How Do Different Physical Stressors’ Affect the Mercury Release from Dental Amalgam Fillings and Microleakage? A Systematic Review

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ABSTRACT

Background: Approximately 50% of dental amalgam is elemental mercury by weight. Accumulating body of evidence now shows that not only static magnetic fields (SMF) but both ionizing and non-ionizing electromagnetic radiations can increase the rate of mercury release from dental amalgam fillings. Iranian scientists firstly addressed this issue in 2008 but more than 10 years later, it became viral worldwide.

Objective: This review was aimed at evaluating available data on the magnitude of the effects of different physical stressors (excluding chewing and brushing) on the release of toxic mercury from dental amalgam fillings and microleakage.

Material and Methods: The papers reviewed in this study were searched from PubMed, Google Scholar, and Scopus (up to 1 December 2019). The keywords were identified from our initial research matching them with those existing on the database of Medical Subject Headings (MeSH). The non-English papers and other types of articles were not included in this review.

Results: Our review shows that exposure to static magnetic fields (SMF) such as those generated by MRI, electromagnetic fields (EMF) such as those produced by mobile phones; ionizing electromagnetic radiations such as X-rays and non-ionizing electromagnetic radiation such as lasers and light cure devices can significantly increase the release of mercury from dental amalgam restorations and/or cause microleakage.

Conclusion: The results of this review show that a wide variety of physical stressors ranging from non-ionizing electromagnetic fields to ionizing radiations can significantly accelerate the release of mercury from amalgam and cause microleakage.

Keywords
Amalgam; Mercury; Magnetic Resonance Imaging; Microleakage; Radiation; Electromagnetic; Radiofrequency

Introduction

Despite the wide application of mercury in industry and medicine, it has known toxic effects. Methylmercury (MeHg), mercury vapor (Hg\textsuperscript{0}), and ethylmercury (EtHg) are the three main forms of mercury which are the origin of concerns to human populations non-occupationally exposed to this toxic element [1]. Scientists’ effort for increasing human knowledge about the risks linked to mercury exposure is complicated due to its variable environmental fate as well as the key role of environmental, biological, and socioeconomic factors [2]. Substantial data suggests that mercury causes a wide variety of physiologi-
cal and adverse health effects ranging from bioaccumulation in the central nervous system (CNS), liver and kidney as its major targets to promoting carcinogenesis, immunotoxicity, kidney damage that leads to nephrotoxicity, declined neurological capacity, and neurobehavioral function, changed the functioning of 3 main endocrine axes, and impaired reproduction quality and altered offspring quality [3-24]. Due to the ability of inhaled mercury vapor which can cross the blood-brain barrier, it can cause serious damage to the CNS [11].

Today, exposure of humans to mercury is a major public health concern. These exposures can be due to a wide variety of sources ranging from industrial processes, occupational and household uses of mercury, mercury-containing vaccines, dental amalgams, and consumption of fish [25]. The problems can be appeared differently over 250 symptoms in the clinical picture, involving many systems other than the immune system (e.g. neurological, renal, respiratory, gastrointestinal, cardiovascular, hepatic, and reproductive), along with fetotoxicity and genotoxicity [25, 26].

Among the humans, children are believed to have a greater risk of developing detrimental neurological effects of mercury. The case of a 3-month-old infant reported in a study demonstrated that Hg causes poisoning and finally, it developed pneumothorax and respiratory failure. These kinds of cases highlight that Hg exposure should be considered as a crucial issue [27].

Hg vapor inhalation is the major route of contamination and dental amalgam fillings (~ 50% Hg), are also a significant source of mercury in general population [25].

Several studies have reported that magnetic resonance imaging (MRI) [28], chewing and brushing in an artificial mouth [29], Nd:YAG laser pulse energy [30], radiofrequency radiation sources including Wi-Fi routers, smartphones, light-curing tools [31] and also X-rays [32] might change the rate of evaporation of mercury from amalgam fillings. Iranian scientists firstly addressed this issue in 2008 [33] but more than 10 years later, it became viral worldwide [34].

In a study, the authors investigated the urinary mercury from dental amalgam fillings in MRI-exposed and control groups and reported a significant difference between these groups [28]. Moreover, in another study, electromagnetic radiation from Wi-Fi routers and mobile phones could increase the concentration of mercury released from amalgam restorations [31]. Furthermore, the level of mercury vapor release was significantly linked to the pulse energy of Nd:YAG laser [30]. Recently, it has been suggested that exposure of women with dental amalgam fillings to electromagnetic fields may increase the risk of autism due to higher release of mercury from dental amalgam [35]. A literature review shows that over the past years many publications have been reported to be adversely affected by the key shortcoming of ignoring the role of static magnetic fields or electromagnetic radiation in accelerating the release of mercury from amalgam and microleakage [36-38]. In the current study, the main purpose is to review physical stressor impact on mercury release and amalgam microleakage.

