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Original article

EVALUATION OF IMPACT OF LINING APPLICATION TECHNIQUES ON MARGINAL MICROLEAKAGE IN *RESIN-MODIFIED GLASS IONOMER* CEMENT IN CLASS II COMPOSITE RESTORATIONS: AN IN VITRO STUDY

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SUMMARY:

Aim of the study: The aim is to evaluate and compare marginal microleakage of class II resin composite restorations using a flowable composite and resin-modified glass-ionomer cement as intermediate layers, and to assess whether a difference in the thickness, consistency, and position of these layers would influence microleakage.

Material and Methods: Forty-two extracted intacted molars were divided into six groups. Class II cavities in medial and distal parts were prepared. Cavities in Group A were lined with a flowable composite resin; Group B had no lining; in Group C1, the axial wall was covered with a 1.5 mm resin-modified glass-ionomer cement (RMGIC) layer; in Group C2, axial and gingival walls were covered with a 2.5 mm RMGIC layer; in Group C3, the axial wall was covered with a 1 mm RMGIC layer; and in Group C4, axial and gingival walls were covered with a 1 mm RMGIC layer.

Results: No significant microleakage differences existed between groups A and B and the experimental group C3. In group C3, a low-viscosity RMGIC was applied only on the axial dentin wall of the cavity. Such difference, however, exists in comparison of group C1 or C2 with each of the groups A or B ($p < 0.0001$). The difference between groups C4 and A ($p < 0.0001$) was also significant.

Conclusion: The least microleakage along the gingival walls of the model cavities with RMGIC occurs when a 1-mm layer of resin-modified glass-ionomer with fluid consistency covers only the axial wall of the proximal cavity.

Keywords: closed-sandwich technique, flowable resin composite, marginal microleakage, resin-modified glass-ionomer

INTRODUCTION

The treatment of dental caries and restoration of deep approximal lesions with aesthetic materials is a daily manipulation in dental practice. Direct approximal restorations with resin composite material provide good aesthetic results at a low cost. However, there are critical moments in the treatment associated with the controlled preservation and remineralization of the affected dentin, removal of the contaminated layer and decontamination of the remaining dentin, and the creation of strong and durable adhesive bonds between restorative materials and healthy tooth tissues. In this healing process, preserving the vitality of dental pulp is especially important to prevent diseases of the pulp and periodontium and their complications.

Application of an intermediate layer of a biotolerant material on the affected dentin is essential for its preservation. The "sandwich" technique incorporating resin-modified glass-ionomer cements (RMGIC) or flowable resin composites as an intermediate layer is commonly used [1-5, 7-12]. These materials have a lower modulus of elasticity than standart resin composites and act as an elastic buffer between the tooth and the resin composite [13]. Resin-based glass-ionomers should be considered for the lining or base because of their biocompatibility, antibacterial properties, fluoride release, and better physical properties [13-18]. Many investigators found that RMGIC sealed the cavity adequately [8, 10, 19-21]. However, literature on the selection of the material for the base or liner and its location in deep proximal cavities of premolars and molars is contradictory [21].

For practical purposes, the recommended consistencies of GIC correspond to a 3:1 or 2:1 ratio of the powder to the liquid [14]. According to McLean [1], the ratio defines the liner (thin consistency, almost liquid) and base (thick consistency) by composite restoration. However, the exact consistency and location of application of the glass-ionomer to minimize microleakage around the restoration remain unclear.

The treatment of deep proximal carious lesions is associated with the removal of infected and altered tooth tissues and formation of remaining healthy tooth structures, including those in the immediate vicinity of the gingiva, according to the selected restorative materials. The location of the carious destruction against the cementoenamel junction of the tooth is of great importance. Close to it, the thickness of the enamel decreases sharply from 1.0 mm to 0 mm. The enamel structure changes to aprismatic enamel. Therefore, the formation of the enamel margin of the gingival wall of the cavity should be approached carefully. This is an important factor affecting the strength of adhesive bonds and longevity of restorations with composite materials. When the gingival base is below the cementoenamel junction of the tooth and is made up of dentin only, it is recommended that RMGIC be used as part of an open "sandwich" restoration. If the gingival wall is above the cementoenamel junction and is made of enamel and dentin, a closed "sandwich" restoration is required [10, 22, 25]. The thickness of the existing enamel and the specific location of the enamel rods of the cavity' gingival margin should be taken into consideration. If the latter has a width of over 1–1.5 mm and is positioned at least 1.5 mm above the cementoenamel junction, the gingival wall should be prepared with an enamel margin that is perpendicular to the longitudinal axis of the tooth butt joint [21]. However, if the thickness of the enamel of the gingival wall is 0.5 mm and it is located approximately 0.5–1 mm above the cementoenamel junction, the shaping of the gingival cavity margin wall should be performed with a slight proximal inclination or a bevel. The tooth enamel in the area of the cementoenamel junction is thin with a thickness of about 0.5–0.7 mm and the enamel rods show slight inclination to proximal [23].

