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RESEARCH ARTICLE

A Comparative study of microleakage in bioactive composite resin restoration with filled and unfilled bonding materials

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ABSTRACT

The most recent development in composite resin is bioactive resin, which replaces common resin. If ignored, the tendency for shrinking in bioactive composite resin could result in microleakage. Bonding material innovations that incorporate more filler have also been created to reduce this issue and lower the possibility of microleakage. The purpose of this study is to compare the microleakage of bioactive composite resin restorations with and without filled bonding material. Thirty-two maxillary first premolar samples were split into two groups: group A containing 16 samples repaired with unfilled OptiBond™ Universal (Kerr) and group B containing 16 samples restored with filled SingleBond Universal (3 M). Utilizing ACTIVA™ BioACTIVE-Restorative (Pulpdent), the samples from both groups were restored.The specimens were subjected to a 24-hour artificial saliva incubation period, succeeded by an equivalent duration of exposure to 2% methylene blue. A USB digital microscope stereo was used to measure the microleakage by observing the methylene blue 2% penetration depth. Microleakage was 8.95% in group A and 8.83% in group B, according to the results. The findings of the the parametric test using the independent t-test showed that there was no significant difference ($p > 0.05$) in microleakage across the bioactive composite resin restoration groups. This indicates that the microlekeage of bioactive composite resin restoration is unaffected by the presence of filler in the bonding agent.

Keywords: bioactive composite resin; filled bonding material; microleakage

INTRODUCTION

Caries, or dental decay, is mostly brought on by the loss of minerals in the cementum, dentin, and enamel. If dental caries left untreated, they can lead to discomfort and worsening issues such abscesses, which can disrupt sleep, eating, and social activities due to a lack of confidence. To prevent the progression of caries and restore the teeth to their pre-damaged state, restoration is required.[1]

With its many benefits over glass ionomer cement, including superior durability and good aesthetics, composite resin is currently one of the most widely utilized dental repair materials.[2] It is important to consider the disadvantages of composite resins, including their propensity to shrink during polymerization, which may result in microleakage.[3] Glass ionomer cement, which can release fluorine, has been known to have a lower microleakage rate than composite resin.[4] To address the physical limitations and drawbacks of traditional composite resin, bioactive composite resin was developed.[5]

One benefit of bioactive composite resins is their capacity to release ions such as calcium, fluorine, and phosphate. The teeth’s mineralization process can be aided by the release of these ions, strengthening the link between the restoration material and the tooth structure.[5] The use of bonding material is still advised to support the quality of composite resin restorations to strengthen the binding between the composite resin and the tooth and avoid the potential for microleakage owing to shrinkage.[6]

Nowadays, a lot of bonding materials include extra filler. In contrast to traditional bonding material without filler, bonding material with additional filler will result in several improvements, including better tag resin quality, stronger bonds, and increased adhesive material hardness to aid in the tooth structure's remineralization process.[7] This filler also has the advantage of producing more uniform and homogenous adhesive results, longer storage life, greater stress absorption, and longer marginal seals.[8]

Kaushik and Yadav's earlier study looked at the advantages of employing bioactive composite resins in conjunction with various bonding generations. It was reported that 5th generation bonding materials combined with bioactive composite resins led to a notable reduction in microleakage and improved restoration outcomes compared to 7th generation bonding materials.[9] Alhenaki et al conducted a study in which they examined the dentin bond integrity of conventional composite resins with filled and unfilled resin adhesive improved with silica nanoparticles. In comparison to unfilled adhesive resin, the experimental dentin adhesive based on polymers exhibited a stronger binding when nanoparticle fillers were added. Additionally, it showed better resin tag development and appropriate dentin contact.[10] The application of filled bonding materials with bioactive composite resins has not been the subject of any research. The aim of this current study was to compare microleakage in bioactive composite resin restorations with filled and unfilled bonding materials and to determine whether there is a difference in the improvement effect in line with the results shown in previous studies.

MATERIALS AND METHODS

Ethics approval for this study was obtained from the Health Research Ethics Commission at the Dr. Moewardi General Hospital (project number 2.188 / XII / HREC / 2023). It was a true experimental study with a posttest-only group design. This study was conducted in the Integrated Research Laboratory of the Faculty of Dentistry, Universitas Gadjah Mada, and the Laboratory of the Faculty of Dentistry, Universitas Muhammadiyah Surakarta. Samples for the study were first prepared in the form of maxillary first premolar teeth that met the requirements of being free of cavities and fractures.

