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ORIGINAL RESEARCH

Microleakage Evaluation of Endodontically Treated Teeth Restored with Custom-Made Cast Post-and-Core Using Two Types of Cement and Two Types of Roots Canal Irrigants

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Abstract

Background: To retain endodontically treated teeth, a post and core crown is necessary. The process of creating space for the post removes a significant amount of root canal filling, increasing the risk of microleakage. This study compares microleakage in treated teeth restored with cast post and cores using two different cements and irrigants.

Materials & Methods: This experimental study investigated the effects of different cement and irrigant combinations on cloudiness caused by Enterococcus faecalis. Six groups, each with eight maxillary central teeth, were examined. Groups 1 and 2 used glass ionomer (GI) cement and Panavia resin cement, respectively, with EDTA as the irrigant. Groups 3 and 4 used the same cements with sodium hypochlorite (NaOCl). Group 5 was the positive control, while group 6 was the negative control. Samples were placed in sterilized Brain-Heart Infusion (BHI) and injected with E. faecalis every three days for 60 days. The occurrence of cloudiness was recorded and analyzed using two-way ANOVA ($\alpha = 0.05$).

Results. The results showed no significant difference in microleakage between the cements and irrigants. The interaction between cements and irrigants in the four groups was not significant in the degree of microleakage ($P>0.05$) Group 5 samples became cloudy within three days, whereas Group 6 samples remained clear throughout the study.

Conclusion: None of the cements and irrigants provided a complete coronal seal. However, GI cement showed less microleakage than Panavia resin cement. NaOCl showed less microleakage than EDTA. However, the differences were not significant in cements and irrigants.

Keywords: Microleakage; Dental Cements; Root Canal Irrigants; Smear Layer.

Introduction

In the field of restorative dentistry, especially following endodontic treatment, it is often necessary to perform post-and-core and crown treatment for severely damaged teeth that have undergone endodontic therapy. This approach aims to provide protection and retention for the affected tooth. In fixed prosthodontics, various posts are commonly used to rebuild the crowns of root canal-treated teeth, with post-casting being a popular choice (1). The strength and retention of the restoration are key factors, but it is also crucial to seal the root canal system effectively to prevent microleakage and the entry of bacteria into the periapical area, which can ultimately impact the success of root canal treatment. Microleakage is a significant hindrance to the success of root canal treatment (2), despite the common use of gutta-percha and sealer as filling materials for the canal. Coronal microleakage is another important factor contributing

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to the failure of modern endodontic treatments (3). Various factors, such as poor compatibility of the filling material with the tooth tissue, inadequate canal preparation, operator error in filling material placement, shrinkage of the filling material, and dissolution in tissue fluids, can lead to microleakage. The presence of the smear layer can also affect the compatibility of the filling material (4).

Failure to establish a proper coronal seal can result in secondary caries in the restored tooth and periapical lesions due to the infiltration of oral saliva microorganisms into the apical area (5). Microorganisms play a vital role in the development, progression, and resistance of pulp and periapical diseases (6). Bacteria and other substances can leak into the root canal through various pathways, including the apical foramen, the outer surface of the root, coronal leakage through the crown, or the root canal filling material (7). Therefore, ensuring a proper seal and preventing microleakage are essential for the success of root canal treatment.

During root canal treatment, the coronal part of the root filling may become contaminated by oral flora, allowing bacteria and bacterial endotoxins to travel through the root canal to the apex (8). Bacteria can also enter the apical foramen within three weeks, particularly in root-treated teeth with weakened or broken crowns. Proper retention of restorative material through the use of a post is crucial in such cases. However, the preparation of the post space can lead to the removal of a significant portion of the root filling and damage to the remaining parts, increasing the risk of microleakage and treatment failure. Research has shown that proper post cementation can reduce the risk of infection at the apex (9).

The choice and method of application of dental cement are important factors that affect the long-term prognosis of post and core treatments and veneers. In fixed prosthesis treatments, a gap between the restoration and the tooth is inevitable, despite precision in clinical and laboratory stages. This gap must be filled by a luting agent, and there are various types of cement available for cementing prosthetic restorations, each with its advantages and disadvantages (10).