The use of RMGIC in combination with composite materials as part of closed "sandwich" restorations of the posterior teeth poses a number of questions. 1) What should be the thickness of the modified glass-ionomer layer for composite restoration? 2) Where should RMGIC be applied—only on the axial wall or entirely on the dentin? 3) Does the consistency of RMGIC for a base or liner influence the quality and durability of the restoration?

The aim of this study is to evaluate the marginal microleakage of class II resin composite restorations by using a flowable resin composite and resin-modified glass-ionomer as intermediate layers and to assess whether the difference in the thickness, consistency, and location of these intermediate layers would influence the microleakage.

MATERIAL AND METHODS:

Sample collection

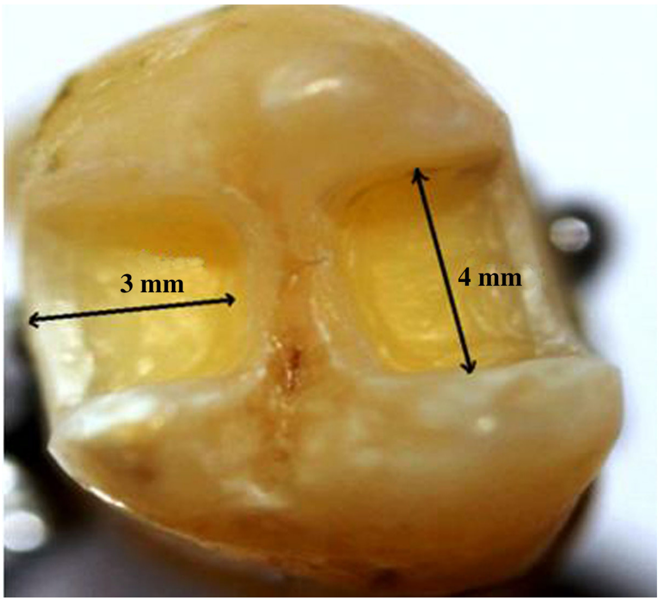
Forty two extracted non-restored, non-carious, non-cavitated human mandibular molars were used in this study. After atraumatic extraction, the teeth were cleaned with a hand scaler to remove any soft tissue, tartar, and plaque and stored in distilled water before preparation of the experimental cavities. Cracks if present on the collected teeth were detected by tactile examination and transillumination. The teeth were then subjected to the exclusion criteria that were as follows: teeth with cracks or cervical abrasions, those affected by abfraction, endodontically treated teeth, and those with dental caries.

Preparation of specimens

Teeth samples with standardized proximal cavities, which differ in texture, thickness of the RMGIC layer, and the position of application of RMGIC in the cavity, were prepared. The control samples had a flowable resin composite of the dentin as a coating or has no coating of the dentin under the restoration.

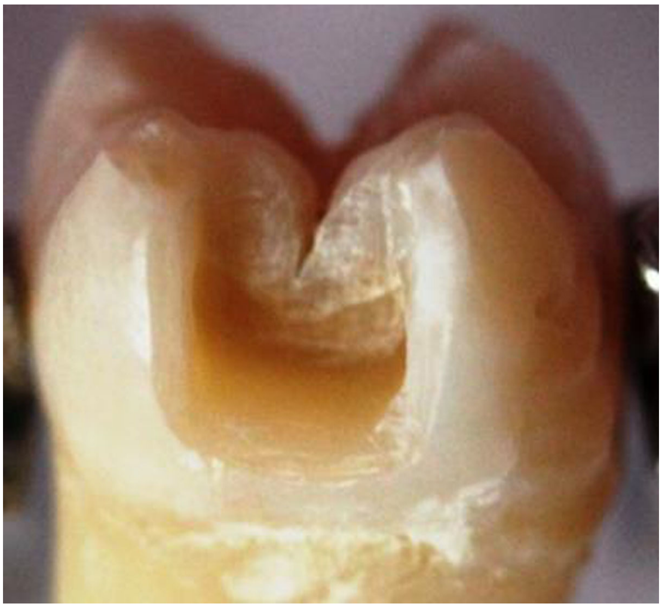
On each tooth, two separate second class cavities are prepared, located mesio-occlusally and disto-occlusally with the following dimensions: mesiodistal size 3 mm bucco-lingual size 4 mm, and axial size 4 mm (Figure 1).

