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Adverse health effects related to mercury exposure from dental amalgam fillings: toxicological or psychological causes?

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ABSTRACT

Background. Possible adverse health effects due to mercury released by amalgam fillings have been discussed in several studies of patients who attribute various symptoms to the effects of amalgam fillings. No systematic relation of specific symptoms to increased mercury levels could be established in any of these studies. Thus, a psychosomatic aetiology of the complaints should be considered and psychological factors contributing to their aetiology should be identified.

Methods. A screening questionnaire was used to identify subjects who were convinced that their health had already been affected seriously by their amalgam fillings ($N = 40$). These amalgam sensitive subjects were compared to amalgam non-sensitive subjects ($N = 43$). All participants were subjected to dental, general health, toxicological and psychological examinations.

Results. The two groups did not differ with respect to the number of amalgam fillings, amalgam surfaces or mercury levels assessed in blood, urine or saliva. However, amalgam sensitive subjects had significantly higher symptom scores both in a screening instrument for medically unexplained somatic symptoms (SOMS) and in the SCL-90-R Somatization scale. Additionally, more subjects from this group (50% *versus* 4·7%) had severe somatization syndromes. With respect to psychological risk factors, amalgam sensitive subjects had a self-concept of being weak and unable to tolerate stress, more cognitions of environmental threat, and increased habitual anxiety. These psychological factors were significantly correlated with the number and intensity of the reported somatic symptoms.

Conclusions. While our results do not support an organic explanation of the reported symptoms, they are well in accord with the notion of a psychological aetiology of the reported symptoms and complaints. The findings suggest that self-diagnosed 'amalgam illness' is a label for a general tendency toward somatization.

INTRODUCTION

In the past two decades the potential health problems caused by mercury released by dental amalgam fillings have attracted public and scientific interest. Dental amalgam material consists of approximately 50% mercury (Hg) and various other metals, like silver, copper and tin (Visser, 1993). There is a continuous release of low doses of mercury from amalgam fillings; both the number of amalgam fillings and of amalgam surfaces correlate significantly with the mercury levels in urine and blood (Sandborgh Englund *et al.* 1994; Bratel *et al.* 1997*a*; Langworth *et al.* 1997). Persons with

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amalgam fillings generally show significantly higher mercury levels in body fluids than persons without such fillings, but the mercury concentrations of persons with amalgam fillings are typically < 5 μg/l in urine and 2·5 μg/l in blood (Lewalter & Neumann, 1996). These levels are well below recommended values (i.e. 50 μg Hg/g creatinine in urine (WHO, 1991)) or biological tolerance values for occupationally exposed persons (i.e. the current German biological exposure (BAT) values of 100 μg Hg/l urine and 25 μg Hg/l blood (Triebig & Schaller, 2000)).

Some authors assume that a long-term low exposure to mercury due to amalgam fillings may cause 'mercury poisoning' and produce psychological distress symptoms, including sudden anger, depression and irritability (Siblerud, 1989), as well as mental disorders (Siblerud *et al.* 1994). But the majority of studies failed to find significant positive correlations between number of amalgam fillings or mercury levels in body fluids and reported symptoms (e.g. Ahlqwist *et al.* 1988; Björkman *et al.* 1996; Bratel *et al.* 1997*b*; Langworth *et al.* 1997; Malt *et al.* 1997). Thus, there is no convincing evidence that mercury release from dental amalgam causes serious adverse health effects, which should encourage the search for a psychosomatic aetiology of complaints attributed to amalgam. However, very few studies of patients seeking health care for problems attributed to amalgam fillings have considered psychiatric symptoms in sufficient detail. These studies have found a high prevalence of medically unexplained physical symptoms and other mental disorders like depression and anxiety syndromes among patients with self-diagnosed 'amalgam illness' (Bratel *et al.* 1997*b*; Malt *et al.* 1997), pointing towards psychological factors in the aetiology of the reported symptoms.

We suggested earlier a cognitive–behavioural model of 'amalgam illness' which posits that many of the individuals with 'amalgam illness' actually suffer from subclinical or clinical states of somatoform disorders (Bailer *et al.* 1995). According to this model, trait anxiety, a tendency to attend to bodily sensations, dysfunctional beliefs, health attitudes and bodily concerns serve as risk factors for somatization. In case of amalgam-related somatization, individuals attribute their symptoms to mercury intoxication due to amalgam fillings.