Ideal cement that possesses all desirable properties is yet to be developed. The cement with a creamy consistency, which is appropriate for casting restorations, does not penetrate demineralized dentin. This results in the formation of a layer of demineralized collagen fibers around them. Over time, these fibers react with saliva and water, undergo hydrolysis, and result in a gradual decrease in bond strength and leakage. Microleakage has been reported at the dentin-cement border as early as 24 hours after cementing with acid cements. Therefore, the selection and application of dental cement should be given careful consideration by dental professionals to ensure the success of prosthetic treatments (11).

The rationale that the initial microleakage is attributed to the demineralized layer and exposed collagen, rather than solubility, shrinkage, or non-bonding of the cement, is further supported by existing literature (11). Cements are generally divided into three categories: water-based (such as zinc phosphate and glass ionomer), oil-based (such as zinc oxide eugenol), and resin-based. Each cement presents distinct advantages and disadvantages, primarily differing in strength, adhesion, and bacterial microleakage (12, 13). Although most existing cements can be successfully used with posts, the use of resin cement is generally preferred when using a post with a suitable length and design due to its superior adhesion properties. However, resin cement is expensive and requires a sensitive application process, which can be challenging for some dentists. Additionally, removing the post can be difficult due to the excessive adhesion of these cements. It is important to note that achieving an unlimited bond is not the goal when cementing the post, as the root may require further treatment (14). Laboratory studies have shown that resin cements have higher absorption than glass ionomer cement and lower absorption than zinc phosphate cement (13). The least sealing has been observed in posts cemented with zinc phosphate, while the most sealing has been observed in restorations cemented with resin cement (15). If the cement-dentin connection is not fully established, bacteria, liquids, or saliva can be drawn into the space between the restorative material and the tooth wall due to capillarity, leading to microleakage (16). During cleaning and shaping, pulp organic materials and inorganic dentin debris form an amorphous and irregular layer called the smear layer, which can interfere with the activity of canal cleaners and disinfectants between sessions. Smear layer removal is generally recommended before filling, as it allows for better contact between the sealer and the canal wall, promoting adhesion and sealer penetration into the dentinal tubules (8). Resin cements have shown greater adhesion in post, core, and crown treatments when the smear layer is removed (17).

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The efficacy of various EDTA salts in the smear layer removal within root canals was examined; however, none of the solutions completely eliminated the smear layer from the canal surfaces (18). Research indicates that different preparation techniques and cement types significantly influence the post retention. Sodium hypochlorite is the most commonly used irrigant for root canal treatments due to its ability to mechanically wash debris from the root canal system, dissolve living and necrotic pulp tissues, and provide antimicrobial and lubricity activities (8). Material leakage in dentistry has been investigated using various techniques such as air pressure, electrochemical methods, fluid filtration, bacterial leakage, and radioactive materials. Given that most pulp and periradicular diseases are directly or indirectly related to microorganisms and are the primary etiological factor along with other microorganism irritations, using the leakage method with microorganisms is more intriguing (19).

After cleaning and shaping, the smear layer is removed using acids or chelating agents, such as EDTA.The recommended approach is to rinse with 17% EDTA for 1 minute, followed by a final rinse with NaOCl. Chelators remove inorganic components while leaving organic components intact, necessitating the use of NaOCl to eliminate any remaining organic components (8). Previous studies have shown that due to the superior compatibility of casting posts with the dental canal compared to prefabricated posts, casting posts were utilized in this study to provide retention.

Microbial leakage from the space between the post and core, as well as the canal wall covered with cement, can lead to periapical lesions, the need for retreatment, additional costs, and ultimately treatment failure. The aim of this study was to evaluate the role of cement and irrigants in the rate of bacterial microleakage in teeth restored with cast post and core.

Material and Methods

The present study was conducted experimentally in controlled laboratory conditions on 48 single-rooted extracted maxillary central teeth, with no curve, decay, or root cracks. The soft tissues, debris, bone remains, and plaques were removed from the root surface using a curette. The teeth were disinfected in sodium hypochlorite (NaOCl) overnight and stored in normal saline during the experiment. Dental radiographs were taken to ensure the teeth met the research criteria, including the absence of internal and external root absorption, calcification, and other anomalies. The roots were cut to a uniform length of 13 mm from the cementoenamel junction (CEJ) using a diamond disk (Figure 1).