Subsequently, a class 1 G.V. Black cavitation was applied to the prepared tooth, measuring approximately 4 mm in diameter and 4 mm in depth from the preparation source. A round diamond bur and a wheel diamond bur (Dentsply) were used for the preparation. The samples were then split into two groups. First, the prepared teeth were subjected to acid etching for 15 seconds, followed by rinsing and drying once more. OptiBond™ Universal (Kerr) unfilled bonding material was applied to the first group, and SingleBond Universal (3M ESPE) filled bonding material was applied to the second.

Using a microbrush, the same method was used to apply bonding materials to both sample groups. It was then dried and exposed to light using a light curing device for about 20 seconds. Following the completion of the application of both bonding types, the bioactive composite resin ACTIVA™ BioACTIVE-Restorative (Pulpdent) was placed using the bulk fill method, split into two layers until it was fully covered. It was then formed using a plastic instrument in accordance with the original anatomy of the tooth. Following the application, the composite resin was polymerized for about 30 seconds using a light curing unit. A pear-shaped finishing bur was then used, and an improved polishing bur was used to polish the material.

Following their immersion in artificial saliva with a pH of 6.8, the embedded samples were incubated for a whole day at 37 °C. Following this, nail polish was applied to the entire sample, extending about 1 mm beyond the repair region and covering it from the root end to the crown. After being coated in nail polish, the samples were submerged in 2% methylene blue solution and kept in an incubator for twenty-four hours at 37 °C. After removing the nail polish and 2% methylene blue solution from the samples using acetone, they were dried and broken into two sections using a diamond disc bur in the bucco-palatal direction.

A USB digital microscope stereo was then used to measure the microleakage of the broken teeth. The laptop device was linked to the USB digital microscope stereo driver before the measurement. An object table was installed to hold the sample, and the microscope stand was adjusted to stand upright. The sliced sample was positioned on the object table with the plane of the microscope as its axis. In order to calculate the penetration length of 2% methylene blue color in millimeters, measurements were made using OptiLab Viewer4 software at a magnification of 1.6 times. The measurements were taken at two points in the buccal and palatal sections, and the average was then divided by the cavitary depth that was measured.

Based on the Shapiro-Wilk test for normality, all data were found to be normally distributed ($p > 0.05$). After subjected to Levene's homogeneity test, the microleakage data also exhibited homogeneity ($p > 0.05$). The independent t-test was then used to determine whether there was a difference between the two groups based on the percentage of microleakage data.

RESULTS

The data in this study was obtained using a USB digital microscope stereo at 1.6 times magnification to measure the penetration depth of 2% methylene blue in composite resin restorations. This enabled the identification of microleakage (Figure 1).

Table 1 displays the restoration groups' measurement data for both filled and unfilled bonding materials, and Table 2 displays the mean and standard deviation of microleakage in bioactive composite resin restorations for both filled and unfilled bonding materials. Group B (filled bonding material) had a higher mean value of microleakage than group A (unfilled bonding material). The Shapiro-Wilk test was used to assess the normality of the microleakage mean, and the Levene test was used to determine whether the data was homogeneous. All of the data were homogeneous and regularly distributed, according to the test results ($p > 0.05$).

The results of the independent t-test indicate that adding filler to bonding materials for dental restorations does not significantly increase the prevention of microleakage in restorations performed. A significance value of 0.926 > 0.005 was obtained, indicating that there is no significant difference in microleakage between the sample group with filled bonding materials and the sample group with unfilled bonding material.

DISCUSSION

The results of this study showed a smaller percentage of edge leakage in the filled group. However, no significant differences were found between bioactive composite resin restorations using filled and unfiled bonding materials.

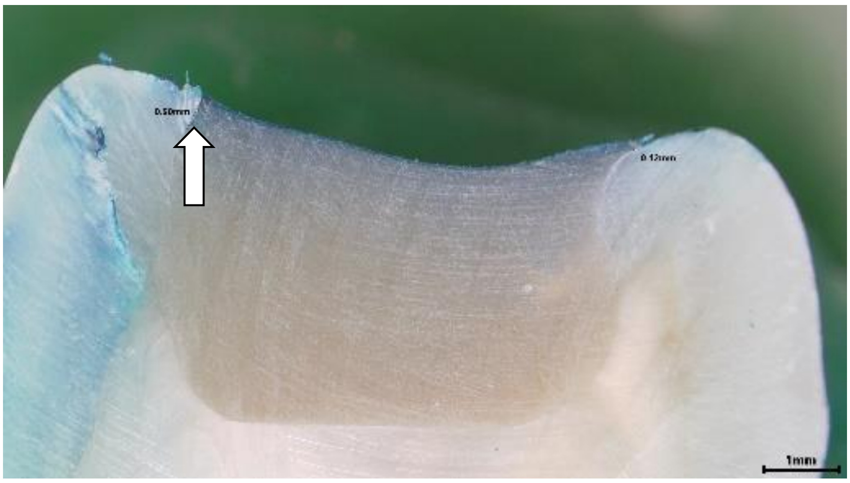

Figure 1. Arrow shows the penetration of 2% methylene blue in bioactive composite resin restoration

