Research Square

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Evaluation of Coronal Microleakage of Temporary Restorative Materials in Primary Molars with Different Cavity Designs: An In Vitro Micro-CT Analysis

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Abstract

Background

In multi-visit primary root canal treatment, preventing coronal leakage of temporary restorative materials is particularly important. In addition, cavity design may influence the extent of microleakage. This study aimed to evaluate the coronal microleakage of different temporary restorative materials used in multi-visit root canal treatment of primary molars with Class II and Class III cavities using micro-computed tomography (micro-CT).

Methods

Sixty-six primary second molars with root resorption not exceeding one-third of the root length were included in the study. The teeth were divided into two main groups according to cavity design, and endodontic access cavities were prepared as Class II or Class III. Cotton pellets were placed in the pulp chambers, and each main group was further divided into three subgroups according to the temporary restorative material used: Cavit G, glass ionomer cement, and the Double Seal technique. All specimens were immersed in 50% silver nitrate solution, and microleakage was assessed using micro-CT. Data were analyzed using the Kruskal–Wallis H test, with the level of statistical significance set at $p < 0.05$.

Results

Microleakage differed significantly among the groups (Kruskal–Wallis $H = 41.08$, $p = 0.0001$). In two-surface cavities, Cavit G showed the lowest mean microleakage (0.079 ± 0.109), followed by glass ionomer cement (0.305 ± 0.199) and the Double Seal technique (1.106 ± 1.128). In three-surface cavities, the Double Seal technique showed the lowest mean microleakage (0.361 ± 0.321), followed by Cavit G (1.516 ± 1.096) and glass ionomer cement (2.144 ± 1.112). Overall, the highest microleakage was observed in the glass ionomer cement group, particularly in three-surface cavities. According to cavity design, lower microleakage values were generally observed in two-surface cavities than in three-surface cavities.

Conclusions

Within the limitations of this study, Cavit G and the Double Seal technique may be preferred as temporary restorative materials in multi-visit root canal treatment of primary teeth, depending on cavity type.

Introduction

A successful root canal treatment requires proper canal shaping to facilitate the elimination of bacteria and pulp tissue remnants and to ensure effective obturation. Root canal treatment can be completed in a single-visit endodontic procedure, which eliminates the need for temporary sealing in vital and non-infected teeth [1]. However, in many cases, thorough cleaning, shaping, and obturation cannot be achieved in a single-visit, which necessitates a multiple-visit approach. Under such circumstances, the integrity of the temporary restorative material becomes critical to prevent coronal leakage. During this time interval, temporary filling materials should prevent the entry of bacteria, fluids, and organic materials from the oral cavity into the root canal system. They should also prevent the leakage of medicaments placed into the pulp chamber and/or root canal system into the external environment [2]. Temporary restorative materials should be insoluble in saliva, biocompatible, resistant to occlusal stress and should be easy to apply [3].

Materials such as zinc oxide-calcium sulfate (Cavit-G), glass ionomer cement (GIC), zinc oxide-eugenol, and light-cured resin-based temporary filling materials have been evaluated in earlier studies, and it has been reported that these materials provide successful results in terms of sealing [4, 5, 6, 7]. However, some studies have also reported that sufficient sealing could not be achieved with these materials [8, 9]. Therefore, the search for new temporary filling materials continues. In addition to temporary restorative materials, the use of the “double seal technique” to prevent possible leakage during root canal treatment has drawn attention [10, 11, 12]. Considering

especially the possibility of occlusal forces or abrasions that may occur in temporary restorations, the use of the double seal technique may be required [13].

In the double seal technique, a combination of calcium sulfate-based filling material and IRM or GIC is usually used. A calcium sulfate-based material is first placed over the dry cotton pellet positioned in the pulp chamber, and then an IRM layer is applied [10, 13]. In this way, the strength of the material is increased and it becomes less soluble. Alternatively, a GIC layer can be placed over the calcium sulfate-based filling material [13]. Studies have reported that in multiple-visit root canal treatments, possible coronal leakage from temporary restorative materials is a major factor in treatment failure [14, 15]. Furthermore, it is also thought that the cavity design of the tooth to be treated with root canal therapy may have an effect on leakage [16].

