ORIGINAL RESEARCH

Comparative Evaluation of Microleakage of Direct Tooth-colored Restorative Materials on Class V Cavities: An *In Vitro* Study

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Abstract

Aims and background: The aim of the study is to evaluate and compare the marginal sealing efficacy of four direct tooth-colored restorative materials on class V cavities using the dye penetration method.

Materials and methods: Sixty human permanent premolars extracted for orthodontic purposes were used in the study. Class V cavities were prepared on the labial surface of the premolars, with occlusal margins in enamel and gingival margins in dentin or cementum. The teeth were divided into 4 groups of 15 samples each. Equia Forte Fil (GC), Cention N (Ivoclar Vivadent), resin-modified glass ionomer cement (RMGIC—GC Fuji II LC), and Filtek Z350 (3M ESPE) were placed in the class V cavities of the samples in groups I, II, III, and IV, respectively. The samples were then subjected to thermocycling, placed in basic fuchsin dye for 24 hours, and sectioned longitudinally. They were observed under a stereomicroscope. The data were analyzed using the Chi-squared test, Kruskal–Wallis test, and Mann–Whitney *U* test.

Results: The Chi-squared test shows a statistically significant difference in the gingival margin ($p = 0.038$) among the four study groups. The Kruskal–Wallis test shows a statistically significant difference between the four groups in both the occlusal margin ($p = 0.043$) and the gingival margin ($p = 0.036$). The Mann–Whitney *U* test at the occlusal margin shows a significant difference between groups II and IV ($p = 0.040$), and at the gingival margin shows a significant difference between groups I and IV ($p = 0.024$).

Conclusion: The nanocomposite exhibited the least microleakage in both the occlusal and gingival margins compared to the other groups, with microleakage being lesser in the occlusal margin than in the gingival margin.

Clinical significance: Microleakage can lead to secondary caries, tooth hypersensitivity, and pulpal infection. Therefore, the selection of a restorative material with the least or no microleakage is important.

Keywords: Cention N, Dye penetration, Equia Forte, Filtek Z350, GC Fuji II LC, Microleakage.

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Introduction

The principle of restorative dentistry is to restore the tooth to its proper shape, form, function, and esthetics.[1] The adhesiveness of the restorative material to the walls of the cavity is important to achieve a proper seal between them and to prevent the seepage of microorganisms and oral fluids.[2]

The longevity of the restorative material depends on the structural integrity and durability of the material used.[3] Inability to attain a complete seal at the margins by the restorative materials results in microgaps through which oral fluids and bacteria pass, causing secondary caries, tooth hypersensitivity, and pulpal infections. Therefore, microleakage is a major cause of restoration failure and the need for replacement of restorations.

In class V cavities, due to their gingival/cemental margins, bonding restorations to dentin becomes a challenging factor because dentin has a complex pattern and less mineral content compared to enamel.[2]

Amalgam and gold restorative materials, which were used earlier to restore class V cavities, have become obsolete due to their poor esthetic results. Nowadays, newer and more esthetic materials are used to restore class V cavities.[4]

Equia Forte Fil (GC) is a newly introduced, highly viscous glass ionomer-based cement. It contains evenly dispersed, ultrafine, and highly reactive micron-sized fluoroaluminosilicate fillers and high molecular weight polyacrylic acid, which releases a large amount of fluoride and metal ions. The set material has improved physical properties, such as Vickers hardness and flexural strength.[5,6]

Cention N (Ivoclar Vivadent) is a tooth-colored, newly introduced basic bulk-filling restorative material and a subgroup of composite resin. It is an "alkasite"-based restorative material containing alkaline glass fillers that release fluoride, calcium, and hydroxide ions. It is a self-curing material with optional additional light curing. It also contains a special patented isofiller that relieves shrinkage stress, thereby reducing polymerization shrinkage and microleakage.[7]

