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Assessment of Occupational Exposure to Mercury Concentrations in Hair and Nail of Dental Staff at Some Dental Clinics in Makkah Region

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Abstract

Studies showed that dentists and dental staff working with amalgam are chronically exposed to mercury that accumulates in their bodies in higher levels than those individuals not occupational exposed to mercury. Mercury levels in dental staff averaged at least 2 times that of control subjects in hair, nails, urine and blood. This study aimed to review long-standing mercury monitoring concentration in dental staff hair and nail in Makkah Saudi Arabia. 139 hair and nail samples were collected among male and female with average age ≥30 years. 83 samples were collected from dental staff working at different polyclinics and private clinics in Makkah region while 56 samples were collected from volunteers as control sample. Hair and nail samples were analysed using a Perkin Elmer (ICP-MS 7300). The study showed that in dental staff both males and females the mercury concentration in hair increased with age up to mid-30s, then gradually decrease. Moreover, the study found that mean hair mercury levels in both males and females were highest in individuals had preference of fish consumption ≥4.46 µg/l, followed by dental staff had a higher supplementation intake. While the nail mercury concentrations in both males and females were also higher in those individuals with high fish consumption (≥3.08 µg/l). The study approved a significant correlation between mercury levels in dental staff hair and nail, although conclusive evidence is lacking that directly correlates amalgam with adverse health effects, dental staff should remain knowledgeable about mercury release from amalgam through direct exposure.

Keywords: Mercury concentration; Dental staff; Occupational health; Hair analysis; Nail analysis; Mercury exposure

Introduction

Dental amalgams may contain about nearly 43-54% elemental mercury (ATSDR) [1,2]. Recent animal and human studies had identified the uptake, distribution, and rate of excretion of elemental mercury from dental amalgams as important contributing source to mercury body burden in humans [3,4]. As there is wide range of potential exposures and high retention rate for elemental mercury, dental amalgams potentially represent the largest single contributing source of mercury exposure in most individuals with large numbers >8 of amalgam fillings.

Experimental results regarding the daily intake of inhaled mercury vapour that may be released from dental amalgam restorations are few and contradictory (Berglund) [4]. Recently, [3] reported that approximately 80% of the inhaled mercury from dental amalgams is absorbed [3]. Different laboratories have estimated the average daily absorption of amalgam mercury ranged from 1 to 27 µg [3,5,6].

Studies showed that dentists and dental staff working with amalgam are chronically exposed to mercury that accumulates in their bodies in higher levels than those individuals not occupational exposed to mercury [7]. Mercury levels in dental staff averaged at least 2 times that of control subjects in hair, nails, urine and blood [8].

Sweden, has proposed to ban the use of mercury in fillings, is the country with the most exposure and health effects studies regarding amalgam, and urine levels in dental staff from Swedish and European studies ranged from 0.8 to 30.12 µg/l with study averages from 3.7 to 6.2 µg/l. Other study for a large survey of dentists at the Norwegian Dental Association's meeting found that the mean mercury level in 1986 was 7.82 µg/l with approximately 16% were above 13.62 µg/l, and for 1987 found an average of 8.62 µg/l with about 15% above 15.82 µg/l, and women having higher levels than men in general [9]. A more recent study in U.S. sample of dentists provided by the American Dental Association had an average of 5.2 µg/l. In that study of dentists, 10% of dentists had urine mercury levels over 10.4 µg/l and 1% had levels over 33.4 µg/l, indicating daily exposure levels of over 100 µg/day. Another large U.S. study had an average mercury level in urine of dentists of 3.2 µg/l [10].

Some recorded concentrations for mercury levels in hair of non-exposed individuals in the U.S. population are very limited. A summary of mercury levels in hair from residents (adults, men, women, and children) of several U.S. communities is presented in Table 1. For populations studied in the United States, mean hair concentrations range was 0.47-3.8 ppm for adults (maximum value of 15.6 ppm) and 0.46-0.77 ppm for children (maximum value of 11.3 ppm). The mean concentration of mercury in hair based on a review of existing data from other countries is 2 µg/g (ppm) [11] and the WHO advisory maximum tolerable level for hair is 6 ppm.