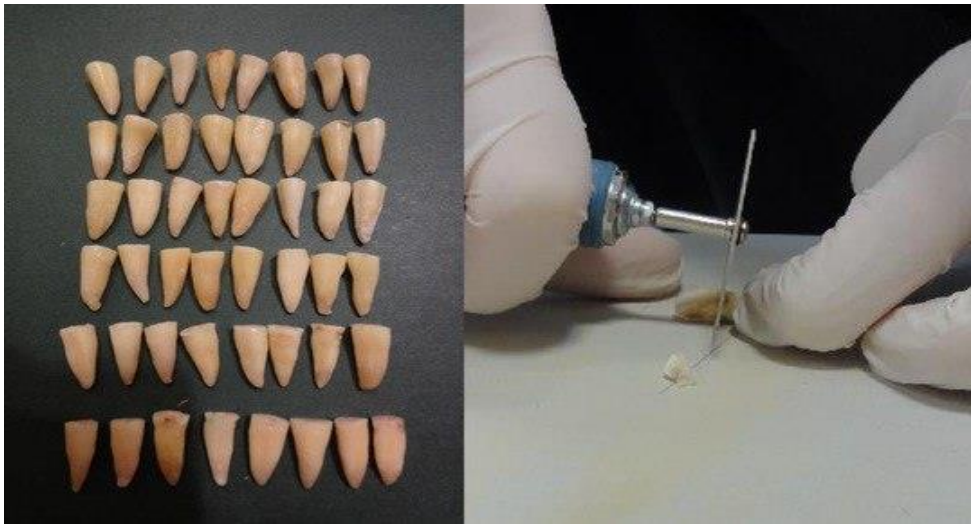

Figure 1. Samples after cutting the tooth crown using diamond disk

The working length was determined by subtracting 1 mm from the length of the K-File (MANI, Tochigi, Japan) tip observed in the apex. The teeth were randomly divided into four experimental groups, a positive control group, and a negative control group. Groups 1 and 2 were washed with 17% Ethylenediaminetetraacetic acid (EDTA) and 2.5% NaOCl after shaping to remove the smear layer. Groups 3 and 4 were washed with 2.5% NaOCl alone. Group 5 served as the positive control group with the smear layer remaining, and Group 6 served as the negative control group with 17% EDTA (MORVABON, Tehran, Iran) and 2.5% NaOCl used to remove the smear layer. The canals were dried with

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paper cones, and gutta-percha (MAC#45) (PUMADENT, Orpington, UK) and AH26 (DENTSPLY, Konstanz, Germany) sealer were used to obturate the canals using the lateral condensation method. A radiograph was obtained to ensure the quality of obturating the canals. Peeso reamer (DENTSPLY, Konstanz, Germany) No. 2 and 3 were used to prepare the post space, leaving 4 mm of gutta-percha at the apical area of the root canal. The remaining gutta-percha was evaluated for obturation quality (Figure 2).