Although several studies have investigated coronal leakage during root canal treatment, most have been conducted on permanent teeth. Evidence regarding primary teeth remains limited, and to the best of our knowledge, no previous study has evaluated the coronal microleakage of different temporary restorative materials in primary molars with different cavity designs using micro-computed tomography (micro-CT) [17].

Therefore, the aim of this in vitro study was to evaluate and compare the coronal microleakage of different temporary restorative materials used in primary molars with different endodontic access cavity designs by means of micro-CT. Also, the null hypotheses tested were that: (1) the type of temporary restorative material would not significantly affect coronal microleakage, and (2) cavity design would not significantly affect coronal microleakage in primary molars.

Materials and Methods

2.1. Study Design and Reporting

The current work has a blinded in vitro design and the microleakage assessments were performed under blinded conditions to minimize assessment bias. The study was designed and reported in accordance with the CRIS guidelines (Checklist for Reporting In-vitro Studies).

2.2. Ethical Approval and Consent to Participate

Ethical approval

for this study was obtained from the Clinical Research Ethics Committee of Ankara University Faculty of Dentistry (06.10.2021; Decision No: 14 − 06). All procedures were carried out in accordance with the ethical standards of the institutional research committee and with the principles of the Declaration of Helsinki. Extracted second primary molars were obtained from pediatric patients whose parents had been informed about the study and had provided written informed consent.

2.3. Tooth Selection

Extracted second primary molars were used in this in vitro study. Teeth obtained from pediatric patients whose parents had been informed about the study and had provided written informed consent were included. Only second primary molars with physiological root resorption not exceeding one-third of the root length were considered eligible for inclusion. Teeth with excessive root resorption, extensive structural damage, or conditions that could interfere with standardized cavity preparation and microleakage assessment were excluded. Before the experimental procedures, plaque deposits and soft tissue remnants on the tooth surfaces were removed using brushing under running water. Following cleaning, the specimens were stored in 0.2% thymol solution at room temperature until use in order to preserve the teeth and maintain standardization of the samples throughout the study period.

2.4. Sample Size Analysis

Sample size estimation was performed based on data from previous similar studies reported in the literature. An effect size of 0.40 was assumed for detecting significant differences among the groups in terms of microleakage measurements. With a confidence level of 95% and a statistical power of 80%, sample size calculation based on one-way ANOVA indicated that at least 11 teeth were required per group. Accordingly, a total of 66 teeth were included in the study.

2.5. Grouping

A total of 66 independent samples were randomly allocated into two main groups according to cavity design: Group 1, consisting of teeth with two-surface cavities (n = 33), and Group 2, consisting of teeth with three-surface cavities (n = 33). Each main group was then further divided into three subgroups based on the temporary restorative material used: Cavit G, glass ionomer cement, and the Double Seal technique, with 11 teeth in each subgroup. Thus, six experimental subgroups were established according to cavity design and temporary restorative material.

2.6. Procedure

All cavity preparations were performed using a high-speed air-turbine handpiece under continuous water cooling with a diamond fissure bur (ISO SF-41, approximately 1.2 mm in diameter). The cavity depth was standardized to at least 4 mm and verified using a periodontal probe (UNC-15, Hu-Friedy, Chicago, IL, USA). To maintain cutting efficiency and reduce variability, each bur was replaced after the preparation of four teeth. No bevel was applied to the cavity margins. Following cavity preparation, the coronal pulp tissue was removed using an excavator, and the root canals were instrumented with a size 15 H-file. Each canal was then irrigated with a total of 2 mL of 2.5% sodium hypochlorite solution using a 30G side-vented irrigation needle (NaviTip, Ultradent, USA). The pulp chamber was subsequently cleaned with a cotton pellet moistened with saline to remove residual debris [18]. No intracanal medicament was placed in any specimen. Afterward, a cotton pellet was positioned in the pulp chamber, leaving a standardized 4-mm space for placement of the temporary restorative material.