Population	Mean Concentration (ppm)				Maximum Concentration (ppm)			
	Adults	Males	Females	Children	Adults	Males	Females	Children
Metropolitan area								
Adults n=203	0.77	-	-	0.67	14	-	-	11.3
Children=280								
LaJolla-San Diego								
Males n=13	2.3	2.4	2.7	-	4.5	6.2	5.5	-
Females n=13								
Adults n=17								
Maryland	1.8	-	-	-	3.8	-	-	-
Adults n=33								
Seattle WA								
Males n=9	2.6	3.3	2.2	-	5.6	5.6	4.1	-
Females n=3								
Adults n=16								
Nome AK	-	-	-	-	-	-	15.2	-
Females of child bearing age n=80								
Florida	1.3	-	-	-	15.6	-	-	-
Adults that consumed wildlife n=330								

Table 1: Mercury concentrations in hair (ppm hair) from residents of different US communities (USEPA).

Objective

This study aimed to review long- standing mercury monitoring concentration in dental staff hair and nail in both private and governmental dental clinics in Makkah, Saudi Arabia.

Materials and Methods

Study population

139 hair and nail samples were collected among male and female with average age ≥30 years. 83 samples were collected from dental staff working at different polyclinics and private clinics in Makkah region while 56 samples were collected from volunteer as control sample. All subgroups have joined the study after signing a consent form and full description of the research benefits and collection methodology were described to all contributors. Samples were cut near the scalp area with thin-blade stainless steel scissors. Then, it was accurately weighed and placed inside polyethylene bags, and stored in at controlled temperature (25°C) and humidity (65% RH).

Nail sampling collection and storage

To obtain more nail masses, participants have been asked in advance not to trim their nails for a couple of weeks or longer. Nails were collected by clipping with stainless steel clipper from the two great toes (or thumbs) and small toes (or another finger). Nail samples have been placed in a labelled envelope and stored at room temperature in the driest condition possible.

Sample preparation (hair and nail)

Hair samples were first washed with distilled water on a magnetic stirrer for 15 mints in a beaker. Wash with acetone-water-water-water-acetone as recommended by the International atomic energy agency [12]. The washed samples were placed in glass beakers individually, and allowed to dry at 50°C overnight in a drying oven. For nails, before washing the nails samples any visible dirt on the surface of nails has been removed. Nails were thoroughly washed using an ultrasonic bath with distilled water followed by Milli-Q water, then acetone.

Sample digestion (hair and nail)

Approximately, 0.1-0.5 g of dry sample was weighed into dry, clean Teflon digestion vessel. Three millilitre of concentrated nitric acid and 1 ml of hydrogen peroxide were added and kept overnight. The vessel was placed in a microwave digestion (Henan Brand, model no. APEX-LJ91). Efficiency of 600 W was applied in the process for 30 mints. Then cooling for 30 mints was applied. Each digested solution

quantitatively transferred to a 10 ml volumetric flask, and 100 µl of an internal standard solution was added.

Sample analysis (hair and nail)

Samples were analysed three times using a Perkin Elmer (ICP-MS 7300). The operating conditions were as follows: 1) Carrier gas (argon, 99.999%), 0.8% L/mints; 2) Plasma gas (argon, 99.999%), 13 l/mints; 3) Auxiliary gas (argon, 99.999%), 0.8 l/min; pump rate, 1.5 ml/mints and power 1055 KW. The recovery yields of metal elements were higher than 95%. The detection limits of Hg were higher than 95% with detection value ≤3 ng/m^3. The maximal value of relative standard deviation for the three replicate analyses of every individual sample was less than 4%.

Instrumental parameters		Data acquisition	
RF power	1450 W	Measuring Mode	Segmented scan
Argon gas flow		Point per peak	5
Nebulizer	1.0 l/mints	Scans /Replicates	3
Plasma	17.0 l/mints	Replicate/sample	3
Sample uptake rate	190 s	Integration time	2/20 s

Table 2: Instrumental and data acquisition parameters of ICP-Perkin Elmer 7300.

To check the instrumental errors, high purity ICP Mercury Element Standard Solution VI CertiPUR 10 mg/L from Perkin Elmer, USA was used for external calibration. All solutions were prepared and stored in polypropylene vessels, which was cleaned prior to use by soaking in 10% HNO3 and then rinsed several times with ultra-pure water, which is produced by Millipore Mill-Q System (resistivity of 18.2 Ω cm). All calibration solutions were prepared daily at appropriate mass fractions as the samples to be analysed and in the same acid matrix as the sample and blank solutions. The use of the same matrix for all solution preparations ensured that no additional variability or bias was introduced into the analytical determination from the nitric acid content of the matrix (Tables 2 and 3).