Resin modified glass ionomer cement (GC Fuji II LC) is a modification of conventional glass ionomer cement (GIC) that

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combines properties of both composite resin and GIC. It contains water-soluble resin that provides strength similar to composite resin, while bonding to the tooth is similar to GIC. The setting involves both acid-based and monomer polymerization reactions, which are initiated either chemically or by curing light. It has high fracture toughness, water and wear resistance, and increased working time.[8]

Nanocomposites (Filtek Z350 3M ESPE) are materials that contain nanosized filler particles ranging from 1 to 100 nm, incorporated into a matrix of standard material.[9] The reduced dimension and wide distribution of particles lead to increased filler loading, thereby reducing polymerization shrinkage and microleakage.[10]

Nowadays, GIC-based and composite-based materials are more commonly used for restorations because of their tooth-colored nature, biocompatibility, ease of use, and strength. Therefore, selecting a tooth-colored restorative material with longevity in the oral cavity is necessary. One of the main drawbacks of these restorative materials is microleakage, which is a significant parameter for detecting the early signs of restoration failure.

Since there is a lack of comparative evidence in the field of microleakage evaluation between various newly introduced tooth-colored restorative materials, which aids in the better selection of restorative materials, the present study aimed to evaluate and compare the microleakage of the newly introduced Equia Forte Fil, Cention N, nanocomposite, and RMGIC restorative materials on class V cavities using the dye penetration method.

Materials and Methods

A detailed protocol about the purpose and procedures of the study was submitted to the Institutional Ethics Committee. Ethical clearance number VDCW/IEC/292/2022.

The study was conducted at Vivekanandha Dental College for Women over a period of 6 months (from September 2022 to February 2023).

Sixty human permanent premolars extracted for orthodontic purposes were collected, stored, disinfected, and handled as per the recommendations and guidelines of the Occupational Safety and Health Administration (OSHA) and the Centers for Disease Control and Prevention (CDC). The teeth were divided into 4 groups with 15 teeth per group, distributed as mentioned below.

Class V cavity preparations with the occlusal margin in enamel and the gingival margin in cementum or dentin were performed on the labial surface of each tooth using a no. 245 bur in a high-speed turbine airotor under water coolant. Preparations were centered on the cementoenamel junction and had the following dimensions: 2 mm axial depth, 1.5 mm occlusogingival height, and 4 mm mesiodistal width. For group IV samples, the preparation margins were beveled at 45° with a width of 0.5–1 mm at the occlusal margin.

Group I: Samples were restored with Equia Forte Fil (GC) according to the manufacturer's instructions.

Group II: Samples were restored with Cention N (Ivoclar Vivadent) according to the manufacturer's instructions.

Group III: Samples were restored with RMGIC (GC Gold Label 2 LC) according to the manufacturer's instructions.

Group IV: A bonding agent (G Premio Bond, GC) was applied, and Nanocomposite (Filtek Z350, 3M ESPE) was placed in increments and light-cured for 20 seconds.

After the placement of the restorations, finishing was done, and the teeth were stored in water at 37°C.

The samples were subjected to 250 thermal cycles between 5 and 55°C water baths. The dwell time was 1 minute with a 10-second transit time between baths. This was done to simulate physiological aging.

After thermocycling, the samples were dried. The apices of all the teeth were sealed with sticky wax. Two coats of nail varnish were applied over the teeth, except for 1 mm around the restoration. The teeth were then subjected to dye leakage by immersion in an aqueous solution of 0.5% basic fuchsin dye for 24 hours at room temperature. After immersion, the teeth were removed from the dye, rinsed in tap water for 30 seconds, and dried. The teeth were then sectioned longitudinally into two halves using diamond disks in a buccolingual direction under constant water cooling.

The dye penetration of the occlusal and gingival margins of each section was evaluated independently under a stereomicroscope (40× magnification). The following criteria were used to score the extent of leakage at the margins according to Alonso et al.[11] (ISO TR 11405, 2003).

