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A SYSTEMATIC REVIEW ON MERCURY TOXICITY FROM DENTAL AMALGAM FILLINGS AND ITS MANAGEMENT STRATEGIES

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Abstract

Dental amalgam fillings containing approximately 50% mercury have been used for almost 200 years and have been controversial for almost the same time. Allegations of effects caused by amalgams have involved many diseases. Amalgam is one of the most popular dental restoratives, but concerns exist over its safety because of the mercury in its formulation. Small amounts of mercury are released from dental amalgam by vaporization and dissolution. More serious actions to drastically reduce mercury sources by employing alternative energy sources, restricting mercury trade and banning various mercury containing consumer products, such as dental amalgam are as essential as cleaning up the historical deposits of mercury in the basin. A strong political will and mass momentum are crucial for efficient mercury management. Recent evidence that small amounts of mercury are continuously released from amalgam fillings has fuelled the controversy. The purpose of this article is to create awareness among the people handling mercury so that better strategies can be developed to manage this hazardous waste and to protect the society from toxic effects of mercury.

Keywords: Mercury toxicity, Dental amalgam, adverse effect, Hazardous waste

Introduction

Mercury combines readily with other metals to form solid amalgams, which have been used continuously in dentistry for nearly 200 years to reconstruct decayed teeth. Use of Mercury in dentistry has generated certain amount of controversy, since the middle of the 19th Century. This controversy has gained momentum over the last 25 years, since sensitive analytical chemical techniques showed continuous release of mercury from dental amalgams.[1] It is known from animal studies that mercury vapors are emitted

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continuously from dental amalgam and are absorbed and accumulated in tissues and organs.[2-8]

Humans with amalgam fillings have significantly elevated mercury levels in blood,[9-13] and about 3 ± 5 times more mercury in urine [9-11, 13]; 2 to 12 times more mercury in their body tissues[14-19] than individuals without dental amalgam. Blood and urine concentrations are not necessarily indicative of mercury load in body tissues.[17]

Amalgams fillings currently comprise about 50% Mercury, with the remainder principally Silver, plus small amounts of Copper, Tin, or Zinc. Although other filling materials are available, popularity of amalgam is maintained by its relative cheapness, durability, and ease of use.[18] In many countries amalgam is still the most commonly used filling material in posterior teeth.[19] Dental personnel potentially can be exposed to mercury through direct skin contact with mercury (or freshly mixed dental amalgam) or through exposure to the following potential sources of mercury vapors: accidental mercury spills, malfunctioning amalgamators, leaky amalgam capsules or malfunctioning bulk mercury dispensers (although the American Dental Association recommends against the use of bulk elemental mercury); trituration, placement and condensation of amalgam; polishing or removal of the amalgam; vaporization of mercury from contaminated instruments; and open storage of the amalgam scrap or used capsules.[20]

Amalgam fillings release mercury vapor continuously at low levels. The release rate is dependent on filling size, tooth and surface placement, chewing, food texture, tooth grinding, and brushing teeth, as well as the surface area, composition, and age of the amalgam. Correlations have been demonstrated between the number of amalgams and expired breath[21] and urinary mercury concentrations.[22] Subjects with amalgam fillings have more mercury in saliva and feces.[23] The number of amalgam surfaces is correlated with the mercury content of brain and kidney tissue at autopsy. Inorganic mercury primarily affects the nervous and renal systems, although it may also have effects on the immune, respiratory, cardiovascular, gastrointestinal, hematologic, and reproductive systems. These toxic effects may be mediated by binding of mercury to sulfhydryl groups of enzymes.[24]

There are 269 Dental Colleges[25] and 80,000 Dental Clinics[26] functioning in India where mercury is routinely used for various dental procedures but there is general lack of awareness about its ill effects on human health among people. Very little information is available currently on the measures adopted at various dental colleges and clinics countrywide in India, to reduce and prevent mercury burden. The purpose of this systematic review is to sensitize the people handling mercury during dental procedures, and to initiate the process of chalking out strategies to manage this hazardous waste. Relevant studies published between 1992 and 2011were reviewed in this paper.

