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RESEARCH ARTICLE

A Comparative microleakage analysis of two bioactive root perforation sealing materials

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ABSTRACT

Complications during root canal therapy, such as perforation, might lead to failure of root canal therapy. A root perforation allows the root canal system and periradicular tissue to communicate, which may affect the treatment outcome. The ability of perforated sealing materials to stop microleakage is also crucial to the success of the treatment. The latest bioactive materials, such as bioactive calcium silicate cement (BCSC) and enhanced resin-modified glass ionomer (ERMGIC), are used. This study compares the microleakage of BCSC and ERMGIC as a material for sealing root perforations at different observation times. Thirty post-extraction premolars, no caries, and single roots were used in this study. Samples were divided into two different groups. The perforation simulation was created using cylindrical fissure round-end burs at a distance of 2 mm from the cervical line. Following the use of BCSC and ERMGIC to seal the perforation, the samples were separated into three subgroups and immersed in a simulated body fluid for different durations in an incubator set at 37°C. As soon as the samples reached the immersion period, all samples were immersed in 1% methylene blue for 24 hours. It was then divided into two parts and examined under a microscope at 50x magnification. The two-way ANOVA test demonstrated no significant variation in the microleakage of the root perforation seal, depending on the material type and the observation time. This study found that microleakage, a material used to seal root perforations, was unaffected by the types of materials used or the length of the observation period.

Keywords: microleakage; perforation; perforated repair materials

INTRODUCTION

Perforation is a clinical complication that can fail root canal therapy.[1] Perforations at the pulp chamber floor or within the root canal can occur inadvertently during root canal therapy or restorative procedures.[2] A perforation is a mechanical or pathological communication between the root canal system and the tooth's outer surface.[3] Root perforation can result from extensive carious lesions, resorption, instrumentation, or post-preparation errors made by the operator.[1]

The efficacy of perforation treatment depends on the perforation's etiology, location, size, and length of time before repair.[2] The success of perforation management also hinges on the perforation sealing material and infection control.[1] One of the many perforation-sealing materials discovered is bioactive calcium silicate cement (BCSC). BCSC is a bioactive material that assists in the penetration of open dentinal tubules to interlock with dentine and can provide excellent mechanical properties.[4] Based on previous research, it was determined that the marginal sealing ability of BCSC is comparable to that of resin-modified glass ionomer cement (Fuji II LC), indicating that this material has a decent sealing ability.[5]

Additionally, resin-modified glass ionomer cement can be used as a perforation sealing material.[6] This material is dimensionally stable, fluoride-releasing, and bonds to dentin and composites.[7] Enhanced resin-modified glass ionomer cement (ERMGIC) is the first bioactive material with an ionic resin matrix, shock-retaining resin components, and bioactive substances with physical and chemical properties comparable

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to natural teeth.[8] The ionic composition of the resin, which consists of phosphoric acid groups, enhances the interaction between the resin and the reactive shock-resistant glass filler and increases the interaction between the tooth structure and the enamel rim, forming a resin-hydroxyapatite complex and enhancing marginal integrity.[9] The use of bioactive compounds presents a viable approach for facilitating the release of phosphate ions, which may yield favorable outcomes for tooth remineralization in the long run.[10]

The use of chemically active and adhesive sealing materials plays a significant role in reducing microleakage. Microleakage is known to contribute to root canal treatment failure. Despite intense biomechanical and chemical preparations, bacteria can penetrate the dentinal tubules through microleakage in the root canal. This condition must be avoided as it can occur during or after root canal treatment.[11] This research aims to determine the perforation sealing ability against microleakage of two of the most recent bioactive materials at various observation times.

MATERIALS AND METHODS

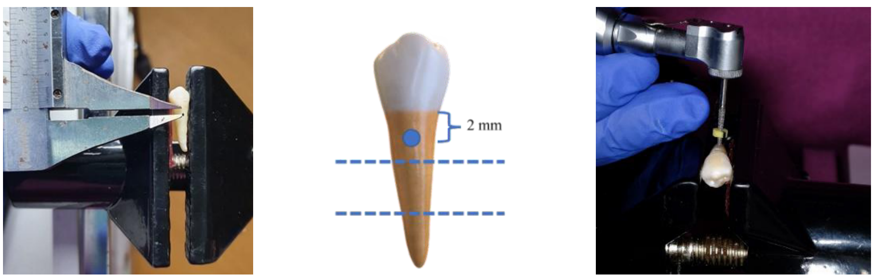
Ethics approval for this study was obtained from the Ethics and Advocacy Unit of the Faculty of Dentistry at Universitas Gadjah Mada (approval number 0058/KKEP/FKG-UGM-EC/2022). The sample consisted of 30 extracted mandibular premolars with no lesions, no prior root canal treatment, straight roots, and a single root. Using an ultrasonic scaler, debris, remaining tissue, and calculus were removed from the sample, and the sample was soaked in the saline solution until the perforation simulation cavity was created.