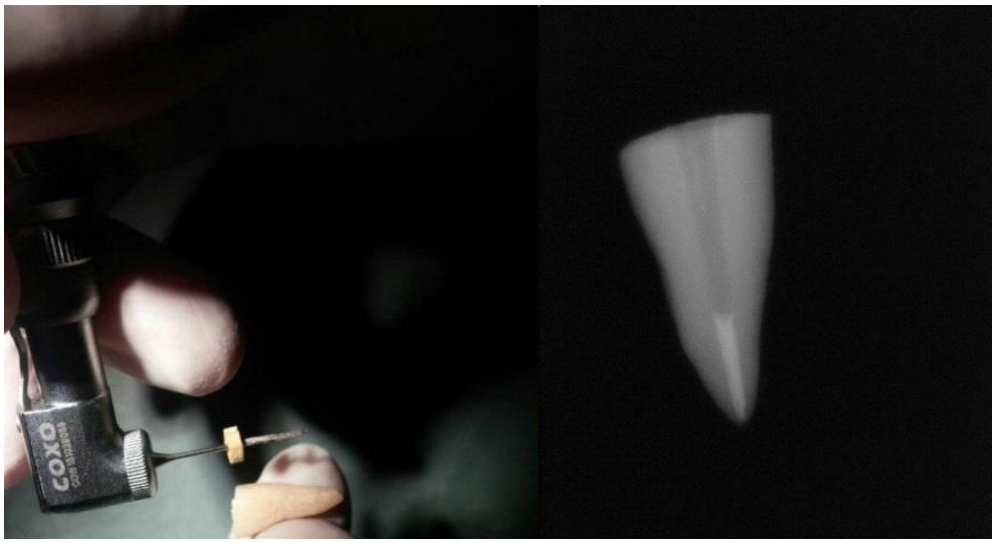

Figure 2. Preparation of post space and related radiography

The canal space was molded using Duralay resin pattern (GC, Tokyo, Japan), and a core shape similar to a chiseled tooth was created with a 1-2 mm ferrule effect and a shoulder finish line (Figure 3).

Figure 3. Preparation of Post-and-Core using Resin Pattern

The casting process was performed by a laboratory technician in the form of 120-gram cylinders. Fireproof cardboard was not used in the cylinder to reduce expansion and facilitate post placement. After cylinder placement and insulation, the cylinder was kept at room temperature for one hour and then placed in cold water. The centrifuge was rotated 5 times for base metal alloys, and a multi-hole showerhead was used to melt and pour the metal due to the high melting point of this alloy.

The metallic cylinders, were poured, and allowed to cool to room temperature. Subsequently, the posts were removed from the cylinders, and the plaster additions were eliminated using sandblasting with 50-micron alumina. Posts with defects were discarded and re-prepared under the same conditions, with none found to be defective in the current study. After these procedures, the posts were cut and subjected to sandblasting. Fit checker and radiography were utilized to ensure the compatibility of the posts, which were then cleaned using 96% medical ethyl alcohol. Groups 1 and 3 were cemented with glass ionomer cement, while groups 2 and 4 were cemented with Panavia resin cement. The Glass Ionomer cement (GC, Tokyo, Japan) was mixed according to the manufacturer's instructions, which involved combining one scoop of powder with two drops of liquid and mixing for 20-30 seconds. The powder was divided into two parts, with one part mixed with the liquid before adding the remaining powder and mixing again. The mixed cement should have a transparent

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appearance. One part of the cement was applied to the post using a lentulo, while the other part was placed inside the canal. In groups using Panavia F-2 cement (Kuraray, Osaka, Japan), the casting post was coated with a layer of metallic primer, and the root canal dentin was treated with Ed Primer (Kuraray, Osaka, Japan), a self-etch, self-curing bonding agent, according to the manufacturer's instructions. A gentle air puff was applied to the bonded areas, followed by the application of two tubes of resin cement, which were mixed over a wide area with a plastic spatula for 20 seconds and then carried into the canal by lentulo (MANI,Tochigi, Japan) and smeared with a post. The cement additions were removed, and the oxygen protective layer (Kuraray, Osaka, Japan) was placed on the open areas of the resin cement and post before using a light cure device for 20 seconds on each surface to hasten the setting process.

In the next step, the surface of the roots was covered with two layers of nail polish (OPI, California, United States), excluding the apical 2 mm. In the negative control group, the entire surface of the tooth root was covered. The teeth were then placed in a device to evaluate the amount of coronal microleakage, which was prepared with a slight modification from the original model described by Siqueira et al. (20). The roots were passed through a microtube until 2 mm from the end of the root was outside the microtube. The junction of the tooth and the microtube was filled with two layers of cyanoacrylate glue and then one layer of nail polish. The microtube was placed in the antiserum bottle containing 10 cc of sterile BHI (Brain heart infusion) (QUELAB, Montreal, Canada), ensuring that at least 2 mm of the apical root was placed in the solution (Figure 4).

Figure 4. Tooth placement in BHI culture medium

The prepared samples were sterilized in an autoclave and placed in an incubator (Binder, Tuttlingen, Germany) for 3 days. The occurrence of turbidity in the solutions indicated sample contamination, and such samples were excluded from the study (Figure 5).