According to the temporary restorative material used, each main group was further divided into three subgroups (n = 11): Cavit G, glass ionomer cement (GIC), and the Double Seal technique (Table 1). The temporary restorative materials used in each subgroup are shown in Fig. 1.

Table 1
Temporary Restorative Materials Used in the Study

Material Type	Product name	Manufacturer (City, Country)	Composition
Glass ionomer cement	Riva Self Cure	SDI, Bayswater, Victoria, Australia	Fluoroaluminosilicate glass, polyacrylic acid, tartaric acid, water
Temporary filling material	Cavit G	3M ESPE, Seefeld, Germany	Zinc oxide, barium sulfate, talc, ethylene bis(oxyethylene) diacetate, zinc sulfate, calcium sulfate, poly(vinyl acetate)

2.7. Thermocycling and Silver Nitrate Penetration

Following restoration, all specimens were stored in distilled water at 37°C for 24 hours to allow the temporary restorative materials to set under standardized conditions. To simulate short-term intraoral thermal stress, the specimens were then subjected to thermocycling. Based on the assumption that 10,000 thermal cycles

correspond approximately to one year of clinical service, 1,000 thermal cycles were applied to simulate an intraoral period of nearly 20 days. Thermocycling was performed between 5°C and 55°C using a thermocycling device (Thermocycler SD Mechatronik, Germany) [19,20].

After thermocycling, all tooth surfaces were coated with two layers of nail varnish, leaving a 1-mm uncoated margin around the temporary restorative material to permit tracer penetration only through the restoration interface. The specimens were then immersed in 50% silver nitrate solution for 15 hours in the dark. Subsequently, the teeth were rinsed under running water for 2 minutes and immersed in a developer solution for 3 hours under light exposure to reduce silver ions and enhance the visualization of leakage pathways. To avoid false-positive staining, only the coronal portions of the specimens were immersed in the solutions. After completion of the staining procedure, the samples were cleaned under running water using a toothbrush.

2.8. Micro-CT Analysis

Following tracer application, all specimens were scanned using micro-computed tomography (micro-CT) (Bruker Skyscan 1275). Image reconstruction was performed with NRecon software (version 1.7.4.2, Bruker Skyscan 1275, Belgium) using the following parameters: smoothing, 3; ring artifact correction, 7; and beam hardening correction, 38%. After reconstruction, the regions of interest (ROI) were identified on the cross-sectional images, and the corresponding volumes of interest (VOI) were defined for quantitative analysis. Microleakage measurements were performed within these predefined areas using CTAn software (version 1.23.0.2, Bruker Skyscan, Belgium). In addition, three-dimensional visualization of the specimens was generated using CTvox software (version 1.23.0.2, Bruker Skyscan, Belgium).

2.9. Blinding

To minimize assessment bias, the micro-CT image analysis was performed under blinded conditions. The examiner responsible for image reconstruction, region-of-interest selection, and microleakage measurements was unaware of the cavity design and temporary restorative material assigned to each specimen throughout the evaluation process. For this purpose, all specimens were coded before imaging and analysis, and the group identities were concealed until completion of the measurements. Blinding was maintained during the definition of the regions of interest (ROI), the determination of the volumes of interest (VOI), and the quantitative assessment of silver nitrate penetration. This procedure was implemented to improve the objectivity and reliability of the microleakage analysis.

2.10. Statistical Analysis

Statistical analyses were performed using SPSS software (version 11.5; SPSS Inc., Chicago, IL, USA). Descriptive statistics were expressed as sample size (n), mean, standard deviation (SD), 95% confidence interval (CI), and minimum–maximum values. Since the microleakage data did not show a normal distribution, comparisons among the six study groups were performed using the Kruskal–Wallis H test. When the overall group difference was statistically significant, pairwise post hoc comparisons were carried out to identify the groups responsible for the difference. A p value of less than 0.05 was considered statistically significant.

Results

A statistically significant difference in microleakage was observed among the six experimental groups (Kruskal–Wallis $H = 41.08$, $p = 0.0001$). The lowest mean microleakage value was recorded in Group 1a (two-surface cavity, Cavit G; 0.079 ± 0.109), whereas the highest mean value was observed in Group 2b (three-surface cavity, glass ionomer cement; 2.144 ± 1.112).

