CLSM, Microleakage, RMGIC, Zirconomer.

Introduction

The term "microleakage" describes the microscopic infiltration of fluids, chemicals, ions, or microorganisms between the restorative material and the cavity walls.[1] Class V cavities are more prone to microleakage as the margins of restorations are located in the gingival region, where cementum or dentin bonding is less predictable than enamel bonding. [2] Earlier, gold and amalgam were used widely for restorations; however, their poor aesthetic appeal has led to a decline in their use. The preferred materials used currently includes resin composites, glass ionomer cements and compomers.[3,4]

Glass Ionomer Cements (GICs), introduced in the 1970s have been modified over time to improve their properties. They offer advantages like tooth structure adhesion, fluoride ion discharge and a thermal expansion co-efficient comparable to dentin which helps reduce microleakage and in turn dentin hypersensitivity. To address the strength and wear resistance limitations of traditional glass ionomer cements, Fuji IX (GC dental, Tokyo, Japan) has been introduced as a solution for stress-bearing areas. This conventional GIC is enhanced with strontium glass which strengthens the material by allowing calcium ions to diffuse into glass ionomer surface when exposed to a calcium-rich environment such as saliva.[5]

Resin-modified GICs (RMGICs) introduced in the 1990s offer additional benefits such as prolonged working time, improved translucency and faster setting, overcoming some of the limitations of conventional GICs.[6] Recently, an innovative material, ZIRCONOMER IMPROVED (Shofu Inc., Japan), was developed which incorporates nano-sized zirconium dioxide fillers, enhancing its strength and durability to levels comparable to amalgam. This material, often referred to as 'white amalgam' offers enhanced performance in dental restorations by combining the strengths of both components.[7]

Amalgomer CR (Advanced Health Care, Ltd., UK) is the first GIC introduced with ceramic reinforcement for added durability. The manufacturer claims that this aesthetic restorative material brings together the

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durability of a metallic restoration with the aesthetic appeal, chemical bonding and fluoride release of glass ionomers.[8]

This study aims at the evaluation and comparison of microleakage in restorations of Class V cavity with various materials including viz. conventional GIC, RMGIC, Zirconomer and Amalgomer CR using CLSM to assess their sealing effectiveness and performance in preventing microleakage.

Materials and Methods

After informing the patient about the study and taking written consent, fifty-six permanent maxillary premolars removed for orthodontic treatments had been included for the study. Premolars with evident abrasion, cracks, fracture, caries, restorations or structural abnormalities were excluded from the study. An ultrasonic scaler was used to clean the teeth. To prevent microbial growth and dehydration, the collected teeth were preserved in a 0.1% thymol solution.

Preparation of sample

Class V cavities of 3 mm, 2 mm and 2 mm in width, height and depth respectively had been prepared on the buccal surface of each tooth using a straight fissure bur (SF 41, MANI Inc., Japan) under continuous air-water spray (Figure.1-a). Standardization of dimensions of prepared cavities were done with graduated periodontal probe (Figure.1-b, 1-c, 1-d). The cavities had been prepared at the centre of cervical third of buccal surface of premolars, 1 mm just above the CEJ. New burs were used in instead of the old ones following each fourth cavity preparation. The sample teeth were randomly categorized into four groups (n=14) according to the materials used for restoration.

- **Group A:** Teeth restored with Conventional GIC (GC Gold Label HS Posterior EXTRA, GC Corporation, Tokyo, Japan).
- **Group B:** Teeth restored with Resin modified GIC (GC Fuji Gold Label 2 LC, GC Corporation, Tokyo, Japan).
- **Group C:** Teeth restored with Zirconomer improved (Shofu Inc, Kyoto, Japan).
- **Group D:** Teeth restored with Amalgomer CR (AHL, Ltd., UK).

All samples were treated over 20 seconds with a dentin conditioner (GC Corporation, Tokyo, Japan) to condition the preparation walls, followed by a 10-second water rinse (Figure.1-e). To avoid complete dehydration, the cavities were dried with blotting paper. Manufacturer's guidelines including powder/liquid ratio and manipulation technique were followed while restoring each sample (Figure.1-f, 1-g, 1-h, 1-i). A transparent mylar matrix strip was placed over restorations for 2 minutes as soon as it was restored. Restorations were finished and polished 24 hours after its placement (Figure.1-j).

