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Method for Measuring Mercury Release from Dental Amalgam

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Dental amalgam restorations continuously release mercury vapor (Hg^0) (Lorscheider et al. 1995). Hg^0 produces adverse symptoms over a very large range of exposures, including levels which might result from amalgam restorations (Echeverria et al. 1998; Ngim et al. 1992). Studies using many different analytical and sampling techniques have examined Hg^0 release from dental amalgams. Some have collected and analyzed exhaled air (Svare et al. 1981; Patterson et al. 1988; Dirks et al. 1994), whereas others have measured Hg^0 directly within the mouth (Vimy and Lorscheider 1985a,b; Ahmad and Stannard 1990). Wide disparities in Hg^0 flux have been reported using these methods. Mackert (1987) discusses factors that can influence measurements of Hg^0 in intraoral air including mouth geometry, breathing rate, breathing volume and the variable rate of release during the period of chewing stimulation. Others have pointed out that dissolution of Hg in saliva, position and movement of sampling devises in the mouth, and proportion of air drawn in by nasal/oral routes are also factors in intraoral Hg measurements (Ahmad and Stannard 1990; Neme et al. 1995; Berdouses et al. 1995).

The Jerome 411 Mercury Vapor Analyzer has proven to be a simple, accurate, reproducible instrument for measuring concentrations of Hg^0 from 0 to 1.000 mg/cu m of air. This paper describes a technique using the Jerome 411 for measurement of intraoral Hg^0 release from amalgam restorations. The method eliminates or minimizes many of the variables mentioned above. It can be useful for estimation of relative risk of Hg intoxication. Measurements on more that 120 amalgam restorations in 42 subjects are reported.

MATERIALS AND METHODS

Mercury measurements were made with a Jerome 411 Mercury Vapor Analyzer (Arizona Instrument Company, Phoenix, AZ, USA). It is a

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portable battery-powered hand-held unit, that provides a digital display of mercury levels in 10 seconds. The Jerome uses a gold film sensor for the detection and measurement of mercury vapor in air, based on the change in resistivity of gold by amalgamated mercury. The gold film sensor is inherently stable and selective to mercury, eliminating common interferences such as water vapor. The instrument precision and accuracy are 5% relative standard deviation and ± 5% at 0.100 mg Hg/cu m, respectively.

Readings were made both before (i.e., baseline) and after chewing stimulation which consisted of vigorous chewing of sugarless gum for 30 seconds. Each subject was supplied with tissues and instructed to dry the surfaces of the teeth immediately before each measurement because Hg^0 can dissolve in saliva, interfering with Hg^0 vaporization. The intake tube was terminated in a 10 cm piece of plastic drinking "straw" that was discarded after each subject's measurements. The sampling tube was held motionless at the edge of an amalgam dental restoration while the subject interrupted breathing for 10 seconds. During that collection interval, 125 ml of air (750 ml/min) are drawn into the instrument via the intake tube. That air has swept across the amalgam surface in the boundary layer region of the tooth and contains all of the Hg vapor emitted by the filling during the 10 second interval. Between each measurement, the instrument was operated for one 10 second sampling period to draw in room air. This flushed the tubing of any vapor from the previous sampling and assured a zero reading prior to the next amalgam measurement. The gold film sensor was subjected to a film-heating cycle as necessary to remove the accumulated Hg and regenerate the sensor.

Two groups of subjects were studied; 11 staff and patients at a nursing home and 31 people attending a lecture related to mental illness. Each subject requested the test and signed an informed consent. The subjects were instructed regarding the details of the testing protocols, including the chewing stimulation, drying of teeth and suspension of breathing during sampling.

RESULTS AND DISCUSSION

Table 1 shows Hg^0 release from 22 amalgam restorations in 11 subjects. Baseline Hg^0 flux ranged from 0 to 0.056 mg/cu m; the median was 0.0035 mg/cu m and nearly 80% of the measurements were below 0.011 mg/cu m. This is consistent with results of several researchers including Neme et al. (1999) who used an intraoral model to measure Hg^0 release; they recorded a mean of 0.011 mg/cu m. Neme et al. (1999) constructed an intraoral model with acrylic teeth that simulated

Table 1. Mercury vapor concentration from dental amalgams before and after chewing stimulation.

Subject	Restoration location[a]	Baseline[b] (mg Hg/cu m)	After Stimulation[c] (mg Hg/cu m)
A	UR	0.006	0.018
B	UR	0.000	0.008
C	UR	0.002	0.013
D	LR	0.003	0.003
E	LL	0.005	0.063
E	LR	0.005	0.064
F	UL	0.056	0.102
F	UR	0.024	0.061
G	LL	0.003	0.005
G	UR	0.002	0.003
H	LR	0.019	0.019
H	LL	0.021	0.041
H	UL	0.014	0.037
H	UR	0.011	0.038
I	LL	0.002	0.001
J	UR	0.002	0.016
J	UL	0.011	0.043
J	LL	0.004	0.011
K	UR	0.000	0.008
K	UL	0.001	0.035
K	LL	0.000	0.005
K	LR	0.000	0.009

a. designates quadrant within the mouth (UR= upper right; UL= upper left; LL= lower left; LR= lower right)
b. baseline (unstimulated) measurement as described in Materials and Methods
c. measurement after 30 sec chewing stimulation

the human mouth and included a lower right first molar (#30) filled with amalgam using standard techniques. Their tests of Hg^0 release using a Jerome 411 in a closed system, or in a system with air flow over the amalgam filling, suggest that the latter could have clinical application. Our results show, in vivo, that placing the sampling inlet over the dry restoration and allowing air to pass over the amalgam, in a manner similar to the intraoral model system, gives high quality measurements.

