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Effect of Polishing and Universal Bonding Application on Mercury Release from Aged Amalgam after Exposure to Bleaching Agents

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ABSTRACT

Objectives: Teeth bleaching is an accepted and modern treatment in cosmetic dentistry. Bleaching agents may affect amalgam restorations and increase mercury release; therefore, patients are at increased risk of mercury exposure in the body. The aim of this study was to investigate the effect of polishing and universal bonding application on mercury release from aged amalgams exposed to bleaching.

Materials and Methods: In this in-vitro experimental study, 64 dental amalgam specimens with dimensions of 3×5×10 were prepared and divided into two experimental and control groups. Each group was further divided into 4 subgroups and received one of the following treatments: no intervention, surface bonding, polishing, or polishing and surface bonding. Subsequently, the samples were immersed in bleaching agent containing 7% hydrogen peroxide and the amount of mercury released after 96h was measured. The results were analyzed by two-way ANOVA and Tukey post hoc tests ($\alpha \leq 0.05$).

Results: The results showed that the type of solution ($P<0.05$) and surface treatment ($P<0.001$) significantly affected the level of mercury release. However, there was no significant interaction between surface treatment methods in the bleaching group and those in the phosphate buffer group ($P=0.621$).

Conclusion: Bleaching agents were found to enhance mercury release from dental amalgam. The application of polishing and universal bonding on amalgam surfaces exhibited significant effects on the reduction of the mercury release.

Keywords: Dental Amalgam; Dentin Bonding Agents; Dental Polishing; Mercury; Tooth Bleaching

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INTRODUCTION

Nowadays, in modern dentistry, not only patients want to maintain their healthy and functional teeth, but they are also seeking to have a beautiful smile [1]. The beauty of a smile depends on many things, such as the shape of the teeth, their texture, their alignment, and their color [2]. Therefore, discoloration of teeth is considered a cosmetic problem [3]. Bleaching as a conventional method of treating superficial enamel stains, has become very popular [4]. Although bleaching is a desirable method due to its cosmetic benefits, multiple studies have investigated the release of mercury from dental amalgam during bleaching procedures. These studies consistently indicate that bleaching can trigger the release of mercury from dental amalgam restorations. Therefore, it is essential to exercise caution and attentiveness during bleaching treatments. Thus, bleaching treatment requires care and attention [1-5].

Factors increasing mercury release from dental amalgam include the type of amalgam, and its composition, age of amalgam, unpolished amalgam surfaces, acidic pH [4] and the brand of amalgam [6,7]. Other factors, such as the concentration and composition of the gel, the duration of treatment, also affect the rate of mercury release [8].

Although bleaching gel is routinely used for anterior teeth and sometimes in the area of premolars, the extra amount of gel may accidentally come into contact with amalgam restorations of posterior teeth, thus increasing the susceptibility of amalgam restorations to corrosion, degradation, and release of ions, especially mercury ions. [1] Therefore, the interaction between amalgam and the bleaching agent is a clinically important issue because patients undergoing dental bleaching treatment may also have amalgam restorations [1].

Rotstein et al. [6] studied the protective effect of the Copalite varnish on mercury released from CP-treated dental amalgam. They showed that the release of mercury from amalgam restorations greatly decreased after the application of a commercial varnish like Copalite as a coating. Azarsina et al. [9] investigated the effect of surface polishing on mercury release from dental amalgam, after treatment with a 16% CP gel. The results showed that polished amalgam restorations released less mercury than unpolished restorations after CP treatment.

Due to the problems mentioned above and considering the lack of an organized study in this field, we decided to investigate the effect of using polish and universal bond containing 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) on the amount of mercury release, especially in aged amalgam restorations. The null hypothesis stated that tooth bleaching and different surface treatments have no effects on the amount of mercury release.