Operating parameters	
wavelength	253.7 nm
Signal Measurements	Peak height
Smoothing	9 points
Read time	20 s
Read delay	0 s

Table 3: Spectrometer operating parameters.

Results and Discussions

Scalp hair is considered as a good indicator to assess mercury exposure in humans, as mercury is incorporated into the hair at the hair follicle in proportion to its content in blood [13]. Although there are inter individuals' variations in body burden, differences in hair growth rates, and variations in fresh and saltwater intake, once incorporated into the hair strand, mercury is stable and gives longitudinal history of mercury levels [14].

The study was conducted for dental staff in Saudi community working at different hospitals (governmental, private sectors, polyclinics, n=83). Results showed mean mercury concentrations (3.47 µg/l), while mean mercury concentrations in hair of healthy volunteers in Makkah area (n=56) was found 1.97 µg/l, these levels were higher than minimal risk level for chronic exposure (0.5 µg/l) recommended by USEPA [13]. Results clearly showed that hair mercury levels were found to be significantly higher in dental staff compared to control subjects (p=0.0001). Moreover, nail mercury levels showed a significantly higher level for dental staff rather than control subjects (p=0.0001) (Tables 4 and 5).

Groups Variables	Dental Staff (N=83)	Control (n=56)	*P* value
Age	34.26 ± 6.75	36.14 ± 9.8	0.21
Gender			
Male	34.9%	50%	0.077
Female	65.1%	50%	
Smokers percentage	15.7%	17.9%	0.7
Fish consumption	63.9%	60.7%	0.7
Supplementation	31.3%	10.7%	0.005
Amalgam exposure			
Use amalgam	51.8%	-	0.0001
With amalgam filling	-	33.9%	-
SBP	117.94 ± 11.05	119.2 ± 5.5	0.31
DBP	77.86 ± 7.95	79.55 ± 3.96	0.1
Creatinine	0.94 ± 0.09	0.97 ± 0.082	0.15
Urea	32.1 ± 6.87	30.03 ± 6.6	0.1
Uric acid	5.36 ± 1.42	5.55 ± 1.95	0.9
Albumin	4.96 ± 0.433	4.69 ± 0.46	0.002
Blood glucose	83.17 ± 29.98	83.73 ± 24.37	0.93
TC	206.6 ± 46.36	166 ± 38.2	0.0001
TG	121.65 ± 57.72	117.3 ± 61.06	0.52
LDLc	117.8 ± 32.74	99.8 ± 34.8	0.0001
HDLc	71.03 ± 15.36	71.03 ± 13.9	0.8
Hair level of Hg	3.47 ± 2.08	1.97 ± 1.49	0.0001
Nail level of Hg	2.79 ± 2.06	1.57 ± 1.44	0.0001

Table 4: Comparison of demographic, clinical and biochemical data among studied groups.

Regarding to nail mercury concentrations, exposed dental staff showed increase concentration of nail mercury than non-exposed

subjects although the difference was not statistically significant. these results were the same found in other studies that reported no statistical significance found between dental staff either exposed or non-exposed to amalgam [15-18].

Variables	Dental staff Exposed not-exposed 43 40		Control group With amalgam without amalgam 19 37		*P* value
Hair Hg	3.61 ± 2.02	3.31 ± 2.15	2.04 ± 1.6	1.95 ± 1.4	0.0001*
Nail Hg	2.9 ± 1.9	2.6 ± 2.1	1.5 ± 1.3	1.6 ± 1.5	0.003•
Post Hoc Test *Exposed dental staff vs. control with amalgam and without amalgam (P=0.014 and 0.0001) *non-exposed dental staff vs. control without amalgam filling (P=0.009) •Exposed dental staff against control with amalgam and without amalgam (P=0.012 and 0.007)					

Table 5: Comparison of hair and nail mercury levels among studied groups regarding amalgam exposure.