Others have used the Jerome in vivo to measure Hg^0 release. Ahmad and Stannard (1990) placed the collection tube of the instrument near the restoration. However, they did not control breathing of the subjects, nor dry the tooth being measured. Vimy and Lorscheider (1985a) moved the collection tube "rapidly and continuously around the open oral cavity". These methods introduce factors that can adversely influence estimates of Hg^0 release (Mackert 1987; Ahmad and Stannard 1990).

Chewing stimulation increased Hg^0 release, generally by 2 to 3-fold (Table 1.). Some amalgams, however, exhibited more than a 12-fold increase (e.g., subject E). Others have reported that chewing or brushing stimulation increases release by factors of 6 to 16-fold (Vimy and Lorscheider 1985a; Ahmad and Stannard 1990; Svare et al. 1981). Disparities in the magnitude of enhanced release could result from different measurement techniques or amalgam characteristics. Amalgam age and type (high copper versus standard) have been found to be factors in mercury release upon chewing or brushing (Berdouses et al. 1995; Ahmad and Stannard 1990). Ahmad and Stannard (1990) found an 11-fold and 8-fold increase in Hg^0 release after chewing stimulation at 1 day or 7 days after installation, respectively. These and many other investigators have used 10 minutes as the duration of stimulation. We found that the time required to substantially increase release is greatly less (~30 sec), facilitating testing, especially in a clinical setting.

Figure 1. summarizes Hg^0 release measured from 106 amalgam restorations in 31 subjects (after chewing stimulation). One third of the readings were above 0.050 mg/cu m. The highest concentration measured in one amalgam was 0.211 mg/cu m. The identification of high release or high copper amalgam formulations is straightforward using the Jerome 411. The Hg^0 release rate of high copper amalgams is reported to be 50 times that of traditional amalgams (Brune et al. 1983; Pleva 1994). In their model system, Neme et al. (1999) found a high copper formulation (Tytin, Kerr Corp., Romulus MI) released 0.030 mg/cu m 7 days after installation. Ahmad and Stannard (1990) showed Hg^0 release of a high copper amalgam in vivo increased from a baseline of less than 0.005 to 0.041 mg/cu m after chewing stimulation. Nine of the amalgams from subjects in Table 1. released > 0.030 mg/cu m after chewing. In subjects for whom we were able to contact the installing dentist, the restorations were confirmed to be high copper formulations in all cases.

The ability to identify high copper or high release amalgams is important from a toxicological standpoint. High copper formulations are a significant risk factor for chronic intoxication. Ely (2001)

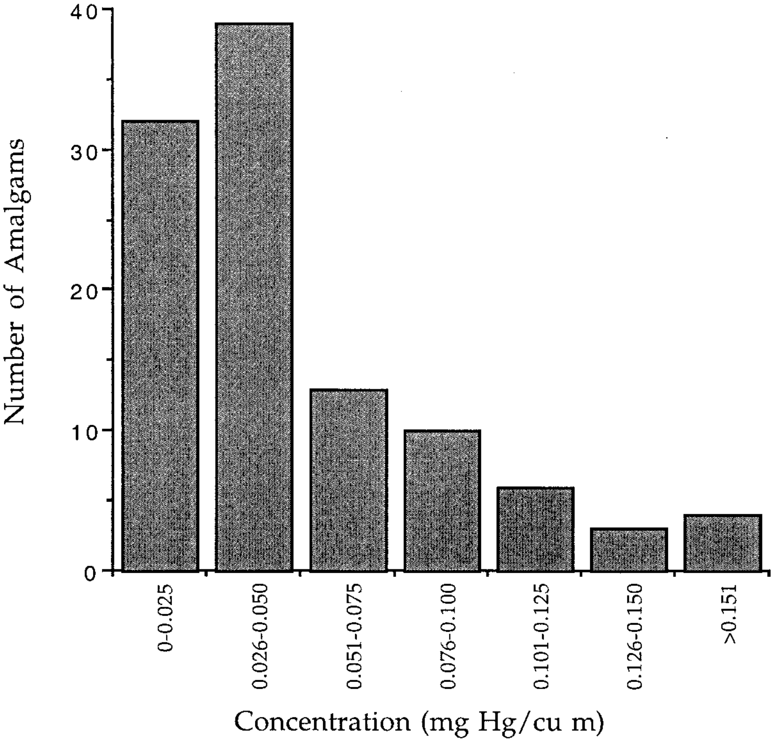

Figure 1. Distribution of mercury vapor concentrations measured in 106 dental amalgam restorations.

presented a model that suggests three factors [bruxing (i.e., grinding of teeth), mouth breathing and high copper amalgam], when taken together, could significantly increase risk of Hg intoxication. Exposure to Hg^0 in air containing as low as 0.017 mg/cu m has been shown to affect motor function, memory and visual reproduction in dentists (Ngim et al. 1993). More recently, Echeverria et al. (1998) demonstrated pre-clinical effects on mood, motor function and cognition associated with very low Hg exposure. The levels were within the range of exposure experienced by the general population. More importantly, they were unable to detect a threshold exposure level; e.g., no lower limit in exposure where symptoms or effects did not occur. Their results suggest that Hg toxicity can occur at levels lower than OSHA's permissible exposure of 0.050 mg/cu m. Over one-third of our measurements were greater than this concentration (Figure 1.).

In summary, our method eliminates most variables that have been identified as limitations in previous techniques. This is accomplished by minimizing the time of chewing stimulation, drying the amalgam immediately prior to measurements, requiring the subject to refrain from breathing during sampling, and placing the sampling tube in close proximity to the amalgam. This method facilitates the in vivo detection of high Hg^0-release amalgams. Although the method might be useful for estimation of total daily dose of Hg from amalgams, its more meaningful application is in the identification of high-release restorations that are risk factors for chronic Hg intoxication.

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