MATERIALS AND METHODS

This experimental laboratory study used 64 specimens prepared from Sepehr (Sepehr Felez Negin, Iran) dental amalgam, which is a lathe-cut high-copper amalgam, free from gamma-2 phase and zinc, which contains 45% silver, 30% tin, and 25% copper. Three-spill amalgam capsules were automatically mixed in a dental amalgamator (25136, Farazmehr, Iran) for 30 seconds according to the manufacturer's instructions. They were then condensed using a manual condenser by an operator in Plexiglass molds with dimensions of 10×5×3mm. After the initial setting (60 minutes), the specimens were taken out of the molds and kept in glass test tubes containing saline at room temperature for 24 hours for completion of their setting. After that, they were kept in distilled water in an incubator (01154, Behdad, Iran) at 37 °C for 6 months to be aged. After 6 months, the specimens were taken out of the incubator and dried using cotton rolls. Next, the specimens were randomly divided into two experimental and control groups. Then, each of the two groups was randomly subdivided into four subgroups: a control group with no intervention (N), a group treated with universal bond application (B), a group treated with polish application (P), and a group receiving both methods in combination (PB). Table 1 illustrates the classification and interventions.

In order to bleach the specimens, 7% hydrogen peroxide (Sina Shimi, Iran: equivalent to 20% carbamide peroxide) was used. To polish all surfaces of the specimens, two color rubber polishing cups (green and brown) (SHOFU, Japan) were applied consecutively, at low speed with air-water spray. Each polisher was used for 10 seconds on each surface of the specimens. After polishing, the specimens were washed with distilled water and then dried.

Universal bonding containing 10-MDP (G-Premio bond, GC, Japan) was used for the bonding of the specimens. Bonding was applied using a soft microbrush according to the manufacturer's instructions. First, the bonding material was applied to all surfaces of the specimens using the microbrush. Ten seconds after the bond was applied, maximum air pressure was exerted on the specimens for 5 seconds. Then, the specimens were light cured for 10 seconds (Dr's Light, Korea) at a light intensity of 400 mW/cm^2 and a distance of 1mm and were kept at room temperature for 30 minutes.

The specimens of the experimental groups were placed in test tubes (Yasa Teb, Iran) containing 5ml bleaching agent (7% hydrogen peroxide), while the control specimens were immersed in test tubes containing 5ml of 0.1 molar phosphate buffer with a pH level of 6.5. All samples were immersed in the solutions for a duration of 96 hours before being analyzed to measure the amount of released mercury, which was done using the VAV-440 mercury analyzer system and Perkin Elmer AAnalyst

800 (Perkin Elmer, USA). The chemical reaction in this system was based on the cold vapor atomic absorption (CVAA) technique. The solution was poured into nitric acid and sulfuric acid in the presence of potassium permanganate and potassium persulfate to oxidize all mercury and turn it into mercury ions (Hg^{++}). The excess oxide was then neutralized by hydroxylamine hydrochloride. By adding a stannous chloride solution, the mercury in the solution turned into metallic mercury and the mercury vapor was carried away by a flow of gas from within the absorption cells [6].

The means and standard deviations of the amount of mercury release were calculated for each group. Data were analyzed with two-way ANOVA and Tukey post hoc tests with ambient solution type and surface treatment method as the variables. Statistical significance was set at P<0.05.

RESULTS

Table 1 shows the means and standard deviations of the amount of mercury released in the eight studied groups in µg/ml. A two-way analysis of variance was performed with two main variables: the ambient solution type (hydrogen peroxide and phosphate buffer) and the surface treatment method (applying the universal bond, applying the polish, a combination of the two methods, and no intervention as a control group). The results showed that both the effect of the solution type (P<0.05) and surface treatment on the amount of mercury release (P<0.001) was significant in all groups. The interaction between different surface treatment methods in the bleaching group and different surface treatment methods in the phosphate buffer group was not significant (P=0.621). This means that changes made in both groups are consistent with each other as shown in Figure 1).

Table 1. Means and standard deviations (SDs) of the amount of mercury (ppm) released in the experimental and control groups

Groups	Surface Treatments	Mean(SD)
Phosphate Buffer	No intervention[a]	270.15(47.4)
	Bonding[b]	157.65(15.99)
	Polishing[bc]	110.24(43.71)
	Polishing and bonding[c]	80.94(82.63)
Bleaching	No intervention[A]	270.1(38.33)
	Bonding[B]	222.75(70.84)
	Polishing[BC]	171.4(4.96)
	Polishing and bonding[C]	144.15(80.65)

Mean values with different letters are significantly different (P<0.05). Lower case letters compare among Phosphate Buffer groups, Upper case letters compare among Bleaching groups.