Fig. 1. Distance between the two separate cavities.



The distance between the two separate cavities is at least 2 mm. The cavity walls are perpendicular to the tooth surface. The gingival wall is prepared perpendicularly to the axial axis of the tooth. The enamel margin of the gingival wall and the vestibular and lingual margins are shaped with a bevel at an angle of approximately 45° (Figure 2).

Fig. 2. Vestibular and lingual cavosurface margins.



Cavities were standardized using a graduated periodontal probe. Diamond turbine burs (DIASWISS, Switzerland) were used to elaborate cavities under water-air cooling and using a contra-angle handpiece with steel burs (Komet, Gebr.Brasseler, Germany). Each bur was used for preparation of four cavities. All teeth were stored in distilled water to prevent drying. Immediately before restoration of the samples, the prepared cavities were smeared three times with hydrogen peroxide (3% solution) for 3 s using a cotton pellet and then dried.

Grouping of specimens

Thus-prepared samples with 84 prepared cavities were divided into three main groups differing in the positions of the base, liner, and type of the material for elaboration. The teeth were divided randomly in 6 groups with 7 teeth.

Group A. A flowable resin composite was applied as a liner (Opal Flow, Heraeus Kulzer, GmbH Germany) along the axial wall of the cavity with a layer thickness of 1 mm and it was polymerized 2×5 s with a LED lamp.

Group B. Restoration of only light-cured composite material (Diamond, Heraeus Kulzer GmbH Charisma, Germany) without a liner or base was elaborated.

Group C. The dentin was conditioned with a 10% solution of polyacrylic acid (GC Dentin Conditioner Liquid, GC Corporation, Tokyo, Japan) for 10 s and then washed before application of RMGIC into the cavity. In subgroups C1 and C2, a base was made of the resin-modified glass-ionomer GC Fuji LINNING LC (GC Corporation, Tokyo, Japan) with a thick consistency; in subgroups C3 and C4, the base was made of the resin-modified glass-ionomer GC Fuji LINNING LC Paste Pak (GC Corporation, Tokyo, Japan) with a thin (flowable) consistency.

Subgroup C1. RMGIC GC Fuji LINNING LC (GC Corporation, Tokyo, Japan) was prepared in a 3:1 powder/liquid ratio (thick texture) and applied on the axial cavity wall with a layer thickness of 1.5 mm.

Subgroup C2. RMGIC GC Fuji LINNING LC (GC Corporation, Tokyo, Japan) was prepared in a 3:1 ratio (thick texture) and applied on the axial cavity wall and gingival base at the cementoenamel junction with a layer thickness of 2 mm and a stepped configuration.

Subgroup C3. RMGIC GC Fuji LINNING LC Paste Pak (GC Corporation, Tokyo, Japan) was prepared with a 1,1/1 ratio paste / paste and with a flowable consistency and applied only on the axial wall of the cavity with a layer thickness of 1 mm.

Subgroup C4. RMGIC GC Fuji LINNING LC Paste Pak (GC Corporation, Tokyo, Japan) was prepared with a 1,1/1 ratio and with a flowable consistency and covered the axial and gingival walls with a layer thickness of 1 mm at the cementoenamel junction.

The thickness was controlled by considering the original cavity depth, by using a standard periodontal probe.