Figure 5. Cloudy samples

Every three days, 1 cc of fresh BHI solution containing 10^9 *Enterococcus faecalis* bacteria was injected (Figure 6), and the samples were kept in an incubator at 37°C. Bacterial microleakage was evaluated by turbidity in BHI in vitro. The samples were examined for 60 days, and the occurrence time of turbidity was recorded for each sample. The cloudy solution of each sample was cultured and stained to ensure that the cause of contamination was solely *Enterococcus faecalis* bacteria (Figure 7).

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Figure 6. Injection of fresh BHI containing Enterococcus faecalis bacteria

Figure 7. Cultivation of *E. faecalis* bacteria and microscopic examination of the turbid solution

The data analysis for this study was conducted using STATA software version 12. In this investigation, two factors, namely irrigant and cement, were examined. To analyze the effect of these factors on the study outcomes, a *one-way* Analysis of Variance (ANOVA) was conducted, followed by Tukey's HSD post-hoc test.

Results

The average turbidity time was calculated for each of the four groups. In Group 1, consisting of EDTA irrigant and glass ionomer cement, the average turbidity time was 18.43 days. For Group 2, which included EDTA irrigant and Panavia resin cement, the average turbidity time was 16.00 days. In Group 3, consisting of NaOCl irrigant and glass ionomer cement, the average turbidity time was 20.50 days. Finally, in Group 4, including NaOCl irrigant and Panavia resin cement, the average turbidity time was 20.86 days (Table 1).

The average turbidity occurrence time calculated for glass ionomer cement in 15 samples in groups 1 and 3 was 19.53 days, and for Panavia resin cement in 14 samples in groups 2 and 4, it was 18.42 days (Table 1). The average turbidity occurrence time calculated for EDTA irrigant in 15 samples in groups 1 and 2 was 14.77 days, and for NaOCl irrigant in 14 samples in groups 3 and 4, it was 19.11 days (Table 1).

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Table 1. The mean turbidity Time and Statistical Summary for Different Cements and Irrigants. This table presents the average turbidity time (in days) for Glass Ionomer and Panavia cements when treated with two different irrigants (EDTA and NaOCl). The mean, standard deviation (SD), and the number of samples (N) for each group are also included

Cement	Irrigant	N	Average Turbidity Time (Days)	Mean ± SD
Glass Ionomer	EDTA	15	18.43	19.53±1.464
Glass Ionomer	NaOCl	15	20.50	19.53 ±1.464
Glass Ionomer	*Total*	30	19.53	19.53±12.82
Panavia	EDTA	14	16.00	18.42±2.030
Panavia	NaOCl	14	20.86	18.42±2.030
Panavia	*Total*	28	18.42	18.42±10.83
EDTA	*Total*	15	14.77**	14.77±10.46
NaOCl	*Total*	14	19.11**	19.11±12.67

To evaluate the significance of the observed differences, a one-way ANOVA was conducted to compare the average turbidity times across the four groups. Prior to conducting the ANOVA, the assumptions of normality and homogeneity of variances were assessed. Normality was evaluated using the Shapiro-Wilk test, and homogeneity of variances was assessed using Levene's test. The results indicated that the data met the assumptions required for ANOVA.

Post-hoc analyses were performed using Tukey's HSD test to identify specific group differences. The results indicated that the differences in average turbidity times among the groups were not statistically significant ($p > 0.05$).

The average occurrence time of turbidity in the four studied groups is as follows (Figure 8):