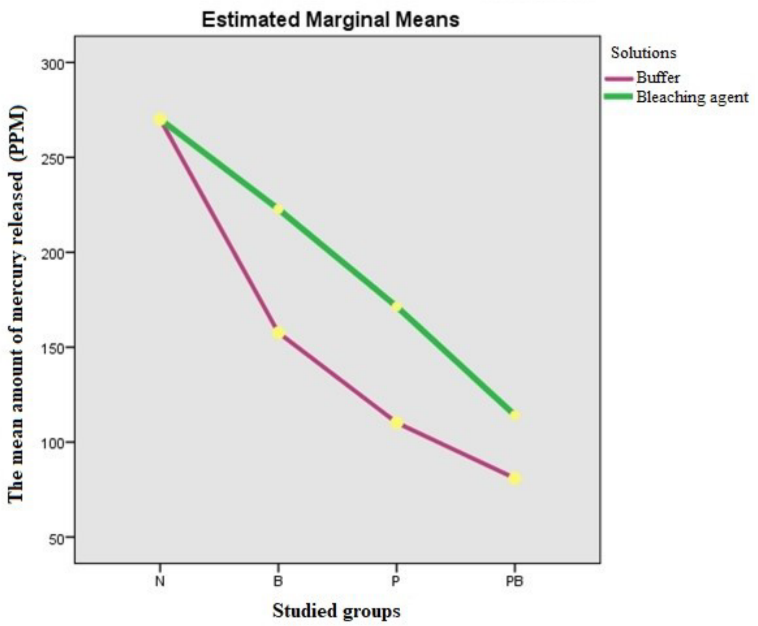

Fig. 1. Means of the amount of mercury released in different experimental and control groups

Tukey's complementary test was used to assess which surface treatment methods are significantly different from each other. Compared to the control group (no intervention), the amount of mercury release significantly decreased in bonding (P=0.037), polishing (P<0.001) and combined polishing and bonding (P<0/001) groups. The combined method (PB) demonstrated a significantly greater reduction in mercury release compared to solely applying the bonding method (P=0.013). However, there was no significant difference between the combined method and the polishing group (P=0.413). Additionally, there were no significant differences between the polishing and bonding groups (P=0.301).

DISCUSSION

In this study, the effects of polishing and universal bonding application on mercury release from aged amalgam after exposure to bleaching agents were evaluated. Based on the results, tooth bleaching (P<0.05) and different surface treatments (P<0.001) have significant effects on the amount of mercury release, so the null hypotheses were rejected.

We showed that bleaching increased the release of mercury from dental amalgams, which is consistent with previous studies [5,6,10,11]. Bleaching agents contain OH^- as a free radical [12], known for its strong oxidizing properties. This radical can induce changes in the metal components of amalgam, potentially exposing the oral environment to the silver-mercury matrix, known to be a significant source of mercury [13]. We also demonstrated that using a universal bond containing 10-MDP, as a layer coating amalgam surfaces, reduced the release of mercury.10-MDP (10-methacryloyloxydecyl dihydrogen phosphate), a component of the universal bond, is an active phosphate monomer that chemically bonds to non-noble metals, a type of which is amalgam [14].

In terms of the corrosion protection mechanism of metals, coatings with relatively low wettability may effectively hinder water from covering the substrate surface, thus demonstrating exceptional resistance to corrosion in moist environments [15]. Application of universal bonding can act as a protective bonded layer against corrosion. According to a study conducted by Rotstein et al, [6] coating the outer surfaces of the amalgam with Copalite reduces the amount of mercury released from an amalgam, which has been exposed to various concentrations of carbamide peroxide. Copalite appropriately bonds to the surfaces of teeth and amalgams, and it can be used as a protective barrier during bleaching sessions without considerable changes or damage [6]. In that study, the amount of mercury released in non-coated specimens was 90 times greater than coated specimens [6]. The difference between this study and the current investigation is that the universal bond contains 10-MDP and that in addition to covering the surface of the amalgam, it forms a chemical bond with it, which makes this coating durable in the long run [14]. However, the durability of the bonding layer in the period of bleaching treatment is important for us, and as the results show, applying a universal bond containing 10-MDP reduces the release of mercury from amalgam. We can conclude that in 96 hours (equivalent to 12 days), the bonding layr was durable; however, further studies are necessary to investigating the actual duration of durability.

