EXPOSURE TO MERCURY FROM DENTAL AMALGAM: ACTUAL CONTRIBUTION FOR RISK ASSESSMENT

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SUMMARY

Objective: Mercury dental amalgam restorations are an important source of chronic exposure to mercury in the whole population and special attention should be paid not only to occupational exposure to mercury during the preparation and administration of amalgam. The authors' report is an up-to-date contribution to the health risk assessment of mercury use in dentistry, namely occupational exposure to mercury in dentists working with dental amalgam and exposure to mercury in persons treated with amalgam dental restorations.

Methods: Determination of total mercury in samples of biological material (urine, hair) was performed during 2017 and 2018 in 50 persons by the AAS method using the mercury vapour generation technique at 254.6 nm.

Results: Current dental exposures based on the most recent findings do not exceed acceptable risk levels and are below the biological limit of mercury in urine valid for occupationally exposed persons ($100 \mu\text{g.g}^{-1}$ of creatinine), namely median value was 1.48 (min. < limit of detection (LOD), max. 17.14) $\mu\text{g.g}^{-1}$ of creatinine (40 persons), total mercury content in hair of dental personnel expressed as median value was 0.340 (min. 0.060, max. 1.628) $\mu\text{g.g}^{-1}$. In controls (10 persons) was total mercury content in urine expressed as median value 0.36 (min. < LOD, max. 2.74) $\mu\text{g.g}^{-1}$ of creatinine, in hair was median value 0.224 (min. 0.059, max. 0.453) $\mu\text{g.g}^{-1}$.

Conclusions: Authors support opinion that amalgam fillings in the oral cavity are a permanent source of mercury for the body itself.

Key words: dental amalgam, mercury, exposure, biological monitoring, health risks

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INTRODUCTION

Dental amalgam is an alloy consisting of silver, tin and copper mixed just before the application with mercury at a ratio of approximately 1 : 1 and is currently one of the main sources of exposure of the population to mercury. The average daily intake of elemental mercury from dental amalgam restorations is estimated from 3 to 17 μg depending on the number of restorations (1). The high content of mercury in dental amalgam has led to efforts to push it out of dental practice. The main argument against amalgam is mercury release from fillings (2). Application of even a single amalgam filling leads to a significant increase in mercury content immediately in saliva and blood with a maximum of 4 to 5 hours after treatment. The consequence of this application is a significantly increased mercury excretion into the urine with a maximum of 8 hours after treatment (3).

During occupational exposure to mercury in dental personnel, inhalation or percutaneous mercury exposure may be considered when removing old amalgam fillings, in their preparation, application, and grinding (4). At present, it is possible to expect the concentration of total mercury in the air of dental workplaces on the order of several $\mu\text{g.m}^{-3}$ (average values of 2.2 $\mu\text{g.m}^{-3}$

for a doctor, or 3.0 $\mu\text{g.m}^{-3}$ for a nurse in personal air sampling). Long-term national monitoring of occupational exposure of dental workers by determination of mercury in urine led to conclusion that 49% of analysed urine samples (788) of nurses, laboratory workers and dentists had findings in the range of 10–39 $\mu\text{g.l}^{-1}$ (50–199 nmol.l^{-1}). The biological limit of mercury in urine valid for occupationally exposed persons ($500 \text{ nmol.l}^{-1} = 100 \mu\text{g.l}^{-1}$ and $100 \mu\text{g.g}^{-1}$ of creatinine, respectively) has been rarely achieved in the past, only in nurses (1.9% of samples). Total mercury content in hair of dental workers was up to 10 $\mu\text{g.g}^{-1}$ of total mercury; findings in the Czech occupationally unexposed population are on the order of tenths of $\mu\text{g.g}^{-1}$ of total mercury (5).