Table 1. Microleakage percentage on bioactive composite resin restoration with unfilled and filled bonding material

Sample	Group A (Microleakage mean per cavity)	Group B (Microleakage mean per cavity)	Microleakage percentage of group A	Microleakage percentage of group B
1	0.295/4.235	0.31/3.885	6.97%	7.98%
2	0.175/3.805	0.14/3.855	4.60%	3.63%
3	0.13/3.03	0.23/3.485	4.29%	6.60%
4	0.17/3.555	0.27/3.82	4.78%	7.07%
5	0.43/3.6	0.23/3.945	11.94%	5.83%
6	0.285/3.53	0.44/3.42	8.07%	12.87%
7	0.26/2.785	0.385/3.29	9.34%	11.70%
8	0.295/3.345	0.44/3.435	8.82%	12.81%
9	0.315/3.52	0.58/3.665	8.95%	15.83%
10	0.45/4.02	0.455/3.435	11.19%	13.25%
11	0.57/3.94	0.26/3.32	14.47%	7.83%
12	0.31/4.43	0.16/3.515	7.00%	4.55%
13	0.395/4.215	0.175/3.26	9.37%	5.37%
14	0.655/4.055	0.54/3.435	16.15%	15.72%
15	0.325/3.425	0.23/3.52	9.49%	6.53%
16	0.24/3.06	0.13/3.505	7.84%	3.71%

Table 2. Mean, standard deviation (SD) of microleakage on bioactive composite resin restoration with unfilled and filled bonding material

Treatment group	Mean ± SD
Group A (Unfilled bonding material)	8.95 ± 3.31
Group B (Filled bonding material)	8.83 ± 4.20

Table 3. Independent t-test on bioactive composite resin restoration microleakage

	T-test for equality of means		
	Sig. (2-tailed)	Mean difference	Std. error difference
Equal varience assumed	.926	.12438	1.33650

The primary restoration material in this investigation was bioactive composite resin from ACTIVA. In addition to not containing Bisphenol-A, Bis GMA, or BPA derivatives, bioactive composite resins are known to bring major benefits in terms of releasing calcium, phosphate, and fluorine ions that can aid in the remineralization process of teeth.[11] This reduces the likelihood of shrinkage and microleakage. Another benefit of ACTIVA™ BioACTIVE-Restorative (Pulpdent) is that its preparation takes the shape of a flowable composite, which is easier to conform to the tooth surface and reduces the likelihood of gaps occurring because of filling technique errors. Additionally, the probability of leakage is reduced by this improved adaptability.[12]

For the investigation, 3M ESPE's SingleBond Universal and Kerr's OptiBond Universal were chosen as the bonding materials for groups A and B. Applying both self-etch and total-etch processes, these bonding materials are universal adhesives. The total-etch technique was used in this investigation to apply both forms of bonding since it has been demonstrated to increase bond strength and enhance the quality of restoration outcomes.[13]

The addition of filler particles to 3M SingleBond Universal distinguishes the two bonding techniques. The mechanical characteristics of the bonding substance can be enhanced by the addition of filler. During the polymerization process, the increased mechanical characteristics can take the form of reduced dimensional changes and improved strength due to greater viscosity.[14] Filler application can also stop cracks in the restoration from spreading. Furthermore, filler is described as a stress buffer agent in bonding materials, which releases pressure caused by shrinkage during the polymerization process.[15] This occurs because combining bonding material and filler can raise the bonding material's elastic modulus and create a flexible layer that relieves strain and stress on the repair material, allowing it to spread more uniformly.[16]

In line with this, the results showed that the group with additional filler had a smaller micro-leakage mean, as seen in Tables 1 and 2. However, the resulting differences were not significant when parametric tests were carried out with the independent t-test.