Lyttle and Bowden [16] reported that using an inactive layer of tarnish for coating, reduces the release of mercury from amalgam, and Mahler det al [17] stated that application of a liquid film as a coating can decrease mercury release from this metal [17]. The results of a study carried out by Steinberg [18] showed that when using bleaching materials, the mercury released from an amalgam, which was coated with a biofilm, was less than that released from the uncoated amalgams. This phenomenon is influenced by two mechanisms: firstly, the biofilm acts as a barrier, inhibiting the penetration of substances like bleaching agents. Secondly, the biofilm impedes the escape of mercury from the surfaces of the amalgam, preventing its release into the surrounding environment.

The present study showed that polishing the surface of amalgam reduced the release of mercury. Kasraei et al. [8] found that finishing and polishing the external surfaces of amalgams are significantly effective in reducing mercury release when exposed to bleaching agents, which is consistent with the results reported by Rotstein et al. [11] and other studies [9,19]. Different factors have effects on the wettability, chemistry of surface for instance (as bonding agent applied on surface in this study), however, it seems that the roughness has the major role in changing the wetting behavior. Literature shows that rougher surface may increase the hydrophobicity by creating many pillars on the surface; and this prevents liquids from wetting the surface [20]. Therefore, despite the result we obtained, it seems that unpolished amalgam with more hydrophobic surface exhibits corrosion resistance, but corrosion mechanism is more complex. From another point of view, the higher number of locally limited defects in the unpolished amalgam lead to pitting corrosion that generally occurs in high rates [21], confirming our result saying that unpolished amalgam corroded more [21]. Moreover, unpolished amalgam possesses a larger surface area compared to polished surfaces, potentially resulting in higher levels of mercury release [11].

In this study, the effect of Hydrogen peroxide on the amount of mercury release was investigated. Hydrogen peroxide (H_2O_2) serves as a strong oxidizer, and produces reactive oxygen molecules and hydroxyl radical [22] that results in the enrichment of hydroxyl ions with negative charges at the amalgam surface. Therefore, oxygen can accelerate the reaction of cathodic corrosion [23]. The rate of mercury release in the corrosion process initially depends on the extent of corrosion (based on bleaching agent type) but is ultimately regulated by the concentration difference with the surrounding environment [24].

According to the results obtained in the present study, the combined method (PB) had a larger effect on the decrease of mercury release compared to when the bonding method was used alone, but there was no significant difference with the polishing group. In other words, the effect of polishing is sufficient by itself. Possibly, this phenomenon arises due to the chemistry involved in the corrosion process of amalgam. Scanning electron microscopy and X-ray analysis conducted by Ferracane et al. [25] revealed a higher concentration of the gamma 1 phase (mercury-silver) at the surface of unpolished amalgam compared to polished amalgam. This phase is a significant source of mercury release. by Rotstein et al. [5] and Gurgan et al. [26], various brands of amalgam, each with distinct compositions, were analyzed for mercury release when exposed to bleaching agents. These studies revealed that mercury release varied among different brands of amalgam. Each brand exhibited unique physical, mechanical, and corrosive characteristics [27]. Among dental amalgams, tin and copper are recognized for their strong anti-corrosive properties. The presence of a thin oxide layer effectively impedes corrosion in the tin-containing phase [28].

The World Health Organization (WHO) guidelines for maximum intake of mercury is 40μg/day [29]. In the present study the maximum average amount of mercury release in 96 hours (12 days) was approximately 270 ppm, that is 22.5 μg/day from 190mm2 surface area of the amalgam specimen. Based on these data average mercury release from a typical restoration (5mm×5mm approximately) will be 2.96μg/day at 7% HP concentrations equivalent to 20% CP that is lower than the permissible limit. It appears that uncoated amalgam, representing the control group, releases significantly lower amounts of mercury according to WHO guidelines during the bleaching process. While interventions such as polishing or applying a bonding layer effectively reduce mercury release in in-vitro studies, their clinical significance may be limited, potentially resulting in increased chair time without substantial benefit.

Comparing oral conditions with laboratory settings is challenging because the laboratory lacks factors like salivary clearance, biofilm presence, and pH fluctuations, all of which influence the oxide layer in the oral environment. Saliva, functioning as an electrolyte, can facilitate mercury release due to its involvement in the galvanizing process. Therefore, additional research on the impact of bleaching on various brands of amalgam, particularly under in vivo conditions, is warranted.

CONCLUSION

Bleaching increases the release of mercury from amalgam. Using different surface treatments, polishing and applying a universal bond containing 10-MDP, alone or in combination with each other, reduces the release of mercury from this filling material.

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