The aim of the present study was to examine some components of this model. In this interdisciplinary study, we compared individuals who were convinced that their complaints are caused by exposure to mercury from amalgam fillings ('amalgam sensitive subjects') with individuals who did not hold this belief ('amalgam non-sensitive controls') with respect to various dental, medical, toxicological and psychological variables. From our model, the following hypotheses were derived. First, the group of amalgam sensitives has a higher prevalence of medically unexplained somatic symptoms than the amalgam non-sensitive controls. Secondly, amalgam sensitive and non-sensitive subjects do not differ with respect to the number of amalgam fillings or the levels of mercury in blood, urine and saliva. Thirdly, amalgam sensitive subjects differ from non-sensitive subjects on a number of psychological risk factors for somatization: they should be characterized by high trait anxiety and specific cognitions concerning environmental threat, body perception, health, and bodily complaints. We expect these psychological factors to correlate substantially with reported somatic symptoms.

METHOD

Subjects

Subjects were recruited by advertisements in local newspapers (36 amalgam sensitive subjects and 29 non-sensitive controls) and from the Department of Operative Dentistry and Periodontology, School of Dental Medicine at the University of Heidelberg, Germany (four amalgam sensitive subjects and 14 non-sensitive controls). The advertisements asked women with amalgam fillings to volunteer for a multidisciplinary investigation of possible adverse health effects of amalgam fillings. The purpose of the study was explicitly announced as exploratory, special treatment (e.g. removal of amalgam fillings) was not offered. From January 1997 to December 1998, 83 female subjects were examined. Only females were included in the present study to avoid possible confounding effects of sex differences. Inclusion criteria were: three or more amalgam fillings, age between 18 and 55 years, good knowledge of German, and signed informed consent. Exclusion criteria were: organic brain disease, present or past

psychotic disorder, presence of a somatic disease that could account for the reported bodily complaints, and clinical signs of a contact allergy to amalgam fillings or a known positive epicutaneous patch test reaction to mercury. The research protocol, including the procedure detailed in the informed consent form, was approved by the Ethics Committee for Clinical Research of the medical faculty at the University of Heidelberg, Germany.

The definition of self-reported amalgam sensitivity was based exclusively on one item of the Environmental Sensitivity Questionnaire (Bailer *et al*. 2000), which referred to amalgam fillings: 'How severely has your health already been damaged by mercury released by your amalgam fillings?' The answer was given on a 5-point Likert scale, ranging from 0 (not at all) to 4 (very severely). Subjects with ratings $\geqslant 2$ were included in the group of 'amalgam sensitives'. The 'amalgam non-sensitive' group was defined by item ratings < 2. In a previous study (Bailer *et al*. 2000), 23% of a large general population sample scored $\geqslant 2$ on this item.

The validity of this procedure of identifying amalgam sensitive subjects was ascertained in a semi-structured interview. A clinical psychologist asked all subjects to rate the health risk of amalgam fillings on a 100 mm visual analogue scale (VAS), ranging from 'not at all dangerous' (0) to 'extremely dangerous' (100). The amalgam sensitive subjects had significantly higher risk ratings compared to the non-sensitive controls ($t = 7{\cdot}23$, $P < 0{\cdot}001$). In addition, the subjects rated the probability that amalgam fillings may in fact cause bodily or mental complaints on a second VAS, with the scale endpoints 'no connection/completely unlikely' (0) and 'certain connection/very likely' (100). Again, the amalgam sensitive subjects were significantly more convinced of this connection than the non-sensitive controls ($t = 5{\cdot}23$, $P < 0{\cdot}001$). Thus, the cut-off point for amalgam sensitivity is justified by these additional procedures.

Sociodemographic variables

Amalgam sensitive subjects were significantly older than non-sensitive controls (37·5 *versus* 33·1 years; $t = 2{\cdot}62$, $P = 0{\cdot}011$). There were no significant differences regarding education, marital status, number of children and employment status.

Procedure

All participants in the study were subjected to an oral, medical and psychological examination. Mercury levels were examined in urine, blood and saliva. The total examination lasted 3 to 5 hours, conducted in two sessions.

Psychological assessment

A clinical psychologist asked all subjects in a semi-structured interview about amalgam related complaints and their dental, medical, and psychiatric history. In addition, the criteria for depressive and somatoform disorders according to the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-III-R; APA, 1987) were checked by a diagnostic psychological interview (Mini-DIPS; Margraf, 1994). The presence or extent of mental and bodily complaints, depressive mood, and psychological risk factors for the development of medically unexplained somatic symptoms were assessed by standard inventories.