Panavia+NaOCl > Glass Ionomer+NaOCl > Glass Ionomer+EDTA > Panavia+EDTA

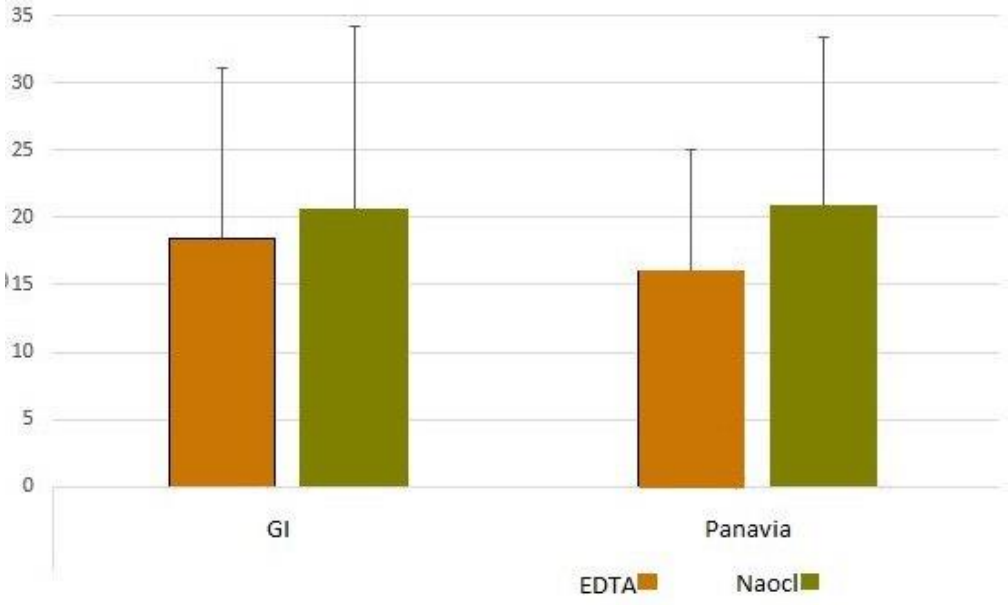

Figure 8. Investigating the time distribution of turbidity in the four studied groups

Despite the observed ranking, the mutual effect of cement and irrigant on the amount of microleakage was assessed using a two-way ANOVA, and the results indicated that this effect was not significant ($p > 0.05$). Additionally, pairwise comparisons between the two types of glass ionomer cement and Panavia resin cement were conducted using Tukey's HSD test, which also revealed no significant differences in microleakage ($p > 0.05$). Furthermore, the difference in microleakage between the two types of irrigants used in the study was evaluated using an independent samples t-test, and this analysis similarly showed no significant differences ($p > 0.05$).

Discussion

Endodontic treatment can fail for various reasons, with persistent bacteria in the root canal being the main cause. Inadequate preparation, insufficient irrigation

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during the procedure, or re-infection due to improper crown and root sealing can all contribute to the presence of bacteria in the root canal (21). Furthermore, the presence of cavities, dental restorations, and access cavity preparation can compromise the integrity of the dental hard tissue, requiring the placement of a post within the canal to enhance the retention of the crown filling (2).

Ricucci et al. (22) found that root canal treatment failure is associated with coronal microleakage within the root canal, which can be exacerbated by removing a large amount of gutta-percha to prepare the post space. The composition and properties of cement play a significant role in determining the amount of microleakage. Microleakage is a critical factor that can lead to secondary caries, affecting the longevity of post and core, and even causing root canal treatment to fail (23). The level of microleakage is influenced by several factors, including the hardness of the post, the solubility of the cement, and the strength of the bond between the post and the tooth. Research indicates that the adhesion between the post and the dentin has a greater impact on microleakage than the physical characteristics of the post itself (24).

In studies perform by Fox and Gutteridge (25), and Bachicha et al (16) showed that all cements have some degree of microleakage. The present study aimed to compare the microleakage of two types of cement and two types of irrigants. Both types of cement demonstrated microleakage; however, there was no statistically significant difference in the amount of microleakage between the two types of glass ionomer cement and Panavia resin cement. Notably, the microleakage observed with glass ionomer cement was slightly less than that found with Panavia resin cement. Furthermore, a study by Fernandes et al. (26) indicated that the microleakage of glass ionomer cement was lower than that of resin cement, which aligns with the findings of the current study.

In similar studies, the assessment of root microleakage has been determined using the turbidity of the BHI culture medium against *Enterococcus faecalis* bacteria. The rationale behind selecting *Enterococcus faecalis* bacteria is that they are part of the normal oral flora and are frequently found in teeth with failed root canal treatments (27). The validity of this method is established through positive and negative control groups, where the culture medium becomes cloudy in all positive control samples and remains clear in all negative control group samples. In the present study, all samples in group 5 (positive control) became cloudy after three days of BHI solution; while none of the samples in group 6 (negative control) stained the BHI culture medium.