Material and Methods
This study was performed as a systematic review. Figure 1 briefly illustrates the process of data collection and analysis.

Search strategy
The papers reviewed in this study were searched from PubMed, Google Scholar, and Scopus (up to 1 December 2019). The keywords were identified from our initial research matching them with those existing on the database of Medical Subject Headings (MeSH) managing by the US National Library of Medicine. Furthermore, to improve the quality of searches, we got helped by an expert who worked in the Medical Branch libraries. The search strings were selected MeSH, title, ab-
Abstract, and keywords based on “amalgam” or “microleakage” or “mercury release” or “electromagnetic field”.

Inclusion and exclusion criteria
The original articles were chosen based on inclusion criteria, by contrast, the non-English papers, and any types of articles related to the review papers, letters, etc. were considered as exclusion criteria.

Selection process
At the first stage, the papers were screened by a reviewer in the point of titles and abstracts views and then they were classified into three sets completely; the first step was included the papers with certain inclusion criteria, the second one has contained the papers without the clear inclusion criteria from reviewers, and the third one, set referred to the papers with no inclusion criteria which were not appropriate and then excluded from the screening.

Data extraction
Four variables for responding to the research questions were extracted in this phase contained mercury release, amalgam microleakage, electromagnetic fields, and radiofrequency wave.

Results
The data extracted from the 13 articles reviewed are shown in Table 1. The fourth variables of the selected papers are represented in the Table 1. As presented in the fourth column of the Table 1, a wide variety of physical stressors were studied. Our review shows that exposure to:
1. Static magnetic fields (SMF) such as MRI
2. Electromagnetic fields (EMF) such as mobile phones
3. Ionizing Electromagnetic Radiation such as X-rays
4. Non-Ionizing Electromagnetic Radiation such as lasers, and light cure devices can significantly increase the mercury release from amalgam fillings and/or cause microleakage.

Mercury release or amalgam microleakage applies in physical stressors study
As shown in the fifth column of Table 1, mercury release and amalgam microleakage have been applied in physical stressors. The fifth and sixth columns of the Table 1 demonstrate the method of various studies and the effects of different physical stressors on mercury release and amalgam microleakage, respectively.

