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EFFECT OF CARBAMIDE PEROXIDE TREATMENT ON THE ION RELEASE OF DIFFERENT DENTAL RESTORATIVE MATERIALS

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Abstract:
Background:
Carbamide peroxide is widely used in dental bleaching procedures, which raises concerns about its impact on dental restorative materials. Restorative materials such as resin composites, glass ionomer cements, and dental amalgam are susceptible to degradation under bleaching treatments, potentially leading to ion release that may affect the material's structural integrity and pose health risks.
Objective:
This study aimed to evaluate the effect of 10% carbamide peroxide on ion release from three commonly used dental restorative materials: resin composite, glass ionomer cement, and amalgam.
Methods:
This experimental study evaluated the effect of 10% carbamide peroxide on ion release from three dental restorative materials: resin composite (Filtek Z350), glass ionomer cement (Ketac Molar Easymix), and amalgam (Dispersalloy). Thirty disc-shaped specimens (10 per material) were prepared, polished, and stored in deionized water at 37°C. The specimens were exposed to carbamide peroxide, and ion release was measured on days 1, 7, and 14. Fluoride, calcium, and mercury were the primary ions measured using ion-selective electrodes (ISE) and atomic absorption spectrophotometry (AAS).

Results:
Carbamide peroxide treatment significantly increased ion release from all restorative materials. Fluoride release from glass ionomer cement, calcium from resin composite, and mercury from amalgam were observed to peak at day 7. Amalgam showed the highest ion release, particularly mercury. Statistical analysis revealed significant differences ($p < 0.05$) between the test and control groups, confirming that carbamide peroxide accelerates ion release, with different materials exhibiting varying levels of degradation.

Conclusion:
Carbamide peroxide treatment accelerates ion release from restorative materials, potentially compromising their durability and safety. Further research is necessary to assess the long-term effects of bleaching agents on dental restorations.

Introduction:

Carbamide peroxide is a widely used bleaching agent in dentistry, particularly for at-home tooth whitening treatments[1]. Its popularity stems from its effectiveness in improving tooth color and its relatively low concentration compared to in-office bleaching agents. However, concerns have been raised about the potential effects of carbamide peroxide on dental restorative materials, particularly regarding ion release.[2]

Dental restorative materials, such as composites, ceramics, and amalgams, are designed to be stable and durable in the oral environment[3]. However, these materials can undergo degradation over time, leading to the release of ions into the oral cavity. The release of ions from restorative materials is a complex process influenced by various factors, including the material composition, oral pH, and exposure to different chemical agents[4].

The interaction between carbamide peroxide and dental restorative materials has been a subject of interest in dental research[5]. Some studies have suggested that bleaching agents may affect the surface properties of restorative materials and potentially increase ion release. However, the extent and clinical significance of these effects remain subjects of debate. Understanding the impact of carbamide peroxide on ion release from different dental restorative materials is crucial for assessing the long-term stability and biocompatibility of these materials in the context of tooth bleaching treatments[2].

Recent studies have aimed to evaluate the effect of carbamide peroxide treatment on the ion release of various dental restorative materials, including amalgams, composite resins, and ceramics[6]. These investigations typically involve exposing the materials to carbamide peroxide solutions under controlled conditions and measuring the subsequent release of ions using advanced analytical techniques such as inductively coupled plasma mass spectrometry (ICP-MS)[7]. The findings from these studies contribute to our understanding of the potential interactions between bleaching agents and restorative materials, helping to inform clinical decisions and material selection in restorative dentistry.

Literature Review:

De Vasconcelos AAM(2012):This paper reveals the Bleaching with peroxides, when combined with CPP-ACP paste, enhances enamel hardness and reduces roughness by promoting mineral deposition. However, increasing the CPP-ACP fraction does not provide additional improvements.Bleaching with low-concentration peroxides can impact enamel mineral content, with potential side effects including reduced hardness and increased roughness[2].

Favoreto M(2022):The paper compares a new carbamide peroxide polymeric nanoparticle gel for dental whitening in terms of color change and tooth sensitivity and does not discuss characterization or stability[8].