Similar findings were reported in a study by St-Pierre et al.,[16] which showed that while filler added to bonding material can lessen the occurrence of large gaps on the restoration surface, it does not significantly alter restorations made with bonding material alone. Filler can be added to bonding material to improve its mechanical properties, which are characterized by increased viscosity, which makes the material more elastic and strengthens the bond. It does not eliminate the possibility of minor gaps forming in the repair, despite the likelihood of large gaps forming is decreased. Uneven resin tags resulting from inadequate filler penetration into the dentinal tubules may be the source of these gaps. For this reason, the amount of filler added has no discernible effect on the microleakage that occurs. In addition, bonding materials with additional filler have the risk of accumulating in the open dentinal tubules and causing obstacles to the penetration of the composite resin into the dentinal tubules. Moreover, the presence of resin tags in the filled bonding material is more irregular, which may be evidence of the obstruction of irregular particles in the inter-fibrillar space.[15]

On the other hand, the lack of significant difference observed in the continuous margin between the two groups may be due to the same treatment they received, involving the use of ACTIVA bioactive composite resin, the total-etch technique, and the same location on the occlusal side. Despite the use of bonding material without additional filler, good restoration results were achieved, with microleakage successfully minimized.

One important factor in reducing microleakage in restorations is the bioactive composite resins' capacity to release phosphate, calcium, and fluorine ions. In addition, it chemically bonds to the tooth through an ionization reaction and forms a strong resin-hydroxyapatite complex, thereby sealing the tooth from bacterial microleakage.[11] Kaushik et al explained that good restorative results in bioactive composite resins can also be attributed to ionic resin components containing phosphoric acid groups with antimicrobial properties. These properties improve the interaction between the resin and the reactive glass filling material and improve the interaction with the tooth structure. Hydrogen ions are released from phosphate groups through a water-dependent ionization process and replaced by calcium in the tooth structure. These ionic interactions bind the resin to the minerals in the tooth, forming a strong resin-hydroxyapatite complex and a positive seal against microleakage. Their study also shows that the combination of bioactive composite resin with 2-hydroxyethyl-methacrylate (HEMA) content in the bonding material also produces a much better bond. HEMA has the characteristic of wetting the tooth surface in a positive way and has a high penetration capacity into the etched dentin. HEMA mixes the hydrophilic and hydrophobic components of the binder into one solution and acts as a co-solvent by dissolving the various components in water, thereby providing a stronger bond. In the absence of HEMA, collagen peptides form intermolecular hydrogen bonds with nearby neighboring collagen peptides. This causes the collapse of the collagen network which results in weaker bonds and higher microleakage. This is in line with the HEMA content found in OptiBond™

Universal (Kerr) and SingleBond Universal (3M ESPE) as the bonding material used in this research. The quality of the restorations achieved is also impacted by the dosage form of ACTIVA™ BioACTIVE-Restorative. It is undeniable that flowable composite preparations can result in improved surface adaptation to the tooth, which can reduce the likelihood of gaps forming because of suboptimal incremental restoration procedures.[12]

The restoration's outcome may also be impacted by the bonding method selected. The findings of this study showed that applying the total-etch approach could strengthen the binding between the restoration material and the tooth surface. In their investigation, Da Rosa et al also noted that the bonding approach employed had a bigger influence on the bond strength and quality of the restoration, with the total-etch technique yielding a much higher bond strength than self-etch and resulting in less microleakage.[17] This is to ensure that the bonding material and composite resin monomer can better penetrate the enamel due to the micro- and macro-porosity that the etching process creates on the substrate's surface.[18]

Another influencing factor could be the location of the restoration. Some studies have shown that restorations performed in the cervical region tend to produce significantly greater microleakage, which is related to the thicker enamel surface on the occlusal side. The enamel area tends to give better results compared to dentin, which has more water structure and organic components, which can give the surface moist properties and risk disrupting the bonding mechanism.[15] Taking this into account, the selection of the occlusal side location in both groups contributed to better restoration results even though one of them used bonding material without additional filler. As a result, this led to insignificant differences between the two groups.

There are some limitations to this study. First, the volume and amount of filler in 3M SingleBond Universal are not clearly stated. Additionally, the bonding brand's filler type and size are unclear. The findings of this research indicate several areas for future studies. A further study could investigate the difference in microleakage in bioactive composite resin restorations with filler and non-filler bonding materials carried out on the root and crown surfaces. Further research on the difference in microleakage in bioactive composite resin restorations using filler bonding materials with different concentrations and volumes is also required. In addition, more research is needed to study the difference in microleakage in bioactive composite resin restorations with filler bonding materials using total-etch and self-etch techniques.

CONCLUSION

Based on the results and discussions in this study, the addition of fillers to the bonding material can improve the mechanical properties of the bonding material and minimize the occurrence of microleakage. However, no significant difference was found in the filled and unfilled groups. This was due to the use of bioactive composite resins, the selection of total-etch techniques, and selected location of the restoration that improved the quality of the restoration in each group, thereby minimizing the formation of microleakage even without additional fillers in the bonding material.

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CONFLICT OF INTEREST

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

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