0—no dye penetration (Fig. 1).

1—dye penetration into the occlusal/gingival wall without reaching the axial wall (Fig. 2).

2—dye penetration including the axial wall (Fig. 3).[11]

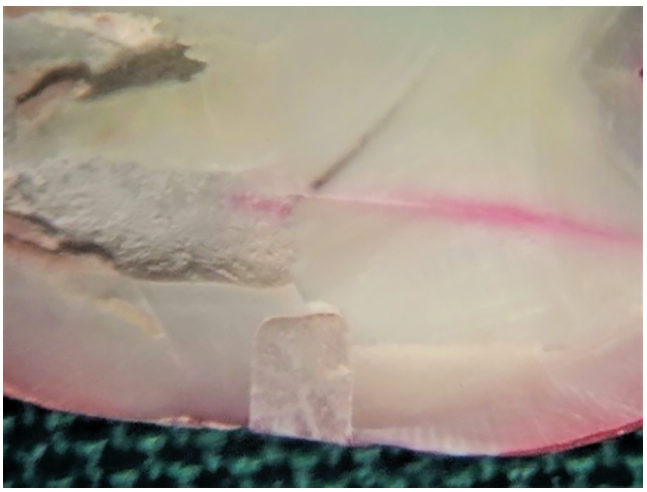

Fig. 1: Microleakage evaluation of class V restoration in a premolar specimen under a stereomicroscope showing score 0—no dye penetration



Fig. 2: Microleakage evaluation of class V restoration in a premolar specimen under a stereomicroscope showing score 1—dye penetration into the occlusal/gingival wall without reaching the axial wall

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) Version 20.0 (Armonk, New York: IBM Corp.). The frequency of different microleakage scores among the groups was compared using the Chi-squared test. Intergroup comparison of mean dye penetration scores was conducted using the Kruskal–Wallis test, with *post hoc* pairwise comparison by the Mann–Whitney *U* test. The level of statistical significance was set at 0.05 with a 95% confidence interval.

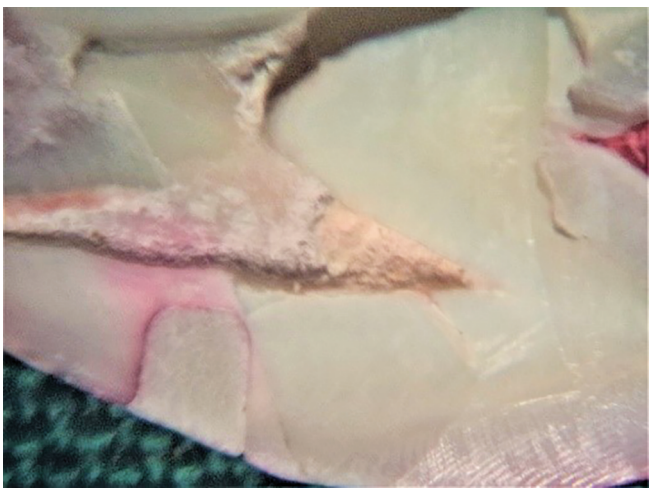

Fig. 3: Microleakage evaluation of class V restoration in a premolar specimen under a stereomicroscope showing score 2—dye penetration including the axial wall

Results

At the occlusal margin, score 0 was found to be more common in group IV, score 1 was more common in groups II and III, and score 2 was more common in groups I and II, as shown in Table 1. The Chi-squared test showed statistically insignificant results ($p = 0.118$) among the study groups.

At the gingival margin, score 0 was found to be more common in group IV, score 1 was more common in group II, and score 2 was more common in group I, as shown in Table 2. The Chi-squared test showed statistically significant results ($p = 0.038$) among the study groups.

The Kruskal–Wallis test shows a statistically significant difference between the study groups at the occlusal margin ($p = 0.043$) and the gingival margin ($p = 0.036$) (Tables 3 and 4) (Figs 4 and 5).