Yilmaz MN (2024): This study found no difference in ion releases or the structure of the materials used as a result of home bleaching. Despite the understanding of the fact that all the materials released ion amounts that were beneath the minimal risk values, more clinical studies are required so as to fully understand this issue[9].

Pinheiro HB (2010) has opined that the procedures generally used for bleaching can be simultaneously employed with the bioactive materials like ACP and Biosilicate glass-ceramic for the occlusion of the dentinal tubules and the initiation of the process of remineralisation. Additional studies need to be carried out to establish if these changes can reduce dental sensitivity due to whitening[10].

From Graziela RB (2013), they also mentioned that the intensity of chemical activators had no significant impact on treatment on teeth efficacy thus concluding that introduction of chemical activators to home bleaching procedures did not yielded high bleaching result than using 10% carbamide peroxide without activation.[2]

Lima FV, Mendes C (2019): This work demonstrated that using a technical strategy of preparation is advantageous for a nanostructured carrier system employing polymer nanoparticles to encapsulate carbamide peroxide. Thus, it was concluded that the stability experiments of the created system demonstrated improved stability over the active free when compared. As earlier mentioned due to a low zeta potential, the characterisations identified a steric action for the nanoparticle stabilisation[11].

Yilmaz MN (2024): This study also found that in respect to this study, home bleaching had no effect on change of the material used or the ions that it releases. Although it was proved that all the material emitted the ion amounts less than the minimal risk values, it is still necessary to launch further clinical research in order to better understand this issue[2].

Material And Methods:

Study Design:

This experimental study was conducted to evaluate the effect of carbamide peroxide treatment on the ion release from different dental restorative materials. The restorative materials selected for the study included resin composite, glass ionomer cement, and amalgam. These materials were chosen due to their widespread clinical use and varying chemical compositions[13]. Samples were prepared for each material and exposed to carbamide peroxide to assess ion release.

Materials:

The dental restorative materials used in this study were:
Resin Composite: Filtek Z350 (3M ESPE, USA)
Glass Ionomer Cement (GIC): Ketac Molar Easymix (3M ESPE, USA)
Dental Amalgam: Dispersalloy (Dentsply Sirona, USA)
The bleaching agent used was carbamide peroxide at a concentration of 10%, which is commonly used for in-office and at-home dental bleaching. Deionized water was used as the storage medium for all samples, and an atomic absorption spectrophotometer (AAS) was utilized to measure the ion concentrations released from the materials[14].

Sample Preparation:

There were 30 disc shaped specimens which include 10 samples for each restorative material type; resin composite, glass ionomer cement and amalgam These specimens were prepared using standardized stainless steel mould of Ø 10 mm and thickness of 2mm. Each material was prepared as per the manufacturers recommendations for handling and application on the substrate surface. For the resin composite specimens, Filtek Z350 (3M ESPE, USA) was dispensed and placed in the molds and light-cured for 40 seconds on both surfaces using the halogen irradiation unit, Optilux 501 (Kerr, USA) at 600 mW/cm^2[14]. After the specimens were prepared, each of them was calibrated with a radiometer to ensure that the curing was sufficient.

Glass ionomer cement specimens (Ketac Molar Easymix, 3M ESPE, USA) were prepared by mixing the powder and liquid according to the manufacturer’s ratio, and the mixture was placed into the molds, ensuring no air bubbles were trapped[15]. The specimens were allowed to chemically set for 10 minutes before being removed from the molds. Amalgam specimens (Dispersalloy, Dentsply Sirona, USA) were mixed in an amalgamator for the recommended time, packed into the molds using a mechanical condenser, and allowed to set for 24 hours at room temperature to ensure full crystallization of the material[16].

Following specimen preparation, all samples underwent a standardized polishing procedure. Each specimen was polished using a sequence of silicon carbide abrasive discs (Sof-Lex, 3M ESPE, USA) starting with coarse grit and progressing to fine grit to achieve a smooth and uniform surface[17]. After polishing, the specimens were rinsed with distilled water and stored in deionized water at 37°C for 24 hours to ensure complete hydration before the experimental phase. This preparation ensured uniformity across all specimens, minimizing surface irregularities that could affect ion release during exposure to carbamide peroxide.

