The use of dental amalgam as a direct restorative material has been a subject of controversy for many years. Concerns have been raised over the potential safety of amalgam because of leakage of elements such as mercury, copper, tin, and silver. Ecologic considerations have led some countries to promote discontinuing the use of amalgam for dental restorations. However, communication of information through the mass media, often not based on scientific fact, has resulted in some confusion regarding the effects of amalgam on human health.1 The mercury content for dental amalgam is approximately 50%, and studies have illustrated that organic mercury compounds and elemental mercury vapor can cause central nervous system damage as well as neurologic damage.2-4 Mercury also has been established as immunotoxic (including other autoimmune disorders) in experiments with animals.5-8 Eggleston and Nylander2 demonstrated a positive correlation between the number of occlusal surfaces of dental amalgams and mercury levels in the brain (P<.0025 in white matter). Abraham et al7 reported a correlation of inorganic mercury levels in the blood of humans to the total surface area of occlusal dental amalgams, and they found that the amount of inorganic mercury was increased 8-fold immediately after mastication.

The leaching of mercury is not the only concern associated with amalgam. Copper is an essential trace element that is an important catalyst for heme (iron) synthesis and absorption, and, after zinc and iron, it is the third most abundant trace element in the body.9

Use of inductively coupled plasma-emission spectroscopy and mercury vapor analyses to evaluate elemental release from a high-copper dental amalgam: A pilot study

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Statement of problem. The use of dental amalgam as a direct restorative material has been a subject of controversy for many years. The potential safety of amalgam has been questioned because of leakage of elements such as mercury, copper, tin, and silver.

Purpose. This study evaluated the elemental leaching from Tytin dental amalgam placed in deionized water for 2 months. Both mercury vapor and elemental (silver, copper, tin, and mercury) analyses were performed.

Material and methods. Two capsules of Tytin amalgam were triturated (one for the precipitate and liquid analysis, and the other for the mercury vapor analysis) and stored in a polypropylene tube with 10 mL deionized water for 60 days at room temperature. The amalgam pellet then was removed and rinsed with deionized water. The resulting liquid was separated from a precipitate, and 2 separate analyses were run: one on the liquid without any precipitate and another on the precipitate. Elemental analyses for copper (Cu), tin (Sn), mercury (Hg), and silver (Ag) were determined by inductively coupled plasma-emission spectroscopy with a Perkin-Elmer P2000 spectrometer. Mercury vapor analyses were performed daily for 60 days with a Jerome 431-X vapor analyzer.

Results. The maximum amount of copper (80 µg), silver (2.6 µg), mercury (15 µg), and tin (550 µg) was found in the precipitate. The maximum amount of mercury vapor released was 67 µg/m³/d.

Conclusion. Under the conditions of this in vitro study, there was a significant amount of elemental leaching and mercury vapor release from the Tytin amalgam over a 60-day period. (J Prosthet Dent 2001;85:409-12.)
Copper leaching is also a concern for dental amalgam because elevated levels of copper can cause liver disorders such as Wilson’s disease. With the use of short-term protocols (72-168 hours), Nelson et al reported that the elements copper and silver are possible cytotoxic agents; they also pointed out that no long-term cytotoxicity data (greater than 1 week) are found in the literature.

Some investigators have found that the safety of dental amalgam restorations may be considered inconclusive. Snapp et al found a decrease in blood mercury levels in subjects after the removal of amalgam fillings and estimated the daily intake of mercury from amalgam fillings to be 1.3 µg. The value of 1.3 µg is about 1% of the corresponding daily dosage obtained for a person in an environment where the WHO (World Health Organization) Standards threshold limit value (TLV) for a work environment is 50 µg/m³ of elemental mercury in air. Mackert demonstrated that the corrected estimates for daily dosage of mercury from amalgam fillings are a factor of 16, which is lower than previously reported studies. Berglund has stated that the amount of mercury exposure to patients from dental amalgam restorations is less than that ordinarily encountered in the modern environment.