In pairwise comparisons using the Mann–Whitney *U* test, at the occlusal margin, group II shows a significant difference with group IV ($p = 0.040$), as shown in Table 3. At the gingival margin, group I shows a significant difference with group IV ($p = 0.024$), as shown in Table 4.

Discussion

Restorative materials with good adaptation to the cavity walls of the tooth and proper sealing of the margins are essential factors

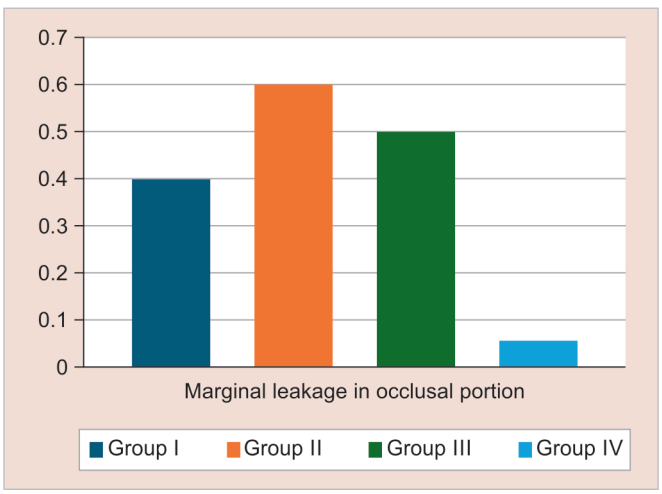

Fig. 4: Intergroup comparison of mean dye penetration scores at the occlusal margin

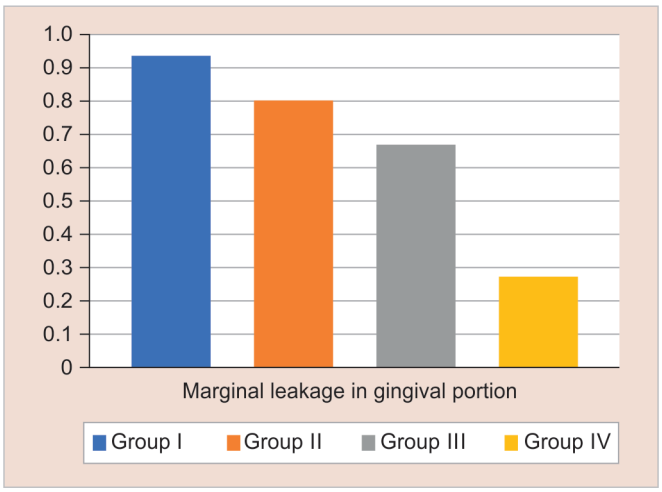

Fig. 5: Intergroup comparison of mean dye penetration scores at the gingival margin

Table 1: Comparison of frequency of occlusal marginal leakage between the four study groups (Chi-squared test)

Occlusal		*Group I*	*Group II*	*Group III*	*Group IV*	*Total*	*p-value*
No dye penetration	Count	10	7	8	14	39	0.118 (NS)
	% of total	16.7%	11.7%	13.3%	23.3%	65.0%	
Dye penetration into the occlusal/gingival wall without reaching the axial wall	Count	4	7	7	1	19	
	% of total	6.7%	11.7%	11.7%	1.7%	31.7%	
Dye penetration including the axial wall	Count	1	1	0	0	2	
	% of total	1.7%	1.7%	0.0%	0.0%	3.3%	
Total	Count	15	15	15	15	60	
	% of total	25.0%	25.0%	25.0%	25.0%	100.0%	

*p-value < 0.05 significant; NS, nonsignificant

Table 2: Comparison of frequency of gingival marginal leakage between the four study groups (Chi-squared test)

