

Disinfectants' effect on mercury release from amalgam

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A amalgam still is a widely used restorative material worldwide.¹ Although there is evidence of a decrease of its use in the United States, its cost, durability, long-term performance and ease of manipulation still make it dentists' first-choice material for restoring posterior teeth.^{1,2} Despite amalgam's long history and popularity, there have been periodic concerns about

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adverse health effects arising from the exposure of the minute levels of mercury released from amalgam restorations.² These concerns largely have been allayed by several expert panels including the National Institutes of Health and the U.S. Public Health Service. These agencies were unable to identify any adverse human health effects arising from the placement of dental amalgam restorations.^{2,3}

Mercury discharge into the environment, regardless of the source, has come under increased scrutiny from the U.S. Environmental Protection Agency (EPA). Mercury is classified as a persistent bioaccumulative toxin, and it is among the top 20 hazardous substances listed by the Agency for Toxic Substances and Disease Registry/Environmental Protection Agency.⁴ A 1996 EPA conference on mercury in the Midwest emphasized the need to eliminate mercury medical waste from entering the wastewater stream.⁵ Moreover, in 1997, the EPA issued a 1,700-page report to Congress

Background. Mercury environmental discharge is under increased scrutiny by the U.S. Environmental Protection Agency (EPA). Dental amalgam should be processed properly to prevent an additional environmental burden. Some processing agencies require that submitted amalgam be noninfectious. Investigations have demonstrated that oxidizing disinfectants mobilize mercury from amalgam into solution and add mercury to the environmental burden if it is disposed of improperly. The authors conducted a study to evaluate the effect of representative disinfectants on amalgam mercury release.

Methods. The authors sized a high-copper spherical amalgam alloy to match that typically found in dental unit suction traps. They exposed 20 grams of the alloy to several disinfectant solutions and evaluated the filtered supernatant solution for mercury content.

Results. Chlorine disinfectant materials discharged the most mercury ions, followed by bromide, iodophor, peroxide/peracetic acid and phenolic disinfectants. The quaternary ammonium compound did not discharge mercury ions above the detection limit (0.2 parts per billion) into solution.

Conclusions. A quaternary ammonium compound did not mobilize mercury ions into solution when used as a disinfectant agent for amalgam. Chlorine disinfectants mobilized mercury ions the most, followed by bromide, iodophor, peroxide/peracetic acid and phenolic disinfectants.

Clinical Implications. Dentists are obligated to be good environmental stewards and should follow practices that reduce environmental mercury release. Dental personnel should be aware that oxidizing disinfectants mobilize mercury ions into solution, which will be added to the environment if they are processed improperly. If required by processing, dental personnel should consider the different oxidizing effects of commonly used disinfectants.

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stressing the need for closer scrutiny and regulation of mercury emissions.⁶ In 1998, the EPA and the American Hospital Association signed a memorandum of understanding to significantly cut hospital mercury wastes by 2005. This agreement included the total elimination of mercury-containing hospital wastes and a one-third reduction in other wastes.⁷

Mercury in dental amalgam exists in a fairly stable equilibrium, with only minute amounts released into the surrounding environment.⁸⁻¹² Despite this, amalgam should be recycled or processed properly and not be disposed of as garbage, medical infectious waste (for example, in “red bag” or biohazard containers) or in sharps containers. Furthermore, amalgam should not be rinsed down the drain into municipal sewer lines. Some communities incinerate municipal garbage, medical waste and sludge from wastewater treatment plants. The high temperatures used in incineration can alter the physical properties of amalgam to cause the release of mercury into the environment. Proper processing or disposal of dental amalgam waste prevents the release of additional mercury into the environment.

Accordingly, amalgam excess from restorative procedures or amalgam scraps retrieved from dental unit suction traps can be processed for proper disposal, recycling or both. Some federal agency guidelines^{13,14} and commercial recycling companies require that submitted amalgam that has been in contact with body fluids (for example, retrieved from dental unit suction traps) be disinfected before undergoing reclamation.¹⁵ The rationale for this disinfection is that materials retrieved from an oral evacuation system may be infectious and biologically hazardous. Some agencies that process recyclable medical materials also may require documentation that the submitted items are noninfectious.¹⁴

Sodium hypochlorite traditionally has been recommended as a disinfectant for amalgam retrieved from dental unit suction traps.² However, some investigations have demonstrated that oxidizing disinfectants—including bleach—mobilize soluble mercury from amalgam into the disinfectant solution.⁴ If the oxidizing disinfectant solution is not processed properly or is discarded into the public wastewater system, it adds to the environmental burden of mercury.