Elaboration of final restorations

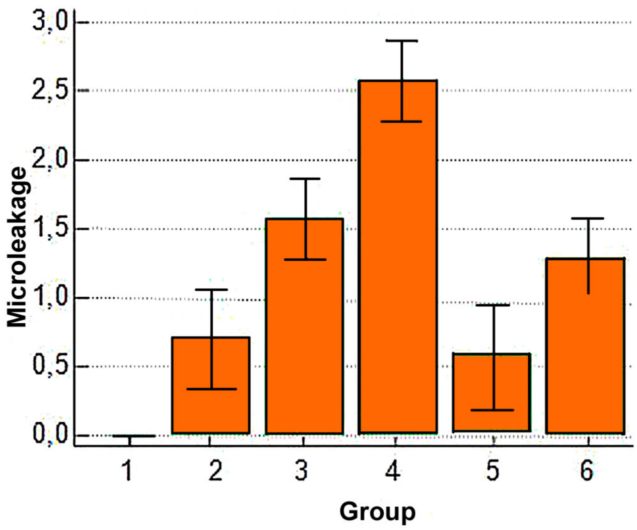
Then, the cavity was restored with a nanohybrid composite material (Diamond, Heraeus Kulzer GmbH Charisma, Germany). The materials were mixed and restored according to the manufacturer's instructions. The technique of enamel etching for 15 s and washing was used, and the adhesive system Gluma 2 bond was applied (Heraeus Kulzer, GmbH, Germany) with polymerization with a LED lamp (Flash Lite Magna 4.0, DenMat Lompos, USA). According to the work protocol, the composite material was pre-heated in an oven at 50°C, and was applied layer by layer according to the incremental technique up to four layers and is was then cured for 10 s per layer. The restorations were completed and polished using Prophy Green Polish Paste (Directa AB, Sweden) and silicone polish brushes. All the restorations are performed by a single operator.

All analyses were conducted using SPSS version 19.0 software (SPSS, Inc., Chicago, IL, USA). The Kruskal–Wallis test was used to compare the mean values of the different groups. The Mann-Whitney test was used to compare the different groups and identify the groups that differ significantly from the other groups. The *Bonferroni correction was applied* to correct for multiple testing (Bonferroni corrected post hoc Mann-Whitney test).

RESULTS:

Figure 3 shows the average values of microleakage in different groups. The highest value of leakage was in group C2 (2.571), followed by group C1 (1.571). The lowest microleakage among the 4 groups with resin-modified glass-ionomers was in group C3 (0.571).

Fig. 3. Comparison of mean of microleakage scores in different groups.



The Kruskal-Wallis test showed that there was a statistically significant difference in the analyzed parameters ($p < 0.05$). The mean gingival leakage in the different groups are shown in Table 1.

Comparison of the results from microleakage between the experimental groups by means of the Mann-Whitney U test is shown in Table 2. The results of the Mann-Whitney U test confirmed the statistically significant difference between some of the groups and the effect of the followed factors was established.

Table 1. Kruskal-Wallis analysis for mean microleakage of various groups.

	microleakage		
Group	n	Mean rank	SD
A	14	13.50	0.363
B	14	33.29	0.611
C1	14	55.79	0.513
C2	14	74.50	0.513
C3	14	29.29	0.646
C4	14	48.64	0.468
Total	84		

Table 2. The comparison of leakage between each tested groups using Mann-Whitney test.

	Group A *p* value	Group B *p* value	Group C1 *p* value	Group C2 *p* value	Group C3 *p* value	Group C4 *p* value
Group A	-	0.009	0.0001*	0.0001*	0.051	0.0001*
Group B	-	-	0.001*	0.0001*	0.514	0.016
Group C1	-	-	-	0.0003*	0.0007*	0.146
Group C2	-	-	-	-	0.0001*	0.0001*
Group C3	-	-	-	-	-	0.004
Group C4	-	-	-	-	-	-

*The difference between the groups is statistically significant (p<0.003 with Bonferroni correction).

The Pairwise Mann-Whitney test results confirm a statistically significant difference between group C1, C2, and control groups (A and B). Group C3 is not significantly different from groups A and B, but group C4 is statistically significantly different only from Group A.

DISCUSSION:

Evaluation of microleakage is important for assessing the success of the restorative materials and methods. The dye penetration testing is one of the methods to assess microleakage. The "sandwich" technique involves the layering of materials to create the optimal combination of desirable properties in a restoration. In the closed "sandwich" technique, the use of GIC, RMGIC, and flowable composite resin are advocated [1-12].