Interestingly, the study found measurable amount of mercury concentrations in both hair and nail of control subjects with and without amalgam restorations (2.04 µg/l, 1.5 µg/l, 1.9 µg/l and 1.6 µg/l respectively) most probably due to environmental exposures and dietary habits. By comparison to the estimated daily absorbance of mercury from dental amalgams (range, 3-17 µg/l), the estimated daily absorbance from all forms of mercury from fish and seafood is 2.31 µg and from other foods, air, and water is 0.3 µg [17]. These other sources taken together only total 2.61 µg/day, in comparison; to estimates of 3-17 µg/day for dental amalgams. Assuming a person has large numbers of amalgams, this source may account 17 µg/day out of a total absorbance of 19.61 µg/day or 87% of the absorbed mercury. In contrast, in individuals with only a few amalgams, mercury from this source may account for only 3 µg mercury/day out of a total absorbance of 5.61 µg/day, or 53% of absorbed mercury. In 1995, Halbach [18] concluded that the sum of the mercury uptake from dental amalgam and dietary [19,20].

Variables	Exposed Dental Staff %	Non-exposed Dental Staff %	*P* value
Position			
Doctors	48.8%	40%	0.42
Dental Assistants	51.4%	60%	
Duration			
<10 years	52.2%	57.5%	0.56
≥10 years	48.8%	42.5%	
Amalgam Use			
Mask	76.2%	97.5%	0.005
Gloves	100%	100%	-
Glasses	40.5%	70%	0.007
Ventilators	50%	32.5%	0.11
Deno	88.1%	82.5%	0.47
Dietary Habits			
Fish Consumption	62.8%	65%	0.83
Supplementation	30.2%	32.5%	0.82

Table 6: Comparison of exposed and non-exposed dental staff regarding descriptive job characterises amalgam exposure, PPEs and dietary habits among dental staff.

In Japan, the concentration of total mercury in hair in the general population was determined by Nakagawa [21]. This author sampled hair from 365 healthy volunteers in Tokyo and the surrounding area from June 1992 to June 1993. The mean concentration of mercury in hair was higher in males (2.98 ppm, 81 individuals sampled) than in females (2.02 ppm, 284 individuals sampled). In both males and females, the mercury concentration in hair increased with age up to the mid-30s, and then gradually declined. The study also looked at dietary preferences and found the mean hair levels in males and females were highest in individuals had preference for fish (4.0 ppm and 2.7 ppm, respectively), followed by those with a preference for fish and meat (2.88 ppm and 2.00 ppm, respectively), a preference for meat (2.38 ppm and 1.96 ppm, respectively), and was lowest in those individuals that preferred a predominantly vegetarian diet (2.27 ppm

and 1.31 ppm, respectively). In other study, the mercury content in human hair was studied in Japanese couples, with husbands having significantly higher mercury concentrations (4.01 ppm) than wives (1.99 ppm), possibly because of greater fish consumption among the men [22]. This same pattern is also apparent for all but one of the U.S. populations (San Diego, California) studied by Airey [23-26]. It is noteworthy that some of the highest mercury concentrations in hair measured in women.

Variable	**Dental staff** **<30 years 30<38 ≥38** **22 40 21**			**•P value**	**Control** **<30 years 30<38 ≥38** **15 13 28**			***P value**
Gender								
Male Female	31.8% 68.2%	27.5% 72.5%	52.4% 47.6%	0.14	73.3% 26.7%	30.8% 69.2%	46.4% 53.6%	0.07
Smoking	9.1%	17.5%	19%	0.6	40%	7.7%	10.7%	0.032
Uric acid	5.4 ± 1.63	5.1 ± 1.3	5.8 ± 1.3	P1=0.45 P2=0.37 P3=0.054	5.3 ± 1.6	5.1 ± 1.95	5.8 ± 2.11	P1=0.72 P2=0.41 P3=0.27
Albumin	5.02 ± 0.38	4.9 ± 0.45	4.9 ± 0.45	P1=0.32 P2=0.65 P3=0.65	4.6 ± 3.3	4.9 ± 0.54	4.59 ± 0.46	P1=0.2 P2=0.48 P3=0.065
TC	190.9 ± 41.9	213.4 ± 48.9	210 ± 43.8	P1=0.07 P2=0.15 P3=0.79	160.8 ± 36.4	164.8 ± 27.56	169.6 ± 43.8	P1=0.79 P2=0.51 P3=0.67
TG	110.6 ± 61.	118.04 ± 48.	140.06 ± 68.	P1=0.18 P2=0.08 P3=0.22	90.6 ± 42.5 79.1	116.6 ± 83.4 89.4	132.02 ± 54.2	P1=0.49 P2=0.06 P3=0.11
LDLc	110.4 ± 31.	115.9 ± 30.2	129.1 ± 37.26	P1=0.5 P2=0.08 P3=0.14	96.1 ± 38.3	97.4 ± 3.5	102.9 ± 32.5	P1=0.93 P2=0.54 P3=0.62
HDLc	69.04 ± 15.9	72.11 ± 15.6	71.07 ± 14.7	P1=0.46 P2=0.66 P3=0.8	70.02 ± 15.	66.3 ± 11.4	73.7 ± 13.5	P1=0.49 P2=0.42 P3=0.09
Hair Hg	3.43 ± 2.02	3.6 ± 2.23	3.23 ± 1.9	P1=0.97 P2=0.78 P3=0.68	2.27 ± 1.14	1.75 ± 1.34	1.92 ± 1.72	P1=0.06 P2=0.04 P3=0.53
Nail Hg	3.32 ± 2.43	2.52 ± 1.79	2.74 ± 2.1	P1=0.21 P2=0.34 P3=0.98	1.87 ± 1.3	1.58 ± 1.82	1.41 ± 1.29	P1=0.11 P2=0.15 P3=0.64

