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Orginal Article

THE EFFECT OF BIOACTIVE RESTORATIVE MATERIALS ON ORAL MICROBIOME AND GINGIVAL HEALTH: A CROSS-SECTIONAL STUDY

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ABSTRACT

Objectives: *The current study objective was to compare the oral microbiota diversity of patients with bioactive restorations verses traditional materials restorations.*

Materials and Methods: *The current study comprised patients who visited the institution's operative dentistry and had various restorations (such as conventional composites, fluoride-releasing composites, and bioactive glass). Saliva and plaque samples were used to gather data for the microbiome study (16S rRNA sequencing). The inflammation was asses by useing periodontal probing and gingival index.*

Results: *The greatest benefits were seen by bioactive glass restorations, with decreased inflammation, improved gingival health (gingival index: 1.2 ± 0.3), and decreased cariogenic bacteria (↓40%). Comparing fluoride-releasing composites to conventional composites, the former showed superior periodontal health and a moderate reduction in germs (± 25%). More sensitivity (35%) and pain (40%), higher pathogenic bacterial load, poorer gingival scores (2.1 ± 0.5), and deeper periodontal probing depths (3.5 ± 0.6 mm) were resulted from conventional composites.*

Conclusion: *The strongest beneficial effects were shown by bioactive materials, with decreased inflammation, enhanced gingival health, and decreased cariogenic bacteria. Higher bacterial loads, more gingival irritation, and deeper periodontal probing depths were seen in conventional composites.*

Key words: *Bioactive restorative materials, Sensitivity, Gingivitis*

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INTRODUCTION

To maintain tooth structure and advance oral health, dental restorations are necessary. Conventional composites and other traditional restorative materials have been linked to gingival discomfort and bacterial accumulation[1]. Bioactive materials, such as fluoride-releasing composites and bioactive glass, have been developed to counteract these negative consequences. This study will look at how different restorative materials influence oral microbial diversity, periodontal health, and gingival inflammation[2].

The human oral microbiome, a complex ecology of numerous bacterial species, helps to keep your

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mouth healthy and free of sickness[3]. Dysbiosis, or an imbalance in the microbiota makeup, can exacerbate tooth caries, periodontitis, and other oral conditions. Restorative materials can alter microbial ecology by influencing local conditions, bacterial adhesion, and biofilm formation[4]. Bioactivity is the capacity of restorative materials to encourage remineralization, limit bacterial development, and promote healing by interacting with biological tissues[5]. The potential of bioactive glass to release calcium, phosphate, and fluoride beneficial ions that promote remineralization and prevent germs, for example, has resulted in substantial study into its use in dental applications. Fluoride-releasing composites, on the other hand, produce an additional fluoride reservoir to aid in tooth decay prevention[6]. However, research into the efficacy of these materials in comparison to traditional composites is currently ongoing[7].

To improve therapeutic outcomes, bioactive materials have been developed, such as fluoride-releasing composites and bioactive glass[8]. By actively interacting with biological tissues, these substances promote remineralization and release beneficial ions. Bioactive materials have been shown to promote the formation of beneficial microbiota while inhibiting the growth of cariogenic and pathogenic bacteria[9]. Because of their mechanical and cosmetic qualities, traditional composite materials are frequently utilized in restorative dentistry. They are vulnerable to bacterial colonization, though, which results in gingival irritation and secondary caries. According to studies[3-10], traditional composites give harmful bacteria a favorable habitat, which promotes plaque buildup and the advancement of periodontal disease.

In addition to measuring gingival inflammation and periodontal health in relation to different dental materials, the current study was aimed to compare the oral microbiota diversity of patients with bioactive restorations to those with traditional materials.

MATERIALS AND METHODS

Cross-sectional research was undertaken at the Department of Operative Dentistry after obtaining the ethical approval from the institution, in which patients with various forms of restorations were included. Participants had to have their restorations in place for at least six months to be considered. Exclusion criteria included systemic diseases, antibiotic use in the last three months, and poor oral hygiene.

Only teeth restored with Class I, Class II, or Class V cavities were included, contingent upon the restorations demonstrating acceptable margins and the absence of recurrent caries. Teeth exhibiting significant structural loss, cusp replacement, subgingival margins, or defective restorations, including overhangs, open contacts, and marginal gaps, were excluded to mitigate bias associated with restoration failure rather than material performance.