Gingival		*Group I*	*Group II*	*Group III*	*Group IV*	*Total*	*p-value*
No dye penetration	Count	5	4	6	11	26	0.038*
	% of total	8.3%	6.7%	10.0%	18.3%	43.3%	
Dye penetration into the occlusal/gingival wall without reaching the axial wall	Count	6	10	8	4	28	
	% of total	10.0%	16.7%	13.3%	6.7%	46.7%	
Dye penetration including the axial wall	Count	4	1	1	0	6	
	% of total	6.7%	1.7%	1.7%	0.0%	10.0%	
Total	Count	15	15	15	15	60	
	% of total	25.0%	25.0%	25.0%	25.0%	100.0%	

*p-value < 0.05 significant

Table 3: Intergroup comparison of mean dye penetration scores at occlusal margin

Study groups	*N*	*Mean*	*Standard deviation*	*p-value*	*Post hoc pairwise comparison test*
Group I	15	0.40	0.632	0.043*	Group I * group II—0.733
Group II	15	0.60	0.632		Group I * group III—0.986
Group III	15	0.50	0.516		Group I * group IV—0.326
Group IV	15	0.06	0.258		Group II * group III—0.902
					Group II * group IV—**0.040***
					Group III * group IV—0.180

*p-value < 0.05 significant

Table 4: Intergroup comparison of mean dye penetration scores at gingival margin

Study groups	*N*	*Mean*	*Standard deviation*	*p-value*	*Post hoc pairwise comparison test*
Group I	15	0.93	0.799	0.036*	Group I * group II—0.935
Group II	15	0.80	0.561		Group I * group III—0.644
Group III	15	0.67	0.617		Group I * group IV—**0.024***
Group IV	15	0.27	0.458		Group II * group III—0.935
					Group II * group IV—0.099
					Group III * group IV—0.301

*p-value < 0.05 significant

for the longevity and success of a restoration. Improper adaptation and sealing ability of the restorative material lead to microleakage between the tooth and restoration, which subsequently results in the development of secondary caries at the margins, postoperative sensitivity, and ultimately failure of the restoration.[12]

Restoration of class V cavities becomes acceptable when the gingival margin is placed in enamel. Difficulty arises when the cavity extends beyond the cementoenamel junction, where the dental tissue differs, and the adaptation and sealing of the restoration margins differ from those of the occlusal margin. Therefore, restoring class V cavities that extend beyond the cementoenamel junction with proper sealing is a challenging factor.[13]

Although scanning electron microscopy, confocal laser scanning microscopy, radioactive isotopes, and neutron activation analysis can all be used to evaluate microleakage, the most popular technique remains the dye penetration method.[14]

Hence, the present study evaluated the sealing ability and marginal microleakage of four different direct tooth-colored restorative materials in class V cavities extending beyond the cementoenamel junction using the dye penetration method.

Eliasson and Dahl concluded that thermocycling is one procedure used to simulate the physiological aging of restorative materials. Several authors have stated that thermal cycling procedures show little or no uniformity in protocols and variables.[15] Pazinatto et al. concluded that the number of thermocycles did not increase microleakage of the restorative material.[16] Therefore, in the present study, only a minimal number of 250 cycles was performed to simulate oral conditions.

Although fluctuations in temperature during the intake of hot and cold foods were measured in the oral cavity and variable tolerance to high temperatures have been reported, various investigators have suggested that a temperature gradient of 5–55°C is acceptable for laboratory studies. A dwell time of 20–30 seconds has been considered insufficient and is routinely used.[15] Therefore, in the present study, a dwell time of 60 seconds and a short transit time of 10 seconds were used.

The results of this study showed that the nanocomposite group had the least microleakage values in both the occlusal and gingival margins. Mithra et al. found a similar result, noting that nanocomposite exhibited the least microleakage in enamel and dentin/cementum margins when compared to two other direct composite resins.[2] Gupta et al. evaluated the microleakage of various restorative materials in class I cavities and concluded that nanocomposite exhibited the least microleakage values.[17] Sharma et al. found results contrasting with our study, where they evaluated the microleakage of class V cavities restored with microhybrid and nanocomposite materials using different light-curing units and concluded that LED light-cured nanocomposite exhibited higher

microleakage.[18] This discrepancy may be due to their use of an LED unit with an intensity of 508 mW/cm^2, whereas our study used an intensity of 700 mW/cm^2. This difference in intensity might account for the different results.