In the two-surface cavity groups, mean microleakage values were 0.079 ± 0.109 for Cavit G (Group 1a), 0.305 ± 0.199 for glass ionomer cement (Group 1b), and 1.106 ± 1.128 for the Double Seal technique (Group 1c). In the three-surface cavity groups, the corresponding mean values were 1.516 ± 1.096 for Cavit G (Group 2a), 2.144 ± 1.112 for glass ionomer cement (Group 2b), and 0.361 ± 0.321 for the Double Seal technique (Group 2c).

Pairwise comparisons revealed significant differences between Group 1a and Group 2a ($p = 0.001$), Group 1a and Group 1b ($p = 0.012$), Group 1a and Group 2b ($p = 0.0001$), Group 1a and Group 1c ($p = 0.035$), Group 1a and Group 2c ($p = 0.002$), Group 2a and Group 1b ($p = 0.003$), Group 2a and Group 2c ($p = 0.021$), Group 1b and Group 2b ($p = 0.003$), Group 2b and Group 1c ($p = 0.035$), and Group 2b and Group 2c ($p = 0.001$) (Table 2).

Table 2
Microleakage values of the experimental groups according to cavity design and temporary restorative material

Microleakage	n	Mean	SD	95% Confidence Interval		Min	Max	Kruskal-Wallis H testi			
				Lower Bound	Upper Bound			Mean Rank	H	p	Posthoc Tests
Group 1a (Two-surface cavity, Cavit G)	11	0.079	0.109	0.006	0.153	0.016	0.402	9.360	41.08	**0.0001**	Group 1a - Group 2a; p = 0.001
Group 2a (Three-surface cavity, Cavit G)	11	1.516	1.096	0.780	2.252	0.056	3.703	46.180			Group 1a - Group 1b; p = 0.012
Group 1b (Two-surface cavity, Glass Ionomer Cement)	11	0.305	0.199	0.171	0.439	0.070	0.700	25.640			Group 1a - Group 2b; p = 0.0001
Group 2b (Three-surface cavity, Glass Ionomer Cement)	11	2.144	1.112	1.397	2.891	1.146	4.869	55.450			Group 1a - Group 1c; p = 0.035
Group 1c (Two-surface cavity, Double Seal)	11	1.106	1.128	0.348	1.864	0.058	3.943	38.730			Group 1a - Group 2c; p = 0.002
Group 2c (Three-surface cavity, Double Seal)	11	0.361	0.321	0.145	0.577	0.004	1.161	25.640			Group 2a- Group 1b; p = 0.003
Total	**66**	**0.919**	**1.073**	**0.655**	**1.182**	**0.004**	**4.869**	-			Group 2a - Group 2c; p = 0.021
											Group 1b - Group 2b; p = 0.003
											Group 2b - Group 1c; p = 0.035
											Group 2b - Group 2c; p = 0.001

Discussion

In multi-visit endodontic treatment, an adequate coronal seal is essential during the inter-appointment period to minimize contamination of the root canal system. Therefore, temporary restorative materials should effectively prevent the ingress of saliva and microorganisms [4,11]. In this context, microleakage is of particular importance, as it refers to the passage of bacteria, oral fluids, molecules, and ions between the cavity walls and the restorative material [21]. This leakage may occur within the restorative material itself, within the tooth structure, or at the tooth-material interface [22], and may adversely affect the success of endodontic treatment.

A variety of methods have been used to evaluate microleakage. Among these, chemical tracers such as 50% silver nitrate are widely preferred because of their ability to penetrate interfacial gaps and reveal leakage pathways [23,24]. In the present study, micro-computed tomography was used in combination with silver nitrate penetration. Micro-CT is a non-destructive method that enables three-dimensional and volumetric assessment of hard tissues and provides an important advantage over conventional sectioning methods by allowing detailed evaluation of leakage without destroying the specimen [25].