RMGIC shows molecular bonding to dentin and enamel, bacteriostatic action, thermal expansion similar to that of enamel and dentin, and a slow setting reaction with low setting shrinkage. The improved mechanical and physical properties of RMGIC compared with those of conventional GIC increase the quality and longevity of "sandwich" restorations [24]. Using RMGIC in the treatment of deep caries after conditioning dentin and removing the smear layer [13, 21, 25-27] allows preservation and remineralization of the affected dentin [7, 11, 13, 17] and the formation strong and lasting adhesive bonds with the restorative materials [6, 8, 15]. Therefore, two RMGIC samples--GC Fuji LINNING LC Paste Pak and GC Fuji LINNING LC--were used in an in vitro study to determine the influence of thickness, texture, and location of application of the intermediate layer of cement in resin composite restorations of proximal cavities.

Marginal microleakage between dental tissue and restorative materials depends on several factors: presence or absence of enamel, enamel structure, smear layer, and polymerization shrinkage. Gingival margins of restorations showed more microleakage than occlusal margins [10, 21, 28]. Some researchers concluded that the use of liners in open "sandwich" technique and close "sandwich" technique for correcting occlusal microleakage was ineffective [10, 21]. The close "sandwich" technique showed significantly lower cervical microleakage than the open "sandwich" technique [10]. These results gave us reason to select the close "sandwich" technique for tracking gingival microleakage around composite resin restorations with a flowable composite liner or variations of coverage of dentin with RMGIC.

Nguyen et al. [29] reported no statistical difference in the degree of microleakage around composite restorations without a base and those with a liner of a flowable composite resin. Therefore, in this study, Groups A and B were used as controls against the main experimental Group C with calibrated cavity preparations, obturated with a base or liner of RMGIC, and a nanohybrid composite resin material. The results of a previous study showed that microleakage in gingival margins depends on the configuration and the type of material for the base [21]. In closed "sandwich" restorations of proximal cavities of molars, microleakage is the least when a bevel of the enamel margin of gingival wall is elaborated [21].

In this study, the least gingival microleakage was observed for samples from Group A with approximal cavities obturated with a nanohybrid composite resin under which a flowable composite resin was applied, followed by Group C3 with an applied thin layer of flowing RMGIC along the axial cavity wall and by Group B in which teeth are obturated by the nanohybrid composite resin without a base or liner. Statistically, no significant difference between these three groups is found ($p > 0.003$).

Literature data on the microleakage and durability of direct composite restorations of distal teeth, depending on the material used for the base or liner, is contradictory [5, 15, 21, 29, 30]. For example, in a study of microleakage, Opdam [31] showed more favorable results when there was no base or there was a low-viscosity composite laid under the composite restorations of posterior teeth. However, like the results of some previous studies [5, 29, 31], our results also show least microleakage around composite restorations without a base (group A) or liner of flowable composite (group B).

In this study, there is no statistically significant difference between the control groups A and B and the experimental group C_3. In the group C_3 samples, a thin layer of low-viscosity RMGIC is applied only on the axial wall of the cavity. Such difference however exists in comparison of group C1 or C2 with each of the groups A or B ($R<0,0001$). The difference between group C4 and group A ($P < 0.0001$) is also significant. The least microleakage occurs in samples from group A with an intermediate thin layer of flowable composite and the samples from group C3 with a thin layer of low-viscosity RMGIC. These results are in agreement with those of the *in vitro* studies that showed a reduction in the microleakage when a thin lining was used [4, 5, 28, 32, 33]. An intermediate 1-mm-thick layer of a flowable resin composite improved the sealing ability to a greater extent than a 2-mm-thick intermediate layer [5, 28]. The results are also in agreement with those of studies that showed that restorations with a thick flowable composite lining exhibited the potential risk of marginal degradation, because they have a lower filler loading and they shrink to a greater extent when the thickness is increased. Some results indicate that flowable and hybrid composites performed equally well in terms of microleakage [34].

Our results do not completely agree with those of Simi and Suprabha [28]. The authors compare closed "sandwich" restorations of nanocomposites with the fluid composite RMGIC and those without a liner/base. Microleakage at the gingival level was more in the group with the flowable liner compared to the RMGIC group, but this difference was not statistically significant. The greatest microleakage was of the restorations without bases [28]. These different results are probably due to methodology differences such as in the formation of enamel margins with or without bevel, the distance of the gingival walls of the cavities from the cementoenamel junction, and the use of different materials and adhesive protocols.