Nanocomposites used in this study include Filtek Z350, a resin system containing Bisphenol A glycol dimethacrylate, urethane dimethacrylate, triethylene glycol dimethacrylate, and Bisphenol A ethoxylated dimethacrylate resins. To reduce shrinkage, polyethylene glycol dimethacrylate (PEGDMA) has also been added. The fillers consist of nonaggregated silica fillers (20 nm), nonaggregated zirconia fillers (4–11 nm), and aggregated silica/zirconia cluster fillers (0.6–20 µm).[13]

The dentin bonding agent used for bonding the nanocomposite to the tooth is G-Premio Bond, which is a universal light-cure adhesive.

The wider distribution and decreased size of filler particles in nanocomposites help achieve high filler loading. Increased filler loading reduces polymerization shrinkage and thereby reduces microleakage.[19] Additionally, the occlusal margin shows less leakage than the gingival margin. This may be due to the beveling of the occlusal enamel margin, which increases the surface area of exposed enamel to compensate for polymerization shrinkage and helps reduce microleakage.[20]

Equia Forte is a recently introduced high-viscosity GIC. Similar to the results of our study, Equia Forte shows higher microleakage than nanohybrid composite resin, as reported by Recen and Yazkan.[14] This is attributed to the high viscosity of the material, which results in improper wetting of the tooth surface. In contrast to our study, Equia Forte has shown less microleakage in class II restorations compared to packable composite, flowable composite, and amalgam in a study by Pawar et al.[21] This difference is likely due to the higher polymerization shrinkage of composites, which induces stress in the network, affects the bonding mechanism, and causes microleakage.

Resin modified glass ionomer cement shows higher microleakage compared to nanocomposite. RMGIC undergoes polymerization shrinkage during and after light curing, producing contraction stress that can create marginal gaps at the restoration-tooth interface. Additionally, RMGIC contains a high amount of 2-hydroxy ethyl methacrylate, which gets released during the first 24 hours and increases water absorption.[22] Toledano et al.[23] evaluated the microleakage of RMGIC and compomer and concluded that RMGIC had less microleakage due to minimal setting shrinkage over a longer period.

Resin modified glass ionomer cement shows less microleakage compared to Cention N. A study by Unnikrishnan et al.[24] stated that the use of cavity conditioners removes or alters the smear layer, increases the surface for micromechanical and chemical bonding, and reduces the marginal microleakage of restorations. In our study, the cavity was treated with 10% polyacrylic acid as a cavity conditioner before RMGIC restoration. The application of polyacrylic acid after cavity preparation removes loose cutting debris, provides a cleansing effect, induces partial demineralization, facilitates chemical interaction between polyalkenoic acid and the remaining hydroxyapatite, and improves bonding efficacy.

Resin modified glass ionomer cement and Cention N are supplied as powder-liquid systems, and alterations in the ratio of powder to liquid might also contribute to their microleakage values.[25]

The limitations of the study include that it is an *in vitro* study and dye penetration was assessed using a stereomicroscope. Various methods to evaluate dye penetration, such as scanning electron microscopy and transmission electron microscopy, are available. In our study, a stereomicroscope was chosen due to feasibility and economic reasons.

Further *in vivo* studies, clinical trials, and nanoleakage studies need to be conducted to provide more reliable outcomes.

Conclusion

Within the limitations of the present study, nanocomposite exhibited the least microleakage values at both the occlusal and gingival marginal levels compared to the other restorative materials. It can be concluded that microleakage values were lower at the occlusal margin compared to the gingival margin.

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