The purpose of this study was to evaluate the elemental release from Tytin dental amalgam specimens placed in deionized water for 2 months. Both mercury vapor and elemental (silver, copper, tin, and mercury) analyses were performed. The experimental results are discussed in terms of the symptoms of mercury poisoning, some current guidelines for mercury exposure, studies of the cytotoxic aspects of dental amalgams, and compositional factors affecting mercury release. Complementary information about the setting reactions of dental amalgams is available in well-known textbooks on dental materials.

MATERIAL AND METHODS

The Materials Safety Data Sheets (MSDS) for Tytin amalgam FC (Kerr Corp, Romulus, Mich.) list the concentration of silver (61%), copper (13%), and tin (26%) in the prealloy powder and the concentration of mercury (43%) in the prepared dental amalgam. A capsule of Tytin amalgam FC (Lot No. 081198) was triturated for 10 seconds with an amalgamator (Wig-L-Bug, Crescent Dental Mfg Co, Lyons, Ill.). The resultant pellet (1 spill) weighed 1.06 g. The amalgam pellet was placed in a 50-mL polypropylene tube containing 10 mL deionized water. Deionized water was used to approximate the oral environment and should not have incurred any significant reactions. The tube was sealed with a screw-top lid and maintained at room temperature for 60 days.

The amalgam pellet then was removed and rinsed with deionized water. The resulting liquid was separated from a precipitate with the use of filter paper, and 2 separate analyses were performed: one on the liquid without any precipitate and the other on the precipitate. Hydrochloric acid was added to the extraction fluid to dissolve any metals that may have been released from the amalgam and subsequently precipitated over the 2-month period. The precipitate was transferred to a beaker containing 10 mL fresh deionized water and heated to approximately 40°C with a hotplate for approximately 15 minutes to dissolve any solids. The resultant solution was transferred to a volumetric flask, and sufficient deionized water was added to yield a total volume of 25 mL.

The resultant 2 solutions (liquid without precipitate and liquid containing dissolved precipitate) were analyzed by inductively coupled plasma-emission spectroscopy (P2000 spectrometer, Perkin-Elmer, Norwalk, Conn.). Elemental analysis for copper (Cu), tin (Sn), mercury (Hg), and silver (Ag) followed procedures recommended by Perkin-Elmer: Cu (ASTM Std E 29-1 Revision 1), Sn (ASTM Std E 50-4 Revision 0), Hg (ASTM Std E 80-5 Revision 0), and Ag (ASTM Std E 47-3 Revision 0). The inductively coupled plasma technique uses a sample that is passed through argon in a ray fluorescence (RF) field. When the sample is introduced into the plasma, the atoms are excited and emit very stable light of varying wavelengths that permit identification of the elements. This technique has become highly popular for elemental analysis. Sample introduction conditions were different for each element per Perkin-Elmer instructions: Cu (1400 W), Sn (1400 W), Hg (1200 W), and Ag (1200 W). The amount for each element was determined by isolation of a characteristic primary wavelength of 325 nm for Cu (detection limit 0.01 ppm), 190 nm for Sn (detection limit 0.10 µg/mL), 194 nm for Hg (detection limit 0.01 ppm), and 328 nm for Ag (detection limit 0.01 ppm). Calculation for each element (amount expressed from ppm to per gram) was performed by using the following equation:

\[
\text{Microprocessor} = \frac{\text{amount expressed from ppm to per gram}}{\text{V} \times \text{D}}
\]

where V = sample volume in milliliters and D = dilution factor.

MERCURY VAPOR RELEASE ANALYSIS

A capsule of Tytin amalgam FC was triturated for 10 seconds with the previously described Wig-L-Bug amalgamator. The resulting pellet (1 spill) weighed 1.06 g. The amalgam pellet again was...
placed in a 50-mL polypropylene dilution tube, with the addition of 10 mL deionized water, and the tube was sealed with a flip-top lid. The sealed container was maintained at room temperature, and measurements of mercury vapor were obtained daily for 60 days. Analysis of the mercury vapor was performed with a Jerome 431-X vapor analyzer (Arizona Instrument Corp, Tempe, Ariz.), which measures mercury vapor concentrations in milligram per cubic meter (mg/m³). These values were converted to microgram per cubic meter (µg/m³) of mercury.