Microleakage Testing

The samples were exposed to 500 thermocycles at temperatures ranging from 5 to 55 degrees Celsius, with a 30-second dwell time. After thermocycling, two layers of nail polish were coated over sample leaving a 1 mm space surrounding the restoration. After sealing teeth apices with sticky wax, the specimens had been dipped in 0.1% Rhodamine B dye (HiMedia, Mumbai, India) over a duration of 48 hours (Figure 1-k). Following immersion, each tooth was thoroughly rinsed in distilled water to remove any excess dye. All samples were cut along the restoration's centre in a buccolingual manner with precision Bain cut low-speed diamond saw under continuous water (Figure.1-l).

Microleakage was measured with CLSM (Leica stellaris 5, Confocal Laser Scanning Microscope). Evaluation of microleakage was carried out by a blinded researcher to

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avoid observational bias. The criteria given by Staninec and Holtz in 1988 was used for identifying degree of dye penetration.[9] (Figure 2).

0 = absence of evident penetration

1 = less than midway to the axial wall but along the gingival or occlusal wall

2 = more than midway to the axial wall along the gingival or occlusal wall

3 = up to and across the axial wall, along the gingival or occlusal walls.

Statistical approach

Software called SPSS version 21 for Windows (SPSS Inc., Chicago, IL) has been used to conduct the statistical analysis. Descriptive quantitative data were presented as mean, standard deviation and standard error. $P < 0.05$ was taken into consideration as the significance criterion for all statistical analyses. Microleakage data had been evaluated by performing one-way ANOVA and intergroup comparisons were further assessed using the Tukey HSD post hoc test.

Results

In cavities restored with various materials, microleakage was measured to determine the degree of dye penetration across the occlusal or gingival wall to the axial wall. Figure 2 displays the results, which are further summarized in Table 1.

Group B exhibited significantly lower dye penetration than groups C and D, indicating reduced microleakage. The statistical analysis revealed a significant difference in mean microleakage scores, with the group B demonstrating a mean score of 0.714, which was notably lower than those of the group C (1.714) and group D (2.071).

Groups A and B did not differ significantly on a statistical basis ($p = 0.199$). Conversely, there were notable distinctions between Group B and C ($p = 0.005$) as well as between Group B and D ($p < 0.001$). (Table 2).

Discussion

Prevention of microleakage is a key element among all the factors for ensuring a successful restoration, which is achieved by properly adapting restorative materials to the cavity walls.[6] When restorative materials fail to establish a complete marginal seal, micro gaps can form, leading to the infiltration of fluids, ions and bacteria. This results in hypersensitivity, secondary caries and pulpal inflammation. In both clinical and research settings, microleakage is frequently employed as a criterion to predict the success of restorative materials.[1,10]

Cervical lesions are of particular concern when evaluating the health of teeth for long-term. Cervical restorations are made more difficult by the early onset of decay in this location, as well as difficulties with isolation, procedure, finishing the restorative material, bonding and the tooth's cyclic flexing in the cervical area.[11,12] Materials like composite resins, glass ionomer cements and compomers are currently recommended for Class V cavity restorations.[13]

Thermocycling is frequently used in vitro to evaluate the microleakage of restorative materials by simulating in vivo aging through repeated cycles of hot and cold temperature exposure. It emphasizes the effect of discrepancies in expansion due to temperature changes among tooth and restorative materials, which can cause marginal gaps and allow the seepage of fluids, bacteria and ions, potentially leading to secondary caries, postoperative sensitivity and pulpal inflammation.[14]

In this study, Rhodamine-B dye, with an average molecular size of 1 nm, was chosen for its ability to infiltrate even the tiniest gaps in restoration interfaces, making it an ideal choice for microleakage assessment.[15]

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Assessment of the interface between restoration and preparation walls of cavity without the need for sectioning or dehydration can be done using Confocal Laser Scanning Microscopy (CLSM).[16] It minimizes artifacts that could affect results unlike Scanning Electron Microscopy (SEM) or Transmission Electron Microscopy (TEM).

The results of the investigation indicated that microleakage was present in all four groups to some degree. Microleakage was highest in the Amalgomer CR group and lowest in the Resin Modified Glass Ionomer group.