Considering that there are over 700 species of bacteria in the oral environment (28), it is logical to measure the resistance of cements against microleakage in an environment that resembles the oral environment, including saliva and bacteria. The antibacterial property of glass ionomer cement has been proven due to the release of fluoride (29), which suggests that glass ionomer may exhibit less microleakage in an environment containing bacteria. Additionally, Irie and Suzuki (30) found that the bond strength of glass ionomer to enamel, dentin, and its bending strength increases after storage in water, indicating that hydroscopic expansion may not only increase marginal sealing of glass ionomer but also enhance bond strength.

Preventing microleakage and bacterial penetration into the periapical area is crucial in determining the prognosis of root canal treatment. Coronal microleakage is a major factor that contributes to the failure of endodontic treatments today (2) The use of sealers and the removal of the smear layer are crucial for preventing bacterial microleakage. Therefore, it is important to evaluate the effectiveness of different types of sealers in preventing the penetration of coronal bacteria, as well as the impact of various irrigants on removing the smear layer.

The smear layer, a mud-like material formed due to root canal instrumentation on the inner surface of the canal, consists of an amorphous, irregular, and grainy layer containing organic materials, bacteria, pulp tissue, and inorganic materials (31). There is no consensus regarding the effect of the presence or absence of the smear layer on the amount of microleakage in root-treated teeth in different studies. For example, Chailertvanitkul et al. (32) found no significant difference in the amount of microleakage of *Streptococcus sanguinis* under the influence of the presence and absence of the smear layer. Similarly, Chailertvanitkul et al. (27) reported no significant difference in bacterial microleakage between the presence and absence of the smear layer. However, Timpawat et al. (33) showed that removing the smear layer results in more microleakage than not removing it, which can be attributed to the fact that the smear layer acts as a barrier against bacterial penetration and their products, thereby preventing bacteria from entering dentinal tubules (34).

Behrend et al. (35) concluded that removing the smear layer before filling the root canal significantly reduces bacterial microleakage. Clark-Holke et al. (36) found

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that removing the smear layer reduces microleakage along the root canal. This occurs for several reasons: 1. The smear layer can act as a pathway for bacterial and oral fluid leakage. 2. The presence of oral fluids may dissolve the smear layer, thus creating a channel for microleakage. 3. The smear layer can serve as a suitable environment for microbial growth. 4. Eliminating the smear layer enhances the compatibility of the sealer and gutta-percha with the dentin wall of the root canal.

Factors that may contribute to the varying results obtained from previous studies include the method of conducting the study, the method of canal preparation, the method of filling the root canal system, the selected bacteria in the study, and the microleakage measurement method. Additionally, the dentist's level of knowledge and abilities is one of the determining factors in the correct selection and application of dental cements (37) and incorporating nanoparticles like selenium in irrigants, cements, and sealers can be beneficial as they provide antimicrobial properties, improve the strength and durability of these materials, and promote faster setting times, ultimately leading to enhanced treatment outcomes and reduced microbial colonization (38). By effectively maintaining and preserving natural teeth, dental professionals can contribute to bone preservation, thereby reducing the need for implant treatments and minimizing the necessity for narrow diameter implants, which are often required in cases of significant bone loss (39).This highlights the importance of ongoing education and training for dental professionals, as a deeper understanding of dental materials and their interactions with the smear layer can significantly impact clinical outcomes.

Conclusion

The current investigation indicates that neither type of cement was able to completely prevent coronal leakage. However, glass ionomer cement exhibited a lower degree of microleakage compared to Panavia resin cement, although this difference was not statistically significant. Regarding irrigants, the presence or absence of a smear layer did not significantly affect the level of microleakage. Nonetheless, sodium hypochlorite as an irrigant demonstrated a lower level of microleakage compared to EDTA irrigant.

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Conflict of Interest: The authors declares that they have no conflict of interests.

Ethical Issues: The protocol of this study was approved by the Ethics Committee of Kurdistan University of Medical Sciences (Ethical approval code: **IR.MUK.REC.1398.302**).

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