Mercury Generation Potential

Mercury and its compounds are everywhere in our environment. Between 2,700 and 6,000 tons of mercury are released annually from the oceans and the earth's crust into

the atmosphere. Another 2,000 to 3,000 tons are released from human activities, primarily burning household and the industrial waste and especially from burning fossil fuels, such as coal.[27] The Asian countries contributed about 54 percent to the global mercury emission from anthropogenic sources in 2000, followed by Africa (18 percent) and Europe, including the European part of Russia (11 percent).[28] Among the various regions Asia has become the largest contributor of anthropogenic atmospheric mercury, responsible for over half of global emission.[29]

Mercury waste materials are also generated during various dental procedures. With so many dental colleges and institutions functioning in India, estimating the quantity of mercury waste generation and its proper disposal is problematic. Several studies that have been carried out in various countries, like Dental Waste Water (DWW) stream study conducted by the University of Illinois at Chicago (UIC) and the Naval Dental Research Institute (NDRI), revealed that on an average dental clinic can generate up to 4.5 g Hg/day/chair. In addition, a Danish study reported an estimate for dental discharges of 100-200 g of mercury per year per dental office. Recent study estimated that 4000 kg/yr of mercury was generated from dental offices, and 1000 kg/yr of mercury flowed into the waste water of the region. [30] Obenauf and Skavroneck, in a report entitled Mercury Source Sector Assessment for the Greater Milwaukee Area, indicated that 60 % by weight of mercury from dental offices ended up in waste water.[31] The municipality of metropolitan Seattle investigated the mercury content of the waste water generated from dental clinics and estimated that the 1650 dental offices in its service region have the potential to contribute up to 14 % of the total mercury load to the local waste water treatment facilities.[32]

Mercury Toxicity

Studies on dentist have suggested adverse effects at air concentrations lower than 50µg Hg /m^3. Average air concentrations as low as 14 µg Hg/m3, were associated with decreased performance on psychomotor tests. Changes in the mood and behavior have also been noted, such as emotional liability, somatosensory irritation, and alterations in mood scores. The major toxic effects of methyl mercury are on the central nervous system. Paresthesia, numbness or a “pins and needles” sensation is the first symptom to appear at the lowest dose. This may progress to cerebellar ataxia, dysarthria, constriction of the visual fields, and loss of hearing.[19]

As a vapor, metallic mercury can be inhaled and absorbed through the alveoli in the lungs at 80 % efficiency. This is clearly the major route of entry into the human body. Metallic mercury is poorly absorbed through the skin or the gastrointestinal tract.[34] The acute toxicity by mercury vapor appears to occur in three phases. The initial phase is characterized by flulike symptoms lasting 1-3 days. The intermediate phase is dominated by signs and symptoms of severe pulmonary toxicity. The victim in final phase will experience gingivostomatitis, tremor, and erethism (memory loss, emotional liability, depression, insomnia, and shyness).[19]

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For many years, dental amalgam has been used successfully. The possibility of adverse health effects from exposure to mercury from dental amalgam has kindled concern among some members of the public and issue has also been debated in the scientific community. Although mercury vapor is released from dental amalgam, the quantities are very small and do not cause verifiable adverse effects on human beings.[35] Mercury blood levels that were measured in one study indicated that the average level in patients with amalgam was 0.7 ng/ml compared with a value of 0.3 ng/ml for subjects with no amalgam.[36] The research literature, involving many retrospective studies, has shown the safety of dental amalgam. In fact, The World Health Organization /Federation Dentaire International issued a consensus statement in 1995 that dental amalgam has not been shown to have an adverse health effect. This same report, however, did emphasize that the mercury should be an environmental concern, both within the dental office and when disposing of amalgam waste.[37]

Mercury Waste Management

- Train all personnel involved in the handling of mercury and dental amalgam regarding the potential hazards of mercury vapor and the necessity of observing good mercury hygiene practices. Remove professional clothing before leaving the work place.