In 2014, Opdam [31] in meta-analysis of literature data on the durability of resin composite restorations on posterior teeth did not find a significant difference between recoveries with liner composed of RMGIC or a flowable composite. These results were confirmed by Van de Sande et al. [30] in 2015 in a longitudinal clinical study. A flowable resin composite is less viscous, so it improves wettability by flowing onto all prepared surfaces, thus resulting in an intimate union with the microstructural defects in the cavity preparation [32, 34, 35]. It also acts as a flexible intermediate layer that helps relieve stresses during polymerization shrinkage of the restorative resin [36]. These characteristics and a syringe delivery system make them an ideal choice for use as a liner [35].

As can be seen in Figure 3, the penetration of the dye around composite restorations, under which a base or liner of RMGIC is placed, is the most pronounced in group C2 and gradually reduces in group C1, followed by C4, and finally C3. Cavities of all samples are recovered with the nanohybrid composite material. Approximal cavities from group C2 have a covering dentin step-shaped base with a 2.5-mm-thick layer of resin-modified glass-ionomer at the cementoenamel junction. Approximal cavities from group C1 have a base of RMGIC with a thicker texture and a thickness of 1.5 mm and cover the axial wall. The dentin of the gingival and the axial walls of the prepared cavities in group C4 is covered with RMGIC with a thickness of 1 mm.

Differences between group C3 and group C1 ($p < 0.003$ with Bonferroni correction) and C2 are statistically significant ($p < 0.0001$). Also, statistically significant are the differences between groups C4 and C2 ($p < 0.0001$) and between C2 and C1 ($p < 0.0003$). These ratios show that the closed "sandwich" restorations with the thin RMGIC layer liner along the axial cavity wall show the least microleakage compared to other "sandwich" restorations with a base or liner RMGIC. Relatively greater leakage is observed around the restorations under which a thin RMGIC layer completely covers the dentin of the axial and the gingival walls at the cementoenamel junction. However, there is no statistically significant difference between these two groups of cavities with closed "sandwich" restorations of the nanohybrid and liner RMGIC ($p < 0,004$ with Bonferroni correction). Definitely greater microleakage is observed when the "sandwich" restorations are elaborated with RMGIC prepared with a powder and liquid with a thick consistency (C1 and C2 groups). A statistically significant difference in the extent of microleakage in samples from group C2 and C1 ($p < 0.0003$) is demonstrated. This means that the leakage around "sandwich" restorations with a thin layer of RMGIC along the axial wall is less than that in the case of a thick base of RMGIC reaching the cementoenamel junction.

In fact, the placement of the flowable composite or thin layer of RMGIC as the liner beneath the nanocomposite restoration results in a reduction in microleakage. Slightly better results were obtained with flowable composites as compared to RMGIC. Probably, the particle size and the viscosity of RMGIC are higher than those of the flowable composite and since it is a two-component system (powder and liquid or paste and paste) there are greater chances for pore formation, leading to increased microleakage. Similar to the results of previous studies [37], our results show that both resin-modified glass-ionomers and flowable composite liners under nanocomposite restorations result in comparable reduction in the microleakage.

Mount [3] noted the effect of the ratio of the powder to the liquid component, and of the used consistency of the glass-ionomer cement on the quality of the restoration. This is confirmed by Sawani S, which clearly showed that the consistency of the liner affected microleakage around the margin of the cavity [10]. Probably, the fluid consistency of RMGIC compensates for the polymerization shrinkage of the composite material for restoration. The same applies to restorations with a liner of a flowable composite. The selection of the areas and surfaces in the cavity on which RMGIC is to be applied in models of proximal cavities affects microleakage around the built composite restoration. The least leakage in cavities with RMGIC lining is established when the axial wall is covered with a thin layer of resin-modified glass-ionomer with fluid consistency. The laying of the same cement on the dentin of the axial and gingival wall of the cavity at the dentinoenamel junction with a high density and thickness is not acceptable as this promotes significant microleakage.

CONCLUSION:

Under the conditions of this *in vitro* study, it was found that the consistency, thickness, and location of the intermediate layer of the resin-modified glass-ionomer cements influence the degree of microleakage around the restorations of the composite material on distal teeth.

The least microleakage along the gingival walls of the model cavities with RMGIC occurs when a 1 mm layer of resin-modified glass-ionomer with fluid consistency covers only the axial wall of the proximal cavity.

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