According to the Regulation (EU) 2017/852 of the European Parliament and of the Council of 17 May 2017 the use of mercury in dental amalgam is the largest use of mercury in the Union and a significant source of pollution. The use of dental amalgam should therefore be phased down and the Commission should assess and report on the feasibility of a phase out of the use of dental amalgam preferably by 2030 (6). Furthermore, particular preventive health protection measures should be taken for vulnerable members of the population, such as children and pregnant or breastfeeding women. Only pre-dosed encapsulated dental amalgam should

be allowed for use, and the use of amalgam separators in dental facilities in which dental amalgam is used or dental amalgam fillings or teeth containing such fillings are removed should be made mandatory, in order to protect dental practitioners and patients from mercury exposure and to ensure that the resulting waste is collected and disposed of in accordance with sound waste management and under no circumstances released into the environment. In this respect, the use of mercury in bulk form by dental practitioners should be prohibited. Amalgam capsules are considered suitable for use by dental practitioners and a minimum level of retention efficiency for amalgam separators should be set. From 1 January 2019, dental amalgam shall only be used in pre-dosed encapsulated form. The use of mercury in bulk form by dental practitioners shall be prohibited. From 1 July 2018, dental amalgam shall not be used for dental treatment of deciduous teeth, for children under 15 years and for pregnant or breastfeeding women, except when deemed strictly necessary by the dental practitioner based on the specific medical needs of the patient.

The authors' report is an up-to-date contribution to the health risk assessment of mercury use in dentistry, namely occupational exposure to mercury in dentists working with dental amalgam and exposure to mercury in patients treated with amalgam dental restorations.

MATERIALS AND METHODS

Determination of total mercury in samples of biological material (urine, hair) was performed during the winter months 2017 and spring months 2018 in 50 persons (volunteers) (Table 1) by the AAS method using the mercury vapour generation technique at 254.6 nm (atomic absorption spectrometer AMA 254, Altec Praha, Czech Republic). The device works on the principle of generating mercury vapours with subsequent capture and concen-

tration on a gold amalgamator. The measurement is characterized by specificity and high sensitivity of the assay (limit of detection – LOD = 0.1 µg/L, limit of quantification – LOQ = 0.3 µg/L). Quality control was performed with standard reference material Seronorm TE Whole Blood L⁻¹ (1406263). Its great advantage is the independence of the sample matrix, a total analysis time is approximately 5 minutes. A sample of known weight or volume (100 µl of urine, 5–10 mg of hair) was weighed or pipetted onto a combustion boat and introduced into the combustion tube. After drying and incineration, the decomposition products were passed through a catalyst to an amalgamator where mercury was selectively retained. The mercury was released from the amalgamator by brief heating and a mercury vapour cloud was fed to a measuring cuvette located in the optical path of the Hg lamp. The absorption of primary radiation corresponded to the mercury concentration.

The first morning urine was collected directly into sterile plastic polypropylene containers (50 ml) for this purpose. For determination of creatinine in urine samples, the Jaffe reaction was used with a UV/VIS Lambda, 2S spectrophotometer (Perkin Elmer) (7). The principle of this method is reaction of creatinine with alkaline picrate where the complex of reddish colour is formed (Jaffe reaction) and can be measured at 490 nm, the intensity of colour is proportional to the creatinine concentration.

For hair collection, samples were taken from the back of the head in accordance with the International Atomic Energy Agency (IAEA) procedures (8) (vertex posterior where there is little growth rate differentiation). Hair samples were taken as close to the head as possible (1–3 cm), placed in paper envelopes and cut with scissors before washing into 5 mm parts. The hair was washed according to the IAEA washing procedure in acetone, then three times with demineralized water and finally again in acetone (in each reagent the hair was left for 10 minutes with occasional stirring). The hair was after that procedure dried by air at room temperature between two filter papers in a non-contaminated environment for 24 hours.

In the part of statistical analysis, we used a simple linear regression. This method is appropriate for our data because we expected the dependence between two variables (the independent variable here is the number of amalgam fillings, the dependent variable is the concentration of mercury in urine or in hair).

RESULTS

The group characteristics and the results of the concentrations of mercury in urine and hair are summarized in Table 1. Age is given at the time of collection of biological material, number of operations means the number of drilled and applied amalgam fillings (in range 15–280, in average 64) for one-month period before the collection of biological material according to documentation.

For data analysis we used simple linear regression, which confirmed our assumption and showed the relationship between the number of amalgam fillings and the concentration of mercury in urine. The regression line is shown in Figure 1 for all samples (dentists and controls), with a correlation coefficient of 0.39. The correlation coefficient of the regression analysis for occupational dentistry is 0.33. The correlation coefficient of the regression analysis for nonoccupational exposure (controls) is 0.72.