Comparing Group A, the standard GIC, to the other groups, revealed modest levels of microleakage. Similar results were noted by Pontes et al., who reported more microleakage using standard glass ionomer as opposed to resin-modified glass ionomer. [17] The current study's findings concur with those of Bouschlicher et al. and Brackett et al.[18,19]

Resin-modified glass ionomers (RMGICs) have been developed to increase the mechanical strength and handling characteristics of glass ionomers. RMGICs have a command set, longer working time, superior appearance, better translucency and higher strength compared with the conventional GICs.[20] These materials contain glass particle fillers which release ions, similar to those found in conventional glass ionomer cements (GICs), but particle size is smaller.[13]

In Resin modified glass ionomer, two type of setting reactions occurs. 1) Poly-carboxylic acid and fluoro-alumino-silicate glass undergo an acid-base reaction. 2) The polymer's methacrylate group and HEMA undergo radical induced polymerization (2 hydroxy-ethyl methacrylate).[21]

In the present study, RMGIC (Group B) exhibited least microleakage compared to other groups. This may be due to RMGICs adhering to the tooth structure via two mechanisms: chemical bonding with enamel and dentin, and the formation of a hybrid layer. Fukuda et al. discovered a chemical link between RMGICs and the inorganic components of enamel and dentin employing photoelectron X-ray spectroscopy and Fourier-transform infrared spectroscopy.[22] CLSM also demonstrated the creation of a hybrid layer in dentin with RMGICs.[23]

According to Brackett et al., resin-modified glass ionomer cement exhibited effective sealing properties and they suggested that preventing dehydration could help limit microleakage. [24] Likewise, Wilder et al. reported significantly reduced microleakage with resin-modified glass ionomer in comparison to conventional glass ionomer cement. [25]

This investigation found that Zirconomer exhibited higher microleakage than both Conventional GIC and RMGIC. This may be due to its unique chemical composition, which includes zirconia fillers. These zirconia particles may disrupt the chelation process between the carboxylic groups (–COOH) of polyacrylic acid and the calcium ions (Ca^{2+}) in tooth apatite, leading to reduced bonding efficiency. [6]

Glass Ionomer Cement reinforced with ceramic (Amalgomer CR) also exhibited increased microleakage. This may be due to disruption of the polyacrylate matrix, possibly caused by the larger ceramic filler particles, which can hinder proper adaptation to the tooth-restoration interface.[8]

Constraints of this investigation was the inability to assess clinically relevant variables because of its in vitro design although procedures like thermocycling simulated oral conditions.

Conclusion

When compared to Zirconomer, Amalgomer CR and Conventional Glass Ionomer, Resin Modified Glass

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Ionomer Cement (RMGIC) showed the least level of microleakage within the parameters of this investigation. To overcome postoperative sensitivity as a result of microleakage, we are in need of better restorative materials and RMGIC proves to be of use in class V restorations to improve longevity and prevent secondary caries. Additional studies are necessary to investigate the microleakage of restorative materials in clinical conditions.

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Legends Tables and Figure

Table 1: Mean microleakage in different groups

Microleakage	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Min	Max
					Lower Bound	Upper Bound		
GIC	14	1.2857	.82542	.22060	.8091	1.7623	.00	2.00
RMGIC	14	.7143	.61125	.16336	.3614	1.0672	.00	2.00

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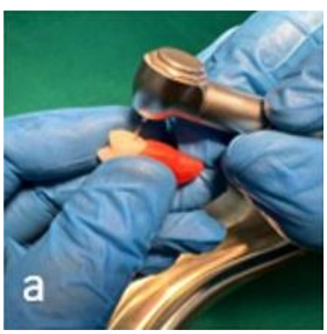
Zirconomer	14	1.7143	.82542	.22060	1.2377	2.1909	1.00	3.00
Amalgomer CR	14	2.0714	.73005	.19511	1.6499	2.4929	1.00	3.00
Total	56	1.4464	.89279	.11930	1.2073	1.6855	.00	3.00