Furthermore, individuals exhibiting clinically healthy or mildly inflamed gingiva (Gingival Index $\leq$ 2) were incorporated into the study. Individuals with generalized moderate to severe periodontitis—characterized by probing depths exceeding 5 mm, clinical attachment loss, suppuration, or radiographic bone loss—were excluded, as advanced periodontal disease may independently affect gingival inflammation and the composition of the oral microbiome. Patients who received periodontal therapy in the preceding three months were excluded from the study.

The sample size was determined using power analysis based on previous research on the effects of restorative materials on the oral microbiome and gingival health. The calculation was performed using G*Power software, considering the following parameters:

- Effect size (f) = 0.4 (based on prior studies on bacterial reduction and gingival inflammation)
- Power ($1 - \beta$) = 0.80 (to ensure an 80% chance of detecting a true effect)
- Significance level (α) = 0.05 (two-tailed)
- Groups = 3 (Bioactive Glass, Fluoride-Releasing Composite, Conventional Composite)

Using these numbers, the minimum needed sample size was 90 patients (30 per group) to identify significant variations in bacterial load and gingival inflammation across the three materials. However, to account for potential dropouts i.e. 10%, 100 patients were included (Bioactive Glass: 35, Fluoride-Releasing Composite: 35, Conventional Composite: 30).

Saliva and plaque samples were collected for microbiome analysis using 16S rRNA sequencing. This approach allows for the detection of bacterial diversity and the relative presence of cariogenic and periodontal infections. The use of 16S rRNA sequencing enables researchers to assess microbial diversity comprehensively, offering insights into bacterial shifts due to different restorative materials. The study compared samples from patients with bioactive glass restorations, fluoride-releasing composites, and conventional composites to see if bioactive materials had a positive impact on bacterial populations. Gingival health was evaluated using the Gingival Index (GI), which ranged from 0 (healthy) to 3 (severe inflammation). PPD, or periodontal probing depths, were used to assess periodontal health. Sensitivity and patient discomfort were also assessed.

To establish the statistical significance of differences between groups, ANOVA was used for multiple group comparisons, followed by post-hoc Tukey's tests as needed. A p-value of <0.05 was judged statistically significant. Standard deviations (SD) and confidence intervals (CI) were also used to assess the variability and reliability of the data.

RESULT

The demographic parameters (age, gender, smoking status, and diabetes prevalence) were not substantially different between the groups, ensuring comparability. The conventional composite group had significantly higher mean plaque scores, indicating greater bacterial accumulation and worse dental hygiene than the bioactive materials (Table 1).

Bioactive Glass Restorations demonstrated the greatest reduction in cariogenic bacteria (40%) and an increase in beneficial microbiota. Fluoride-Releasing Composites decreased bacterial load by 25%, but were less effective than bioactive glass. Conventional composites had the greatest pathogenic bacterial burden. The findings indicate that bioactive materials can actively alter the oral microbiome by increasing helpful bacteria while decreasing the prevalence of detrimental species. The antibacterial impact of bioactive glass restorations can be related to their capacity to change the local pH, release antimicrobial ions, and produce an unfavorable habitat for harmful microorganisms (Table 2).

Bioactive glass restorations had the lowest gingival index scores (1.2 ± 0.3), suggesting improved gingival health. Fluoride-releasing composites exhibited intermediate values, but conventional composites had the highest ratings (2.1 ± 0.5), indicating increased inflammation. Bioactive glass had reduced probing depths, while conventional composites had larger pockets (3.5 ± 0.6 mm), resulting in higher sensitivity (35%), and pain (40%). The findings show that bioactive glass restorations promote microbiota diversity and periodontal health outcomes much more than conventional composites. Patients who had bioactive glass restorations had decreased levels of inflammation and bacterial load, resulting in improved periodontal health. Conventional composites, on the other hand, were linked to greater levels of inflammation and pathogenic bacterial growth, resulting in increased pain and sensitivity (Table 3).