The cavity was created two millimeters from the cervical line in the coronal one-third of the tooth root. The simulation began with a cylindrical diamond fissure bur with a rounded tip until the 19-bit drill penetrated the root surface perpendicularly. The sample was randomly divided into two treatment groups containing 15 teeth each and then into three subgroups.

BCSC was mixed using an amalgamator for 30 seconds. Using the MTA carrier, the BCSC was inserted into the perforated cavity from the buccal direction until it was filled and compacted using a plugger. Excess material extracted from the buccal region was levelled until it was aligned with the tooth surface using a plastic instrument.

The injectable applicator provided by the manufacturer was utilized to apply ERMGIC to the perforated cavity, extending from the buccal to the full extent of the cavity. The excess material extruded in the buccal region was smoothed out with a plastic instrument until it was even with the tooth surface. This step was followed by exposure to a light curing unit for 20 seconds.

Following the completion of the perforation closure, all specimens underwent examination to determine the density of the closure, utilizing radiographic imagery. The tooth samples were immersed in a simulated body fluid (SBF) within a 2 ml tube. The specimen was incubated at 37˚C, with a periodic replacement of the simulated body fluid (SBF) every 72 hours. The soaking duration



(A) (B) (C)

Figure 1. (A) (B) The sample is clamped to a table, and the location of the perforation simulation is measured with a sliding caliper. (C) The procedure for simulating perforation on sampled teeth

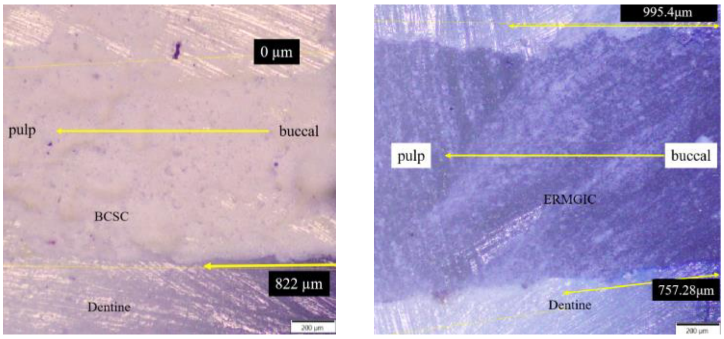


Figure 2. Samples observed through a compound microscope in the BCSC (left) and ERMGIC (right) groups from the buccal to the pulp on both sides

was modified based on the subcategories of each specimen, precisely 24 hours, 7 days, and 28 days.

After the immersion period was achieved, the specimen was subjected to air drying. Subsequently, the entire tooth surface was coated with nail polish, except for a 1 mm margin around the area of recuperation from the buccal aspect. Subsequently, the specimen was submerged in a receptacle filled with a solution of methylene blue at a concentration of 1% for 24 hours. Following a 24-hour incubation period, the specimens were extracted and subjected to a 10-minute rinse under a continuous stream of water, followed by drainage. Following the drying process, the specimens were subjected to magnification in the buccal to the lingual direction and subsequently examined utilizing a compound microscope set at a magnification of 50x. The Olympus Stream Basic software was utilized to capture and quantify the extent of color penetration of 1% methylene blue at the perforation closure. Millimeters (mm) were used as the metric unit for taking measurements, which were subsequently documented.

Two observers conducted observations and measurements. The data acquisition was followed by the data analysis process. The present study assessed microleakage rate measurements and employed the Pearson's correlation to examine the correlation between two observers. The statistical technique of two-way ANOVA was employed to analyze the data further.

RESULTS

Microleakage was identified from the inclusion of 1% methylene blue dye between the perforation covering material and the dentine wall observed under a compound microscope with 50x magnification. The results are shown in Figure 2. The results of microleakage observations can be seen in Table 1. Observations on day 28 had the smallest microleakage in the BCSC and ERMGIC groups. Meanwhile, in the BCSC group, the highest

Table 1. The average and standard deviation of microleakage closure of tooth root perforations Bioactive calcium silicate cement and enhanced resin-modified glass ionomer at different observation times (mm)

Sealing materials	Day	n	Mean ± SD
Bioactive calcim silicate	1	5	1.19 ± 0.28
	7	5	1.24 ± 0.91
	28	5	0.89 ± 0.33
Enhanced resin modified glass ionomer	1	5	1.32 ± 0.35
	7	5	1.13 ± 0.43
	28	5	0.79 ± 0.35

leakage occurred on day 7. For the ERMGIC group, the highest leakage occurred in the 24-hour group.

The results of the two-way ANOVA test on the comparison between types of materials showed no significant difference ($p > 0.05$) in the type of perforation covering material. A comparison of the variable time of observation showed no significant difference at the time of observation ($p > 0.05$). There was no significant difference in the results of the comparison between the interaction between the type of material and the time of observation ($p > 0.05$).