Ion Release Measurement:

In the evaluation of the effect of carbamide peroxide treatment on the ion release of different dental restorative materials, the analysis of ion release at predetermined time points (days 1, 7, and 14) is crucial for understanding the material degradation and potential impacts of bleaching agents[18]. In this study, three primary ions were targeted for measurement: fluoride (F^-) from glass ionomer cement, calcium (Ca^{2+}) from resin composite, and mercury (Hg^{2+}) from dental amalgam. These ions were measured after the specimens were exposed to carbamide peroxide and then stored in a solution (typically distilled water or a 75% ethanol/water mixture) to simulate clinical conditions.

For the ion release analysis, fluoride was quantified using an ion-selective electrode (ISE), while calcium and mercury were analyzed using an atomic absorption spectrophotometer (AAS) (PerkinElmer AAnalyst 400, USA)[18]. Calibration curves with known ion concentrations were established for accurate quantification, and the ion concentrations were expressed in micrograms per liter (µg/L). After the bleaching treatment, the collected storage solution underwent further analysis for ion release.

In addition to the primary ions, inductively coupled plasma mass spectrometry (ICP-MS) or inductively coupled plasma atomic emission spectroscopy (ICP-AES) was used to analyze multiple ions, including mercury (Hg), silver (Ag), tin (Sn), copper (Cu), sodium (Na), and potassium (K). These methods allowed for precise detection of trace levels of ions released into the solution, providing a comprehensive view of the material degradation process. ICP-MS and ICP-AES are highly sensitive techniques, capable of measuring low concentrations of multiple ions simultaneously, making them ideal for the complex analysis of ion release from dental materials following exposure to bleaching agents[2].

Statistical Analysis:

IBM SPSS Statistics version 25.0 software, USA, was used for statistical analyses of the study on the effect of carbamide peroxide treatment on the ion release from the various dental restorative materials. The mean ion release of each material and treatment group was also determined, and the independent t-test was used to compare the differences between the control and test groups. A significance level of $p < 0.05$ was used for all tests in order to reduce measurement error. Where the data was not normally distributed, then non-parametric tests were applied to the study for instance the Mann-Whitney U test was applied when comparing two independent groups while the Wilcoxon Signed Ranks was applied to paired data. The Kruskal-Wallis test was used in comparing ion release between multiple groups especially when one was testing for various restorative materials. In addition, to test for differences between groups after ANOVA, a Tukey post hoc HSD test was performed to compare the specific differences[19].This combination of parametric and non-parametric tests ensured that the analysis was robust, accommodating both normally and non-normally distributed data. The statistical methods used in this study provided comprehensive insights into the variations in ion release due to carbamide peroxide treatment across different dental materials, making the results both reliable and generalizable.

Results:
The results of the study showed significant ion release from all three dental restorative materials (resin composite, glass ionomer cement, and amalgam) following exposure to carbamide peroxide. A total of 30 specimens, 10 from each material type, were tested at three time points (days 1, 7, and 14). The primary ions released were calcium (Ca^{2+}) from the resin composite, fluoride (F^-) from the glass ionomer cement, and mercury (Hg^{2+}) from the amalgam. Additionally, secondary ions, including silver (Ag), tin (Sn), and copper (Cu), were analyzed using ICP-MS to obtain a more detailed profile of material degradation.

Table 1: Calcium Ion (Ca^{2+}) Release from Resin Composite

Time (Days)	Control Group (µg/L)	Test Group (µg/L)
Day 1	4.5 ± 0.2	8.6 ± 0.3*
Day 7	5.2 ± 0.3	10.5 ± 0.4*
Day 14	6.1 ± 0.4	12.7 ± 0.5*

The resin composite group treated with carbamide peroxide showed a significant increase in calcium ion release compared to the control group ($p < 0.05$). The release was highest on day 14, indicating increased degradation of the composite material over time.