The thickness of the temporary restorative material is one of the factors influencing sealing ability. Previous studies have shown that a minimum thickness of approximately 3.5-4 mm is required to reduce microleakage [4,26]. In the present study, cavity depth was standardized at 4 mm in accordance with the literature. However, it should be acknowledged that such thickness may not always be achievable clinically, particularly in primary teeth with extensive caries or substantial coronal destruction. Therefore, the present findings should be interpreted within the limits of a standardized in vitro model.

Thermocycling was used to simulate thermal changes in the oral environment. The temperature range of 5–55°C is widely accepted in the literature to mimic thermal stress caused by hot and cold food or beverages, and 1,000 cycles have been considered to represent approximately 20 days of intraoral function [19]. This protocol was applied to challenge the restorative materials under standardized thermal stress conditions before leakage evaluation.

The present findings showed that both temporary restorative material and cavity design significantly affected coronal microleakage. In two-surface cavities, Cavit G demonstrated the lowest leakage values, whereas in three-surface cavities the Double Seal technique showed superior sealing performance. The favorable performance of Cavit G is consistent with previous reports emphasizing its good sealing ability in temporary endodontic restorations [27]. This may be attributed to the hygroscopic nature of the material, which allows slight expansion after moisture absorption and may improve adaptation to cavity walls [26,27]. The present results support these observations, particularly in less extensive cavity designs.

Glass ionomer cement exhibited greater microleakage than the other tested materials and techniques, especially in three-surface cavities. Although glass ionomer cements have important advantages such as fluoride release and biocompatibility, their sealing performance as temporary restorative materials may be limited under certain conditions [7,28]. In addition, previous studies have suggested that GIC may not bond effectively to polymerized resin composite surfaces; therefore, its use as a temporary restorative material may be less favorable in teeth with pre-endodontic composite restorations [7]. The present findings are in agreement with these observations.

Another important finding of this study was the effect of cavity design on sealing ability. The same materials showed different leakage behaviors depending on cavity type, and two-surface cavities generally exhibited less microleakage than three-surface cavities. This may be explained by the greater complexity of larger cavities, reduced support from remaining tooth structure, and the increased interface area between the material and cavity walls. These findings indicate that cavity design directly influences the sealing performance of temporary restorative materials and should be considered when selecting a temporary restoration strategy.

The results of this study suggest that, in primary molars requiring multi-visit root canal treatment, material selection should not be based solely on the properties of the restorative material itself, but also on cavity configuration. Cavit G may be a suitable option for short-term temporary restorations in more conservative cavities, whereas the Double Seal technique may provide an advantage in more extensive cavities.

Nevertheless, several limitations of this study should be acknowledged. First, as with all in vitro studies, the experimental design could not fully reproduce intraoral conditions such as masticatory loading, saliva flow, biofilm accumulation, and pH changes. Second, leakage models themselves have methodological limitations. In particular, in layered restorative approaches such as the Double Seal technique, if the outer material provides an effective seal, tracer penetration to the underlying material may be prevented. In such cases, the individual contribution of the deeper material may not be fully observed, and the analysis may primarily reflect the sealing performance of the coronal layer. Therefore, the present results should be interpreted as reflecting the overall performance of the restoration strategy rather than the isolated behavior of each component in combined techniques. In addition, although micro-CT provides important advantages, image analysis still depends on thresholding and region-of-interest selection, which may introduce some measurement variability.

Future studies should evaluate the long-term performance of temporary restorative materials under more clinically relevant conditions, including longer thermocycling periods, mechanical loading, and different cavity dimensions. Further studies investigating the individual and combined effects of materials used in layered techniques would also be valuable. In addition, clinical studies are needed to determine whether the differences observed in vitro translate into meaningful differences in inter-appointment sealing and treatment outcomes in primary teeth.

Conclusions

Within the limitations of this in vitro study, both the temporary restorative material and cavity design significantly influenced coronal microleakage in primary molars. In two-surface cavities, Cavit G demonstrated the lowest microleakage, whereas in three-surface cavities the Double Seal technique showed superior sealing performance. In general, two-surface cavities exhibited lower leakage values than three-surface cavities, indicating that cavity configuration plays an important role in the sealing ability of temporary restorative materials.