RESULTS

Results for the precipitate and liquid are provided in Table I. The values of elemental leakage for the liquid are much lower than those for the precipitate. This is because copper, silver, tin, and mercury have very low solubility in water.9,11 Table II presents the results for the mercury vapor analysis. The results show an initial increase in mercury vapor between day 1 and day 4 and then a gradual decrease of mercury vapor between day 4 and day 60. The initial increase was attributed to residual mercury on the surface of Tytin amalgam.

DISCUSSION

The possibility of adverse health effects from exposure to mercury and other elements from amalgam is a controversial issue that is still debated in the scientific community. Chronic mercurialism is characterized by such symptoms as subtle personality changes, irritability, loss of memory, depression, insomnia, and the inability to concentrate.15 Death is possible at exposures of more than 600 µg/mL.15 WHO Standards stipulate the TLV for occupational exposure to inorganic mercury as 50 µg/m³.15 Table II presents the results for the mercury vapor release. Therefore, dental amalgams with high concentrations of tin emit the lowest levels of mercury vapor. This is believed to be possible because the tin found in amalgam is a more efficient “wetting agent” than copper and silver. The net result of an amalgam containing a greater proportion of tin is the matrix phase that incorporates more of the mercury during the setting reaction. The tin concentration of Tytin amalgam is equivalent to that generally found in other commercially available amalgams.20 Therefore, one would expect the mercury vapor release from other commercially available amalgams to be generally similar to that for the Tytin amalgam. In Table I, the concentration of tin in the precipitate is far greater than the other components that make up the amalgam material. The origin of this precipitate is presently unknown and requires

<table>
<thead>
<tr>
<th>Precipitate</th>
<th>Copper (Cu)</th>
<th>80 µg</th>
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<tbody>
<tr>
<td>Silver (Ag)</td>
<td>2.6 µg</td>
<td></td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>15 µg</td>
<td></td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>550 µg</td>
<td></td>
</tr>
<tr>
<td>Liquid</td>
<td>Copper (Cu)</td>
<td>9.6 ppm</td>
</tr>
<tr>
<td>Silver (Ag)</td>
<td>0.19 ppm</td>
<td></td>
</tr>
<tr>
<td>Mercury (Hg)</td>
<td>0.031 ppm</td>
<td></td>
</tr>
<tr>
<td>Tin (Sn)</td>
<td>0.28 ppm</td>
<td></td>
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<table>
<thead>
<tr>
<th>Table II. Analysis of mercury vapor for Tytin amalgam</th>
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<tbody>
<tr>
<td>Daily mercury vapor analysis</td>
</tr>
<tr>
<td>Day 1</td>
</tr>
<tr>
<td>Day 4</td>
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<tr>
<td>Day 60</td>
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<tr>
<td>Average weekly mercury vapor analysis</td>
</tr>
<tr>
<td>Week 1 average</td>
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<tr>
<td>Week 2 average</td>
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<td>Week 3 average</td>
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<td>Week 4 average</td>
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<td>Week 5 average</td>
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<td>Week 6 average</td>
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<td>Week 7 average</td>
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<td>Week 8 average</td>
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</table>
further study. It is not clear that the precipitate composition has a relationship to the setting reaction for the Tytin high-copper dental amalgam.

CONCLUSIONS

Because of the leakage of elements such as mercury, copper, tin, and silver, concerns remain over the use of dental amalgam and its potential safety. In this study, a significant amount of elemental leaching and mercury vapor release from the Tytin amalgam was observed over a 60-day period. These findings may add to the concerns regarding the safety of dental amalgam.

REFERENCES


Correction

In the article by Kiat-amnuay et al, “Effect of adhesive retention on maxillofacial prostheses. Part I: Skin dressings and solvent removers,” published in the September 2000 issue of the Journal, the unit of measure should have been printed as newton/meter (newton per meter) rather than newton-meter. Newton/meter is a common measure of adhesive force and newton-meter is a unit of torque.