DISCUSSION

Table 1: Demographic data

Variable	Bioactive Glass (n=34)	Fluoride-Releasing Composite (n=33)	Conventional Composite (n=29)	p-value
Age (Mean ± SD)	35.2 ± 5.1	34.8 ± 4.9	36.1 ± 5.3	0.720
Gender (M/F)	18/16	17/16	15/14	0.890
Smoking Status (%)	12%	15%	18%	0.670
Diabetes (%)	8%	10%	12%	0.590
Mean Plaque Score	1.5 ± 0.3	1.6 ± 0.4	1.8 ± 0.5	0.040*

*(p< 0.05)

Table 2: Restorative materials and its oral microbiome effect

Restorative Material	Reduction in Cariogenic Bacteria	Increase in Beneficial Microbiota	Pathogenic Bacterial Load	p-value
Bioactive Glass Restorations	40%	Significant Increase	Lowest	<0.01
Fluoride-Releasing Composites	25%	Moderate Increase	Moderate	<0.05
Conventional Composites	Highest	Lowest	Highest	>0.05

Table 3: Restorative materials and its gingival effects

Restorative Material	Gingival Index (Mean ± SD)	Periodontal Probing Depth (mm)	Sensitivity (%)	Discomfort (%)	p-value
Bioactive Glass Restorations	1.2 ± 0.3	2.5 ± 0.4	10%	12%	<0.01
Fluoride-Releasing Composites	1.8 ± 0.4	3.0 ± 0.5	22%	25%	<0.05
Conventional Composites	2.1 ± 0.5	3.5 ± 0.6	35%	40%	>0.05

Calcium, phosphate, and fluoride are among the physiologically active ions released by bioactive glass, which promotes enamel remineralization and inhibits microorganisms. To further prevent demineralization and bacterial colonization, bioactive glass can form a covering on tooth surfaces that resembles hydroxyapatite. By continuously supplying fluoride into the oral environment, fluoride-releasing composites increase bacterial resistance. By inhibiting bacterial metabolism and lowering acid production, fluoride lowers the risk of secondary caries. Its effectiveness, however, depends on constant fluoride release, which diminishes with time[11].

Similar findings on the benefits of bioactive restorative materials were observed in a number of earlier studies. According to Darvell et al. (2022)[12], bioactive glass significantly increased the number of beneficial commensal bacteria in dental plaque while decreasing the amount of Streptococcus mutans. In a randomized clinical investigation, Estrela et al. (2023)[13] found that patients receiving fluoride-releasing restorations had superior periodontal outcomes and a lower incidence of secondary caries than those receiving conventional composite restorations. Par et al. (2021)[14] examined the long-term benefits of bioactive restorations in another study and discovered that they improve gingival healing in addition to inhibiting bacterial adhesion, which eventually lowers gingival inflammation scores. These investigations corroborate our results, showing that bioactive restorations are a superior choice for maintaining oral health compared to conventional composites.

Because of surface characteristics and polymer degradation over time, conventional composites often encourage bacterial adherence and lack antibacterial properties. These substances encourage the growth of germs, raising the possibility of gingival inflammation and eventual decay[15]. The study's conclusions emphasize how crucial it is that physicians take bioactive materials into account when performing restorative procedures. Because bioactive restorations can improve oral microbiota and reduce pathogenic bacterial load, they may be beneficial for patients at high risk for periodontal disease, gingival inflammation, or caries. Future research ought to examine how bioactive restorations affect oral health outcomes over the long run. To fully understand the overall benefits of bioactive materials in clinical practice, more study should look at patient-reported experiences including comfort, sensitivity, and restoration length[16]. One possible strategy to enhance patient outcomes in restorative dentistry is the application of bioactive materials. The field of dental restorations might undergo additional change as research advances and new bioactive formulations with enhanced antibacterial properties are developed.

CONCLUSION

Bioactive materials, particularly bioactive glass, help to balance the oral flora and promote gingival health. While fluoride-releasing composites have certain advantages, traditional composites have been associated to higher bacterial loads and periodontal tissue discomfort. Our findings underscore the need of using bioactive restorative materials into clinical practice to improve oral health outcomes.

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CONFLICT OF INTEREST
Authors declare no conflict of interest.
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AUTHORS' CONTRIBUTION

The following authors have made substantial contributions to the manuscript as under:

Conception or Design:	AU, MZ, ZA, ZR, FA, AE
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All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.