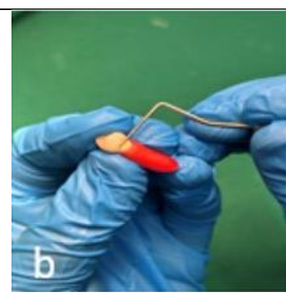
Table 2: Multiple group comparisons

Tukey HSD						
(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
GIC	RMGIC	.57143	.28468	.199	-.1841	1.3270
	Zirconomer	-.42857	.28468	.442	-1.1841	.3270
	Amalgomer CR	-.78571*	.28468	.039*	-1.5413	-.0301
RMGIC	GIC	-.57143	.28468	.199	-1.3270	.1841
	Zirconomer	-1.00000*	.28468	.005*	-1.7556	-.2444
	Amalgomer CR	-1.35714*	.28468	<.001*	-2.1127	-.6016
Zirconomer	RMGIC	1.00000*	.28468	.005*	.2444	1.7556
	GIC	.42857	.28468	.442	-.3270	1.1841
	Amalgomer CR	-.35714	.28468	.596	-1.1127	.3984
Amalgomer CR	RMGIC	1.35714*	.28468	<.001*	.6016	2.1127
	GIC	.78571*	.28468	.039*	.0301	1.5413
	Zirconomer	.35714	.28468	.596	-.3984	1.1127
*. The mean difference is significant at the 0.05 level.						

Figure 1: Preparation of samples



a. Class V tooth preparation



b. Preparation mesio distal width 3mm

c. Preparation occluso gingival height 2mm

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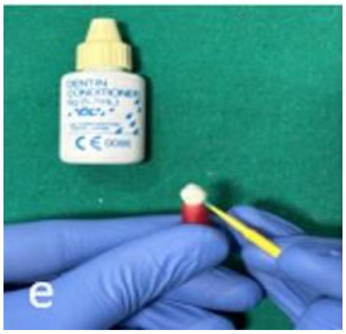
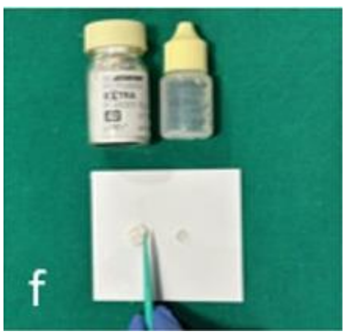
d. Preparation depth 2mm



e. Conditioning of preparation walls



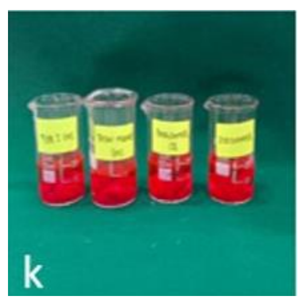
f. Manipulation of GIC

g. Manipulation of RMGIC

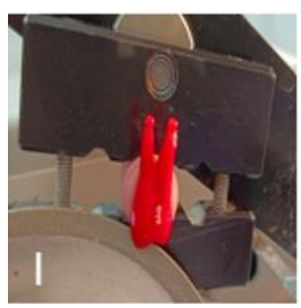
h. Manipulation of Zirconomer

i. Manipulation of Amalgomer CR

j. Finishing and polishing of restoration.



k. Immersion of samples in rhodamine dye



l. Sectioning of tooth

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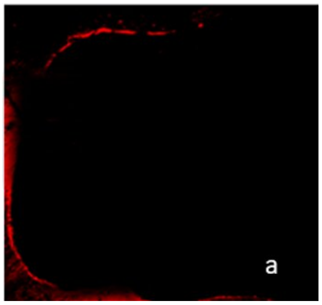
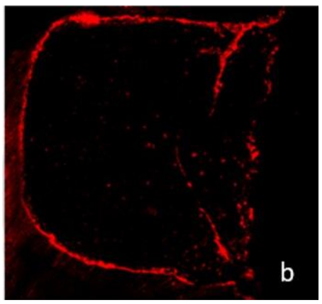
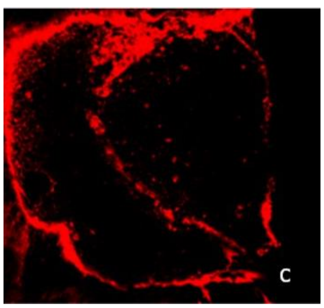
Figure 2: CLSM images of the samples showing scoring criteria 0-3



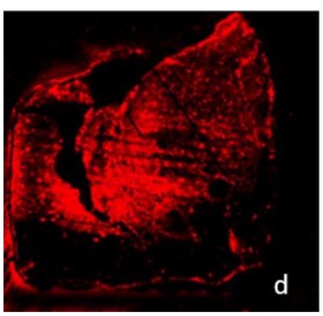
a. Score 0 = Group-B, (absence of evident penetration)



b. Score 1 = Group-A, (less than midway to the axial wall but along the gingival or occlusal wall)



c. Score 2 = Group-C, (more than midway to the axial wall along the gingival or occlusal wall)



d. Score 3 = Group-D, (up to and across the axial wall, along the gingival or occlusal walls)

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