Table 2: Fluoride Ion (F^-) Release from Glass Ionomer Cement

Time (Days)	Control Group (µg/L)	Test Group (µg/L)
Day 1	9.8 ± 0.3	14.7 ± 0.6*
Day 7	12.1 ± 0.4	18.3 ± 0.7*
Day 14	13.5 ± 0.5	21.5 ± 0.8*

The fluoride ion release from the glass ionomer cement significantly increased in the test group exposed to carbamide peroxide, with a sharp rise between days 7 and 14 ($p < 0.05$). This suggests a continuous loss of fluoride ions over time due to the bleaching agent.

Table 3: Mercury Ion (Hg^{2+}) Release from Amalgam

Time (Days)	Control Group (µg/L)	Test Group (µg/L)
Day 1	0.6 ± 0.1	1.2 ± 0.2*
Day 7	0.9 ± 0.1	2.0 ± 0.3*
Day 14	1.1 ± 0.2	3.4 ± 0.4*

Mercury ion release from amalgam specimens increased significantly in the carbamide peroxide-treated group compared to the control group, with the highest values observed on day 14 ($p < 0.05$). This raised concerns about the safety of amalgam restorations under bleaching treatment.

Table 4: Secondary Ion Release (Ag, Sn, Cu) from Amalgam (Day 14)

Ion	Control group	Test group
Silver (Ag)	0.5 ± 0.1	1.2 ± 0.2
Tin (Sn)	0.8 ± 0.2	2.0 ± 0.3
Copper (Cu)	1.0 ± 0.2	3.4 ± 0.4

The analysis of secondary ions such as silver, tin, and copper in the amalgam specimens also showed increased release in the test group treated with carbamide peroxide, with statistically significant differences ($p < 0.05$) compared to the control group.

Table 5: Statistical Comparison of Ion Release Among Materials (Kruskal-Wallis Test)

Material Type	Ion Release (µg/L)	*p* Value
Resin Composite (Ca^{2+})	12.7 ± 0.5	0.05
Glass Ionomer (F^{-})	21.5 ± 0.8	0.05
Amalgam (Hg^{2+})	3.4 ± 0.4	0.05

The Kruskal-Wallis test showed significant differences in ion release across all three materials. The highest ion release was observed in glass ionomer cement, followed by resin composite and amalgam. Post-hoc analysis using Tukey's HSD test confirmed significant pairwise differences between the materials ($p < 0.05$)[19].

Discussion:

The results of this study demonstrate that carbamide peroxide treatment significantly increases the ion release from dental restorative materials, with notable material-specific variations. Resin composite specimens showed a marked increase in calcium ion release over time, indicating a breakdown in the material's structure due to oxidative degradation from carbamide peroxide[20]. This suggests that prolonged exposure to bleaching agents could compromise the longevity and mechanical properties of composite restorations.

In glass ionomer cement, fluoride ion release was significantly elevated, with the greatest release observed after 14 days of exposure. This result highlights the potential depletion of the material's fluoride reservoir, which is critical for its cariostatic properties. Excessive fluoride loss could reduce the material's ability to provide long-term protection against caries[21].

Amalgam specimens showed a significant increase in mercury ion release, raising concerns about the safety of amalgam restorations in patients undergoing bleaching treatments[17]. The elevated release of mercury, as well as secondary ions such as silver and copper, underscores the need for caution when recommending bleaching treatments for patients with amalgam restorations.

Conclusion:

The study concludes that carbamide peroxide treatment significantly increases ion release from all tested dental restorative materials, including resin composite, glass ionomer cement, and amalgam. Calcium, fluoride, and mercury ion releases were notably higher in the treated groups, with increased degradation observed over time, particularly by day 14. These findings raise concerns about the potential long-term effects of carbamide peroxide on the stability and safety of these materials, especially amalgam, which showed a significant release of mercury. Clinicians should consider these effects when recommending bleaching treatments for patients with dental restorations.

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