We conducted this study to evaluate the effect of representative disinfectants on mercury released from amalgam.

MATERIALS AND METHODS

We triturated a high-copper, spherical amalgam alloy in a dental amalgamator following the manufacturer’s recommendations. We stored the resulting dry amalgam alloy pellets in a sealed container for one month. We then pulverized the amalgam alloy pellets using a mill and put them through 900- and 710-micrometer standard testing sieves.

We prepared five samples for each disinfectant solution from each representative class (Table 1) using the following procedure. We placed 20 grams of the sized amalgam alloy particles into a new, sealable 50-milliliter plastic test tube, followed by 50 mL of a disinfectant solution. If required, we prepared the disinfectant solution following its manufacturer’s recommendations immediately before use. Then we sealed the test tube and agitated it for 30 seconds to disperse the amalgam alloy powder in the disinfection solution. Next, we left the mixture undisturbed for contact time recommended by the disinfectant’s manufacturer. Finally, we filtered the mixture through 0.2- μ m filters and placed the supernatant in clean and dry test tubes, which then were sealed and submitted for testing.

We assessed the samples for mercury content according to EPA method 245.1A using an atomic absorption spectrophotometer and ranked the mean mercury levels using the Kruskal-Wallis test with post hoc analysis using the Hochberg and Benjamini method at a significance level of .05.

RESULTS

The results of our study are given in Table 2 (page 918). We found that the chlorine disinfectant materials discharged the most mercury ions into solution, followed by the bromide, iodophor, peroxide/peracetic acid and phenolic disinfectants. The distilled water control discharged the same levels of mercury ions as the peroxide/peracetic acid disinfectant. Surprisingly, the quaternary ammonium compound disinfectant did not cause mercury ion release that was detectable above the 0.2 parts per billion threshold of the method used.

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TABLE 1

DISINFECTANT SOLUTIONS.				
PRODUCT	CLASSIFICATION	ACTIVE INGREDIENT	CONTACT TIME (MINUTES)	MANUFACTURER
Distilled Water (Control)	Control	—	10	—
5.25 Percent Sodium Hypochlorite Bleach	Chlorine	Sodium hypochlorite	10	Clorox, Oakland, Calif.
Dispatch	Chlorine	Sodium hypochlorite	2	Caltech, Midland, Mich.
Biocide	Iodophor	Iodine	10	Biotrol, Louisville, Colo.
BIREXse	Dual phenolic	Ortho-phenyl phenol, para-tertiary phenol	10	Biotrol
TriCide	Triphenolic	Para-tertiary amyphenol, ortho-benzyl-para-chlorophenol, ortho-phenylphenol	10	Dentsply, Milford, Del.
GC Spray-Cide	Quaternary ammonium compound	N-alkyl-dimethyl ethylbenzyl ammonium chloride, N-alkyl dimethyl benzyl ammonium chloride, isopropanol	10	GC America, Alsip, Ill.
Microstat 2	Bromide	Sodium bromide, sodium dichloroisocyanurate-dihydrate	5	Septodont, New Castle, Del.
Compliance	Peroxide/peracetic acid	Hydrogen peroxide, peracetic acid	15	Metrex Research, Orange, Calif.

DISCUSSION

Our study evaluated the effect of nine disinfectants' abilities to mobilize mercury ions into solution. We chose a spherical amalgam alloy product that commonly is used in federal service dental facilities. We stored triturated amalgam alloy for one month to simulate more closely mature amalgam that might be removed during operative procedures and remain in the dental unit's suction trap. After grinding amalgam alloy pellets in a mill, we put the particles through successive 710- to 900-µm standard testing sieves. This produced a representative group of amalgam particles that were large enough to be caught in a dental unit suction trap, while providing a uniform particle size distribution that afforded a similar reaction surface area for all of the disinfectant samples.

We found that the chlorine disinfectants discharged the greatest amounts of mercury ion, followed by the bromide, iodophor, peroxide/

peracetic acid and phenolic disinfectants. It is interesting to note that the peroxide/peracetic acid and triphenolic disinfectants discharged similar levels of mercury as the distilled water, which

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we used as a control. The most surprising finding of our evaluation was that the quaternary ammonium compound disinfectant did not mobilize mercury ions into solution. In fact, the initial test results were unexpected, so we considered them to be either a laboratory error or equipment malfunction, and we tested another group of samples.

Repeated testing of the newly prepared samples combined with atomic absorption spectrophotometer recalibration produced the same results in both control and quaternary compound samples.

The rate of mercury released into a liquid environment depends on the bond strength of mercury in the amalgam; the presence, nature and stability of any surface oxide films; and the chemical transformations of mercury in the solution.¹⁶

TABLE 2

MERCURY ANALYSIS RESULTS (N = 5).