These findings suggest that the selection of a temporary restorative approach in multi-visit endodontic treatment of primary teeth should be based not only on material properties but also on cavity design. Cavit G may be preferred in less extensive cavity preparations, while the Double Seal technique may provide an advantage in larger and more complex cavities. However, because the present findings were obtained under standardized laboratory conditions, further in vitro and clinical studies are needed to confirm their clinical relevance and long-term implications.

Declarations

Ethics Approval and Consent to Participate

Ethics committee approval for this study was obtained from the Clinical Research Ethics Committee of Ankara University Faculty of Dentistry (Date: 06.10.2021, Decision No: 14 – 06). All procedures were carried out in accordance with the Declaration of Helsinki. Extracted teeth were obtained from pediatric patients whose parents had provided written informed consent.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author Contribution

All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.Conceptualization and design of the study: B.K., H.S.G., E.A., N.Ö., A.B.Acquisition of data: B.K., H.S.G., E.A., N.Ö., A.B.Analysis and interpretation of data: B.K., H.S.G., E.A., N.Ö., A.B.Drafting of the manuscript:B.K., H.S.G., E.A., N.Ö., A.B.Critical revision of the manuscript for important intellectual content: B.K., H.S.G., E.A., N.Ö., A.B.

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Data Availability

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Figures

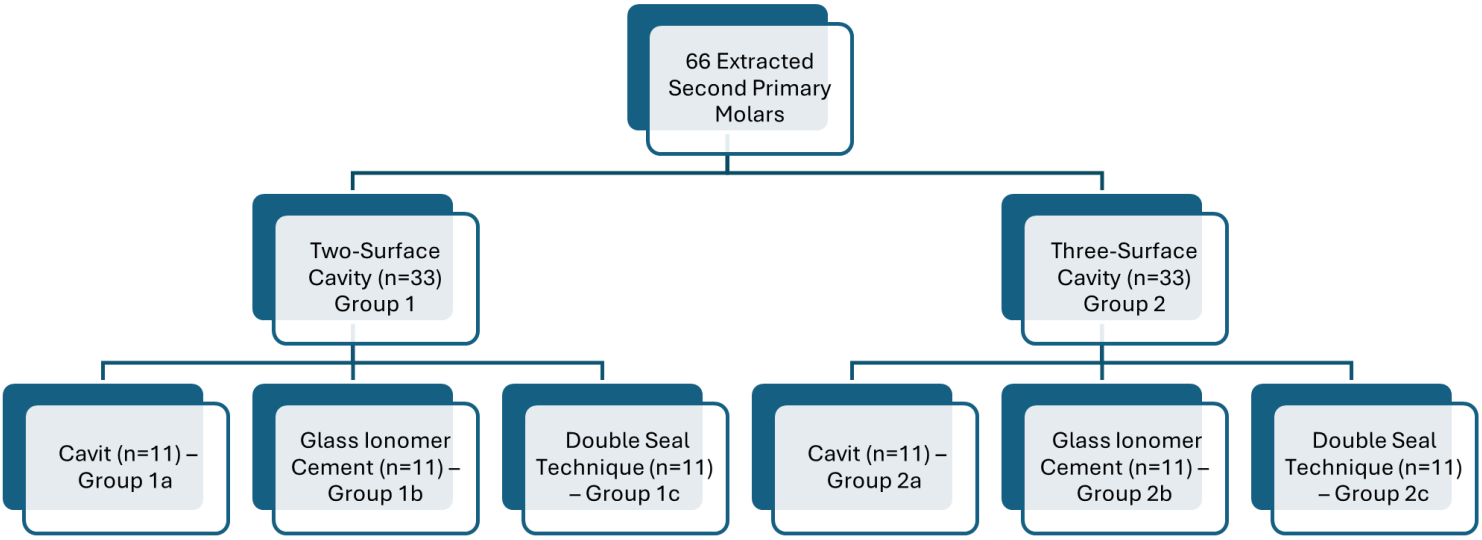


Figure 1

The distribution of second primary molars according to cavity type and the material types used in the study.