DISCUSSION

The results showed no significant difference ($p < 0.05$) between the types of materials for microleakage in sealing tooth root perforations. Both of these materials have the advantage of bonding to the tooth surface, thereby helping to reduce microleakage in closing perforations. BCSC can bind to dentin through materials that can enter the dentinal tubules. This allows them to interlock, providing good perforation closure results. This is supported by previous studies suggesting that the ability to seal BCSC results from the formation of a mineralized intermediate zone with a tag-like structure that extends into the dentinal tubules as a micromechanical anchor. BCSC also releases calcium and silica ions, stimulating mineralization and forming a mineral infiltration zone along the dentin-cement interface to provide good edge closure.[12]

ERMGIC also has a good bond with the teeth due to the ionization process of the phosphate groups between the resin and glass filler on one side and the tooth structure on the other. Hydrogen ions released from the phosphate group are replaced with calcium in the tooth structure, forming an ionic bond between the restorative material and the tooth structure. This material also has bioactive fillers to form a hydroxyapatite layer.[13]

The comparison based on different observation times showed that although the results showed no significant difference ($p > 0.05$), there was a decrease in the average microleakage rate, especially on the 28th day of observation. The 28th day had the smallest leakage value compared to the 24-hour and 7th-day groups. The condition in the use of ERMGIC material might be caused by the buildup of calcium and phosphate ions, which started on day 7 and peaked on day 28, resulting in good edge sealing. As a result, microleakage that occurs can be reduced when compared to observations made on other days.[14]

BCSC also showed an increased release of calcium ions from observations on day one and increased significantly on day 28.[15] The capacity for binding between calcium and silica ions within the bioactive calcium silicate cement (BCSC) is robust, forming tag-like structures that strongly adhere to the dentin matrix. The observed material demonstrated a significant ability to maintain successful marginal integrity due to the formation of hydroxyapatite crystals on its surface, thereby enhancing its sealing capacity.[16]

There was no significant difference ($p < 0.05$) in the comparison between the type of material interaction and the observation time. This result could be due to the material's solubility during the immersion process in the SBF solution, which can affect microleakage in both materials. Previous studies on the solubility of the latest calcium silicate-based materials as root tip sealing materials found that BCSC results had the most significant solubility value among the other materials tested.[17] This result may be due to porosity within sealing material cements. The mixed cement material is a mixture of liquid and powder, increasing the risk of porosity. This could harm the cement's ability in multiple adverse ways.[18] The internal void space within the material has the potential to accommodate fluid or air throughout the entirety of the material's volume,[19] thereby influencing the solubility of the cement material components.

The solubility and water absorption tests were also carried out on ERMGIC compared to resin-modified glass ionomer cement. It was found that ERMGIC experienced solubility. This could be due to increased degradation or hydrolysis with decreased pH.[20] The rise in acidity levels can increase the plastic effect on the resin components in the material, thereby reducing the bonding between the polymer chains in the dimethacrylate matrix. This may weaken the polymer chain bonds, and as a result, the monomers become unpolymerized and loose, causing solubility in a restoration. Porosity and solubility, when they occur in BCSC and ERMGIC, can result in a reduced density of the material. Consequently, the ability to close the perforations to avoid micro-leakage decreases, although both materials experience accumulation of ions, which can help close the perforations until the 28th day.

Another influence can occur due to anatomical and morphological variations in teeth, and this plays a role in the adhesion of the material. The perforation in this study was carried out in the cementum area of the teeth. This area contains a non-homogeneous matrix with several calcified layers devoid of collagen fibers. Two-thirds of the coronal root surface is usually covered by a thin layer of acellular extrinsic fiber cementum consisting of short collagen fibers fixed in the dentinal matrix perpendicular to the root surface. The dentin in the root has a lower density of dentinal tubules than the dentin in the coronal area.[21] These factors can affect the adhesion capacity in using resin-based materials such as ERMGIC.

Research on the effectiveness of ERMGIC with self-adhesive attachments compared to adhesive materials shows that the use of adhesive materials is more recommended because it provides a more stable bond compared to self-adhesive attachments with lower bond strength.[22] This can also affect the adhesion between this material and the tooth as a perforation sealing material, affecting the value of ERMGIC microleakage.

Both materials are known to have the ability to exchange ions with the tooth surface. This ability can help prevent microleakage because the gap between the teeth and the material surface can result in maximum perforation closure. It is necessary to carry out further research regarding the release and exchange of ions between the two materials and the tooth surface as a material for covering tooth root perforations.

CONCLUSION

Based on the results of the study regarding the comparison of microleakage in closing tooth root perforations using bioactive calcium ciliate cement and enhanced resin-modified glass ionomer cement at different observation times, it can be concluded that the type of material and observation time did not significantly influence microleakage in closing tooth root perforations. No interaction was observed between the material type and the observation time on the microleakage of the tooth root perforation closure. It is necessary to conduct further research regarding the release of ions in the two materials as a material for closing tooth root perforations.

CONFLICT OF INTEREST

The authors declare no conflict of interest with the data contained in the manuscript.

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