MATERIAL	MEAN MERCURY LEVEL (ppb*)	SD†	HOMOGENOUS SUBSETS BASED ON OVERLAP/NONOVERLAP OF DATA POINTS‡			
GC Spray-Cide [§]	ND¶	ND	A			
TriCide [§]	852	206		B		
Distilled Water (Control)	1,048	234		B		
Compliance [§]	1,415	911		B	C	
BIREXse [§]	2,184	276			C	
Biocide [§]	4,798	752				D
Microstat 2 [§]	5,536	1,040				D
5.25 Percent Sodium Hypochlorite Bleach	38,380	7,082				E
Dispatch [§]	46,782	30,292				E

* ppb: Parts per billion.
 † SD: Standard deviation.
 ‡ The letters indicate statistically similar groups.
 § The product's manufacturer is listed in Table 1.
 ¶ ND: Not detectable (detection limit = 0.2 ppb [0.2 micrograms/liter]).

Since we used the same amalgam in all of the tests, the binding of mercury in the different amalgam phases and the amalgam's film-forming ability were the same. However, the properties and stability of the oxide surface films, which form a barrier to mercury dissolution, depend on the chemistry of the solution. Many chlorine-containing solutes destabilize metal oxide films, including the tin oxide of dental amalgam; this degrades the oxides' ability to reduce the amount of mercury released. The observed high rate of discharge associated with the use of chlorine disinfectants can be attributed mainly to this effect. The comparative aggressiveness of the ions in the solutions with respect to oxide films may be largely responsible for the ranking in Table 2.

Another factor that may play a role in the release of mercury is the oxidation power of the environment within which the amalgam may exist. A higher oxidation power increases the electromotive potential of the metal, as well as the rate of conversion of elemental mercury-to-mercury ions. Although the mercury released from dental amalgam in synthetic saliva is insensitive to the potential in a wide range,¹⁶ the relationship may be different in other environments if the oxide properties are potential-dependent. Higher oxidation power also accelerates the transformation of the released elemental mercury-to-mercury ions.¹⁷ Since the solubility of

elemental mercury in aqueous solutions is quite low, oxidation to ionic mercury may increase the mercury dissolution rate by lowering the solubility barrier.¹⁷

The relative oxidation potential of a solution can be determined by measuring the open-circuit potential of an inert electrode potential with respect to a reference electrode. In light of the surprising results we found in this study, we sought to compare the oxidative potentials of the quaternary ammonium compound and a representative chlorine disinfectant. Accordingly, we measured the reduction oxidation (redox) potentials of the quaternary ammonium compound and 5.25 percent sodium hypochlorite bleach, as well as the corrosion potential of the high-copper, spherical amalgam alloy in both solutions at 25 C using a temperature-controlled corrosion cell and a computer-controlled electronic potentiostat. We measured the stabilized potentials with respect to a standard saturated calomel electrode. The results presented in Table 3 show that both the redox potential and the corrosion potential of high-copper, spherical amalgam alloy were substantially lower in quaternary ammonium compound than in the bleach. It is possible that the low redox and corrosion potentials may have contributed to the low rate of mercury released by the quaternary ammonium compound by keeping the potential in a range beneficial for the forma-

TABLE 3

REDUCTION-OXIDATION POTENTIAL AND CORROSION POTENTIAL FOR THE HIGH-COPPER, SPHERICAL AMALGAM ALLOY.		
DISINFECTANT	REDUCTION-OXIDATION POTENTIAL (VOLTS)	CORROSION POTENTIAL (VOLTS)
5.25 Percent Sodium Hypochlorite Bleach	+ 0.642 (SCE)*	+ 0.082 (SCE)
GC Spray-Cide†	+ 0.086 (SCE)	- 0.285 (SCE)

* SCE: Saturated calomel electrode.
† The product's manufacturer is listed in Table 1.

tion of an oxide barrier and by reducing the rate of conversion of elemental to ionic mercury.

CONCLUSIONS

We found that a quaternary ammonium compound did not mobilize detectable mercury ions into solution when it was used as a disinfectant for amalgam. Chlorine disinfectants mobilized mercury ions the most, followed by bromide, iodophor, peroxide/peracetic acid and phenolic disinfectants. We conjecture that the low oxidation power of quaternary ammonium compounds is beneficial for the formation of a barrier oxide film and slows down mercury dissolution by decreasing the rate of oxidation of elemental mercury to the ionic form. Further research is warranted to determine the mechanism responsible for our findings and if different quaternary ammonium compounds produce results similar to ours. ■

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