Discussion
Currently it seems unlikely that dental amalgams can lead to health problems in majority large proportion of humans. However, specific groups such as pregnant women, children, elderly people and hypersensitive individuals.
| Study | Method | Physical Stressor | End Point | Outcome summary |
|-------|--------|------------------|-----------|-----------------|
| 1     | Mortazavi et al. 2016 [44] | Dental amalgam microleakage | MRI | Using extracted molars, various groups exposed to microleakage was higher in the gingival region compared to occlusal region in all groups. The strength of the magnetic field depended on the magnetic field strength of the magnetic field. |
| 2     | Yilmaz et al. 2018 [40] | Mercury release from dental amalgam | MRI | Extracted caries-free molar or premolar teeth were exposed to 1.5 or 0.7 T MRI. While mercury released from teeth exposed to 0.7 T MRI was 1.5 or 0.7 T MRI. The mercury released from teeth exposed to 0.7 T MRI was higher. |
| 3     | Hosseini et al. 2018 [41] | Mercury release from dental amalgam | Wi-Fi and X-Ray radiation | Numerical analysis of the technologically induced | |
| 4     | Paknahad et al. 2016 [42] | Mercury release from dental amalgam | Radiofrequency radiation from Wi-Fi devices | Non-carious extracted human premolars were exposed to Wi-Fi. Conventional Wi-Fi routers could increase the release of mercury from mercury levels. |
| 5     | Mortazavi et al. 2016 [43] | Dental amalgam microleakage | Radiofrequency electromagnetic fields | Investigation of the mechanisms behind the accelerated microleakage of amalgam after exposure to electromagnetic radiation. Multiple reflections of the radiofrequency radiation on the inner walls of the tiny spaces between amalgam and teeth and their interferences on the interproximal surfaces of the restorative materials. |
| Study | Physical Stressor | End Point | Method | Outcome Summary |
|-------|------------------|-----------|--------|----------------|
| 7     | X-rays and MRI   | Mercury Release | X-rays of MRI on a loss-equivalent material. Amalgam capsules were modeled into discs. The samples were exposed to increased release of mercury was observed. |
| 8     | MRI              | Mercury Release | MRI | No difference found in surface microroughness between MRI and control samples. |
| 9     | MRI              | General amalgam release from the MRI | MRI, ND:YAG laser | Surface of amalgam for 4 seconds. Amalgam samples in sealed containers were exposed to ND:YAG laser. |
| 10    | MRI              | Mercury Release | MRI, 209 MHz, Raman spectroscopy | Increased microroughness was observed in MRI and mobile phone radiation could not lead to release in microroughness. The enhancement of the diffusion process and the thermo-electromagnetic convection caused increased microroughness. |
| 11    | MRI              | Mercury Release | MRI | Increased micro-leakage was reported in MRI-exposed teeth. The authors believed that thermo-electromagnetic convection caused increased micro-leakage. |
| 12    | MRI              | Mercury Release | MRI and low-field following mobile phone | Stimulated saliva samples from 30 patients were collected just before and after 0.23-T MRI. Thirty patients were investigated. In the second phase of the study, eighteen female healthy university students who had not used mobile phones before the study and did not have any previous amalgam restoration were measured. The authors believed that both MRI and mobile phone radiation could increase the mercury release from dental amalgam. |
| 13    | MRI              | Mercury Release | MRI | Increased release of mercury was observed in X-ray group; while no change was seen in MRI group. No difference was found in surface microroughness between MRI and control samples. |
| 14    | MRI              | Mercury Release | MRI | Mercury release from dental amalgam increased by microwave radiation. |
may be in risk [33]. Figure 2, shows studies conducted to date that indicate exposure to different physical stressors can lead to accelerated mercury release from amalgam and microleakage. According to several articles were mentioned in this study, magnetic resonance field has an increasing effect on mercury release. However, the study conducted by Muller-Miny et al., failed to show significant increase in mercury release after MRI [48]. Kursun et al., reported that magnetic resonance field (1.5 T) did not change the level of mercury release from dental amalgam [32]. Akgun et al., reported no statistically significant differences in microleakage in groups with or without exposure to MRI [45]. Exposure to pulsed electromagnetic fields (PEMF) exposure generated by Helmholtz coil, as reported by Mortazavi et al., could not increase the microleakage of amalgam restorations. However, in their experiments, X-ray exposure significantly increased the microleakage of amalgam. In their study, intraoral radiography increased microleakage of amalgam fillings [49]. Amalgam microleakage was not significantly different in the light cure-exposed group or those exposed to mobile phone radiation with that of the control group [44]. Akgun et al., reported that MRI cannot change the microleakage of bonded or nonbonded amalgam fillings [45]. Moreover, laser beams (Nd:YAG) with the pulse energies of 50, 150, and 250 mJ increased the mercury vapor release, that was dependent on the Nd:YAG laser pulse energy [30]. However, Pioch et al., showed that CO₂ laser, no signs of amalgam ablation or mercury vapor release were observed [50]. In Figure 3 a possible mechanism that can be involved in accelerated microleakage of amalgam after exposure to radiofrequency radiation is demonstrated.

Mortazavi et al., have previously introduced “Triple M effect”. According to Triple M” effect, in hot spots, increased amalgam microleakage after exposure to radiofrequency electromagnetic fields increases the temperature in saliva-filled tiny spaces between amalgam fillings and teeth. Reflection of radiofrequency

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**Figure 2:** Studies conducted so far show that a wide variety of physical stressors can induce the accelerated release of mercury from dental amalgam fillings and microleakage.
radiation on the inner walls of these tiny spaces, and their interferences produce specific “hot spots” in these areas. High temperature and fast expansion of the bubbles is responsible for accelerated microleakage of amalgam. Appropriate experiments are needed to verify the validity of this theory [43].

**Hypersensitive People and Pregnant Women Issues**

Although what we know about mechanisms of hypersensitivity to the damaging effects of mercury is very limited, genetic factors can be involved in this phenomenon [51]. Studies conducted so far reveals that a proportion of any population may show hypersensitivity to mercury. Besides hypersensitive people, children and pregnant women with dental amalgam fillings require special attention. Regarding the pregnant women, it’s worth noting that the strong link between maternal and cord blood mercury levels are reported previously. Thus, in order to decrease the toxic effects of mercury in their fetuses, pregnant women with amalgam restorations are requested to limit their exposures (both exposure time and exposure intensity) to electromagnetic radiation.

**Conclusion**

In this paper, we systematically reviewed the physical stressor impact on mercury release and amalgam microleakage. The results of this investigation show that physical stressors such as Electromagnetic fields, MRI and laser, just to name a few, have an effect on mercury release and amalgam microleakage. Furthermore, it shows a new view in providing protections against mercury release and amalgam microleakage.

**Authors’ Contribution**

G. Mortazavi and M. Keshavarz conceived the idea. The first draft was written by all authors. The final manuscript was revised by G. Mortazavi. All the authors read, and approved the final version of the manuscript.

**Conflict of Interest**

None

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