•P1: Dental staff <30 years vs. dental staff 30<38

•P2: Dental staff <30 years vs. dental staff ≥38

•P3: Dental staff 30<38 vs. dental staff ≥38

*P1: Control <30 years vs. control 30-<38

*P2: Control <30 years vs. Control ≥38

*P3: Control 30<38 vs. Control ≥38

Table 7: Comparison of demographic, clinical data in accordance to studied groups ages.

Mercury hair levels were found higher in male dental staff (3.29 ± 1.66 µg/l) than control male subjects (2.04 ± 1.78 µg/l), also mercury levels showed higher values in female dental staff (3.56 ± 2.28) than control female subjects (1.1 ± 0.76 µg/l). In conclusion mercury concentration showed higher significant increase in both male and female dental staff than control subjects. Moreover, for all dental staff age subgroups the mercury concentrations were higher than control subjects age subgroups. For dental staff aged <30 years' mercury

concentrations found to be 3.43 ± 2.02 µg/l higher than the volunteer same age subgroup (2.27 ± 1.14 µg/l). Whereas dental staff aged 30<38 years showed mercury concentration 3.6 ± 2.23 µg/l which was higher than the same age group in control subjects (1.75 ± 1.34 µg/l). For dental subgroup aged ≥38 years old results showed higher concentration values than control same subgroup age (3.23 ± 1.9 µg/l and 1.92 ± 1.72 µg/l respectively).

On the other side, mercury nail concentrations were also found higher in dental staff than control subjects in all age subgroups (Table 6). For dental staff aged <30 years' mercury concentrations found to be 3.32 ± 2.43 µg/l higher than the volunteer same age subgroup (1.87 ± 1.3 µg/l). Whereas dental staff aged 30<38 years showed mercury concentration 2.52 ± 1.79 µg/l which was higher than the same age group in control subjects (1.58 ± 1.82 µg/l). For dental subgroup aged ≥ 38 years old results showed higher concentration values than control same subgroup age (2.74 ± 2.1 µg/l and 1.41 ± 1.29 µg/l respectively) (Table 7).

Conclusion

The study showed that in dental staff both males and females the mercury concentration in hair increased with age up to mid-30s, then gradually decrease that was the same results indicated in other studies conducted in different countries. The study also found the mean hair mercury levels in both males and females were highest in individuals had preference of fish consumption ≥4.46 µg/l, followed by dental staff had a higher supplementation intake. While the nail mercury concentrations in both males and females were also higher in those individuals with high fish consumption (≥3.08 µg/l). Other studies reported the contribution of fish to the total intake of mercury varied from a low of 20% in Belgium to 35% in France, United States and United Kingdom. The highest contribution of fish consumption to mercury was reported in Finland (85%). Even though, using mercury in amalgam has a long history of reliability, cost effectiveness use in dentistry, more studies are required to address amalgam hazards to dental staff's health and mercury levels discharge into the environment.

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Compliance with Ethical Standards

Ethics approval and consent to participate was done. The study protocol was approved by Ethics Review Board for Human Studies at Faculty of Medicine, Umm Al Qura University and conformed to the ethics guidelines to the ethical guidelines of the 1975 Helsinki declaration.

Competing Interests

The authors declare that they have no conflict of interest.

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