Table 1. Total mercury content in urine and hair (N = 50)

	Dentists	Controls
Number of persons (men + women)	40 (13 + 27)	10 (3 + 7)
Age (years) arithmetic mean (min. – max.)	44 (24–66)	56 (26–83)
Number of operations per month* Average (min. – max.)	64 (15–280)	0 0
Number of own amalgam fillings Arithmetic mean (min. – max. value)	4.3 (0–12)	1.7 (0–7)
Hg urine (µg.g ⁻¹ of creatinine) Arithmetic mean Median (min. – max. value)	3.05 1.48 (< LOD–17.14)	0.55 0.36 < LOD–2.74)
Hg hair (µg.g ⁻¹) Arithmetic mean Median (min. – max. value)	0.377 0.340 (0.060–1.628)	0.233 0.224 (0.059–0.453)

LOD – limit of detection

*Number of operations means the number of drilled and applied amalgam fillings (in range 15–280, in average 64) for one-month period before the collection of biological material.

Fig. 1. Total mercury concentration in urine depending on the number of amalgam fillings (dentists + controls).

x is valid for dentists, + is valid for controls

Fig. 2. Total mercury concentration in hair depending on the number of amalgam fillings (dentists + controls).

x is valid for dentists, + is valid for controls

The relationship between the number of amalgam fillings and the mercury concentration in the hair in our sample was not confirmed. The regression line is shown in Figure 2 for all samples (dentists and controls), with a correlation coefficient of 0.07. The correlation coefficient of the regression analysis for occupational exposure (dentistry) is 0. The correlation coefficient of the regression analysis of nonoccupational exposure (controls) is 0.08.

Correlation between the number of amalgam fillings applied and the occupational mercury load of dentists expressed by mercury concentration in the urine, resp. hair was not found (correlation coefficient was 0.07, or -0.14).

DISCUSSION

Our recent mercury concentrations of total mercury in urine in controls are lower than in dentists, but comparison is difficult due to very low number of control persons. These findings are similar to mercury concentrations in the urine of 400 examined children of the Czech population reaching values between 0.04 and 4.28 $\mu\text{g}\cdot\text{g}^{-1}$ of creatinine (5). Concentrations of total mercury in hair of dentists and controls are very close (Table 1).

Our main interest was of course the risk assessment of occupational exposure to mercury in dentists. The introduction of a

new technique (amalgamators) in dental practice has significantly reduced mercury exposure, since the risk operation was previously not only drilling or grinding the amalgam filling, but also mixing amalgam and handling the cuticle for mixing amalgam. According to our findings the biological limit of mercury in urine valid for occupationally exposed persons ($100 \mu\text{g.g}^{-1}$ of creatinine) is no longer exceeded. Although hair is considered primarily to be an indicator of methylmercury exposure, it can also be used to determine the overall mercury content in dental workers; our new findings of total mercury concentration in hair of dentists (hundredths to tenths of $\mu\text{g.g}^{-1}$) are lower than our previously published data (9). The relationship between the number of own amalgam fillings and the concentration of mercury in urine of all 50 examined persons and especially in controls (although 10 persons only) supports assumption that amalgam fillings in the oral cavity are a permanent source of mercury for the body itself, which has been repeatedly reported in the literature, *inter alia* in relation with the use of chewing gum (10). This idea is difficult to apply for relationship between the number of own amalgam fillings and the concentration of mercury in hair. However, mercury from dental amalgam is not the only source of mercury exposure manifested by a certain amount in biological material.

In summary, mercury dental amalgam restorations are an important source of chronic exposure to mercury in the whole population and special attention should be paid not only to occupational exposure to mercury during the preparation and administration of amalgam, but also to the risk of relatively rare mercury allergy (11).

CONCLUSIONS

Current dental exposures based on the most recent findings do not exceed acceptable risk levels for dental personnel and are below the biological limit of mercury in urine valid for occupationally exposed persons ($100 \mu\text{g.g}^{-1}$ of creatinine). The results of the determination of total mercury in the urine of probands have tendency to correlate with the number of amalgam fillings in the oral cavity, which supports the view that amalgam fillings are a permanent source of mercury exposure of such treated persons.

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Conflict of Interests

None declared

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