- Work in well ventilated work areas, with fresh air exchanges and outside exhaust. If the work areas are air conditioned, the air conditioning filters should be replaced periodically. Use of proper work area design to facilitate spill containment and clean up. Floor coverings should be non absorbent, seamless and easy to clean.

- Periodically check the dental operatory atmosphere for mercury vapor. This may be done using dosimeter badges and through the use of mercury vapor analyzer for rapid assessment after any mercury or clean up procedure. [20]

- During the intraoral placement and condensation procedures some mercury vapor is released. To control the vapor, a rubber dam can be used to isolate the patient and high-volume evacuation should be used to prevent intraoral vapor from diffusing.

- Scrap amalgam from condensation procedures should be collected and stored under water, glycerin, or spent x-ray fixer in a tightly capped jar. The jar should be nearly filled with liquid to minimize the gas space where mercury vapor can collect. No more than a small jar of material should be present in the office at any time.

- Waste amalgam particles are generated during the placement and removal of amalgam restorations in the dental office. Some of these particles end up in

dental office waste water. Source control, which is the elimination of mercury from the waste water entering sewage treatment plants, is the method being promoted by the Environmental Protection Agency (EPA) USA and other sewage treatment agencies, for the reduction of mercury discharged into the surrounding aquatic and natural environment. In certain parts of the US, most notably states in New England, in the Great Lakes region and on the West Coast, dental offices are being asked to practice source reduction to decrease the amount of amalgam discharged into the waste water. Source reduction can vary from best management practices, including the proper disposal of chair side traps and vacuum filter traps, to the voluntary installation of the amalgam separators.[38]

- Amalgam separators are evaluated using the ISO Standard 11143. One focus of ISO Standard 11143, is to assess the removal efficiencies of these treatment devices in terms of their potential to reduce the number of amalgam particles entering the sewer system. To pass the above standard, the efficiency of the amalgam separator is required to be at least 95% (mass fraction) removal of particles.[32] However, ISO Standard 11143 has certain limitations like failure to determine the finest amalgam fraction which can result in largest pollution risk. Amalgam separators use one or multiple technologies to remove amalgam from dental office waste water. These technologies include sedimentation, filtration, centrifugation and ion exchange. Sedimentation technology is used in majority of amalgam separators, sometimes in conjunction with filtration and ion exchange.[40]

- Discarding capsules in municipal-solid-waste landfills is not ideal and could, in some cases violate state solid-waste discharge statutes, since some states regulate all generators of hazardous waste, even from Conditionally Exempt Small Quantity Generators (CESQGs). Incineration of used amalgam capsules must be avoided to prevent volatilization of Hg to the atmosphere. Recovery of heavy metals through the recycling processes is environmentally more responsible than disposal in landfills where the potential exist for metals to leach into the ground water. The reclaimed metals can be reused in the manufacturing of dental amalgam.[41] The ADA strongly recommends recycling as a best management practice for dental offices.[42]

- Excess mercury can also be disposed off in safe depositories instead of recycling depending upon the facility and finance available.

- The U.S. Environmental Protection Agency (EPA) and other federal agencies together with state, tribal and local governments have worked over the past two decades to reduce man-made mercury releases into the environment. These efforts are expected to substantially reduce risk to the U.S. population from exposure to mercury. EPA is developing its own goals and activities for reducing mercury pollution and exposure, but the agency is aware that the issues around mercury are complex and it must work with programs in other federal agencies that address the mercury problem. EPA scientists are also aware that mercury

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pollution is global and needs to be addressed internationally. Because, the global circulation of atmospheric mercury is an important component of the deposition and distribution of mercury in any given region, awareness of developing policy at larger levels than a specific region is an important component of mercury management.[43]

Discussion

Many hundreds of millions of people worldwide have teeth containing mercury amalgam fillings. Although the use of these fillings has been decreasing, it was estimated that, in 1990, nearly 100 million amalgam fillings were inserted in teeth in the United States (Department of Health and Human Services, 1993).[44] This represents approximately 75–100 tons of mercury placed in people's mouths [45, 19] has characterized dental amalgam as one of "the three modern faces of mercury". The other two are methyl mercury in fish and ethyl mercury as a preservative in vaccines.

Recently,[46-48] compared two groups exposed to amalgam (all female, one group of patients who claimed to be suffering from symptoms they related to their amalgam fillings and the other group, which did not report any association between complaints and their fillings) in terms of mercury levels in body fluids and psychometric tests. The mean number of amalgam fillings was identical in both groups.

Gottwald *et al*. (2001) concluded that how patients feel impaired by their amalgam fillings does not depend on the exposure to mercury.[47] It is unclear as to why authors came to such a conclusion. A fundamental question should arise: Why do some individuals suffer from amalgam exposure while others don't. In contrast to Bailer *et al*. (2001), Gottwald *et al*. (2001) and Zimmer *et al*. (2002) ,other research groups have offered a partial answer to these question.[46-48] They found that patients suffering from symptoms like fatigue, irritability, mood, poor concentration, headaches and insomnia due to their amalgam fillings exhibit significantly more frequently the presence of the Apolipoprotein E4-allelethan healthy controls.[49] It is known that the presence of this allele is a major risk factor for developing Alzheimer's disease.[50,51] It is not known why, but a possible link could be the fact that Apo-E-4 has reduced detoxifying abilities due to the lack of thiol-groups. In contrast Apo-E-2 and Apo-E-3 can bind and detoxify heavy metals like mercury,[49, 52, 53] lead.[54] In scientific research on the toxic effects of substances, it is necessary to compare at least two samples: one that is exposed to the substance in question and one that isn't.

One of the main dilemmas in so called amalgam studies, is that the vast majority do not incorporate true control groups which have genuinely not been exposed to dental amalgam. What is neglected is the possibility that non-amalgam controls may at some point in their earlier life have had dental amalgam fillings over along period of time and may thus display a higher body mercury load. These studies cited by many authors and institutions.[10, 13, 19, 48, 55-59] as proof of the putative harmlessness of amalgam do not use proper non amalgam control groups. Melchart *et al*.[60] found that amalgam removal

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resulted in a significant improvement in amalgam-related symptoms. Furthermore, Lindh *et al*.[61] showed that the removal of amalgam and other dental metals in 463 patients lead to an improvement in over 70% of the patients in frequently observed symptoms (e.g. fatigue, depression, muscle and joint pain, headaches, dizziness, stomach trouble, forgetfulness). Animals and in-vitro studies have shown that exposure to inorganic and metallic mercury cause neuronal damage[62, 63] biochemical alterations (including induction of amyloid) found in Alzheimer's disease[52,64-68], even at very low levels. Other metals like Al, Cd, Pb, Mn, Zn, Fe, Cr, Cu, were not able to cause this types of neuronal alterations.

Mercury is freely available in chemical markets in India. It is sold openly and one does not require any kind of authorization to buy this toxic metal. In developed countries, the use of mercury in various products is either banned or regulated. There are various provisions and acts pertaining to the prevention and control of pollution and protection of the environment. Mercury finds place in some of them, but nothing that deals with it specifically. The nature and extent of threat from the deadly metal makes it a candidate for specific attention.[69] While mercury contamination of dental-unit waste water is one contributor to the environmental burden of clinical dentistry, the disposal of solid wastes is another major concern. As potential exists for mercury to be transformed into more toxic species, new regulation and methods should be designed to remove mercury from dental waste to minimize the production of organic mercury.[70]

To summarize, studies reviewed in this paper indicate considerable amount of mercury waste is generated during various dental procedures which has to be minimized and proper disposal methods have to be used to control its hazardous effects. Increased mercury hygiene and regular control of working atmosphere should be implemented to prevent mercury exposure. Mercury waste disposal is still an area of concern particularly in developing countries like India. As very few facts and figures are presently available in India regarding mercury waste generation and its proper disposal by dental colleges and clinics, therefore a regulating authority should be made to check and minimize the mercury burden generated by them. Further, as a professionals we should also follow certain regulatory methods to reduce exposure of the society to toxic effects of mercury and prevent the environmental pollution. Additional research is still needed to develop the methods for reduction of mercury waste generation and its proper disposal.

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