Medically unexplained physical complaints were assessed by the Screening for Somatization Symptoms questionnaire (SOMS; Rief *et al*. 1997). It consists of 53 questions for somatic symptoms and 15 inclusion and exclusion criteria (such as duration of illness or frequency of doctor visits) relevant for the diagnosis of somatization disorder according to DSM-III-R and DSM-IV criteria (APA, 1987, 1994). Subjects had to mark all those symptoms present during the last 2 years, which could not be attributed to a medical cause by a physician and which caused suffering. Reported symptoms were added to yield a symptom total score. Good retest reliability ($r_{tt} = 0{\cdot}85$) and discriminative validity has been shown for this symptom score (Rief *et al*. 1997).

The Symptom Check List (SCL-90-R; Derogatis, 1977; German version: Franke, 1995) was used to assess a wide range of psychopathological symptoms. This well-validated self-report scale measures the presence and severity of 90 somatic and psychological symptoms during the last 7 days. Nine syndrome and three global scores are established. Of particular importance for the purpose of the present study was the Somatization subscale which consists of 12 common somatic complaints. Current depressive symptomatology was assessed by a

German version (Hautzinger *et al*. 1994) of the Beck Depression Inventory (BDI; Beck *et al*. 1961).

Psychological risk factors for the development of medically unexplained somatic symptoms were assessed by the following questionnaires: the German version (Laux *et al*. 1981) of the Trait Anxiety Inventory (STAI-X2; Spielberger *et al*. 1970) was used to assess habitual anxiety. Specific cognitions such as the misinterpretation of bodily sensations as somatic symptoms, a self-concept of being weak and unable to tolerate stress, and an inadequate concept of health as state without bodily complaints are also considered as risk factors for the development of medically unexplained symptoms (Rief *et al*. 1998). These specific cognitive aspects were assessed by the 46-item version of the Cognitions about Body and Health (CABAH) Questionnaire (Hiller *et al*. 1997). The CABAH consists of five scales, based on factor analyses. Each scale measures a cluster of cognitive styles, attitudes, and interpretations of body perceptions which were found to be typical for patients with somatoform disorders. The scales are as follows: Catastrophizing Interpretation of Bodily Complaints (20 items), Intolerance to Bodily Complaints (7 items), Bodily Weakness (9 items), Automatic Sensations (6 times), and Health Habits (4 items). All items were self-rated on 4 point scales from 'completely wrong' (0) to 'completely right' (3).

There is a subgroup of patients with medically unexplained complaints who are convinced that their symptoms are caused by exposure to chemical or physical components to the external environment, such as noxious substances or electromagnetic fields (Göthe *et al*. 1995). Therefore, the presence and severity of generalized environmental sensitivity was assessed by means of a 10-item self-report Environmental Sensitivity Questionnaire (ESQ; Bailer *et al*. 2000). The ESQ asks the respondent to appraise a number of neutral or noxious environmental stimuli for their damaging effect on the health of the respondent. The list of risk factors presented includes diverse dental materials (amalgam, gold, composite, palladium) and various more or less harmful environmental agents (electrosmog, passive cigarette smoking, radioactivity from nuclear reactors, and chemicals or other harmful substances in the air, in the water and in the food). In a preceding study (Bailer *et al*. 2000) the internal consistency of the ten-item scale ranged from 0·86–0·89 (Cronbach's alpha). In the current study, the amalgam-item was excluded from the calculation of the total score, because it was used for the definition of the two groups (amalgam sensitive *versus* non-sensitive). Cronbach's alpha for the nine-item scale was 0·84.

Dental examination

A standard clinical examination was performed, and the number of dental amalgam fillings and surfaces was registered by dentists at the Department of Operative Dentistry and Periodontology, University of Heidelberg, Germany.

Physical examination

All subjects had a medical check-up including physical examination, electrocardiogram, abdominal sonography and blood chemistry. The aim of these examinations was to exclude subjects with a somatic disorder that could account for the reported symptoms.

Mercury determination

Concentrations of mercury were determined in blood (μg Hg/l), spontaneous urine (μg Hg/l and μg/g creatinine) and saliva (μg/l) by cold vapour atomic absorption spectrometry at the Institute and Policlinic of Occupational and Social Medicine, University Hospital of Heidelberg, Germany. The results of the mercury determinations in urine were adjusted according to urinary creatinine to correct for the varying degree of dilution. Thirteen subjects with creatinine values $< 0{\cdot}5$ g/l or $> 2{\cdot}5$ g/l were excluded from the Hg-urine analyses (seven in the amalgam sensitive group and six in the control group). Mercury in saliva was determined after standardized stimulation by 10 min of gum chewing.

Statistical methods

For tests of group differences, *t* tests or ANCOVAs with age as covariate were used for parametric analyses, and the Mann–Whitney *U* test for non-parametric analyses. The chi-square test was used to compare frequency data. Relationships between variables were tested by Pearson's correlation coefficient. Two-tailed *P*

values are presented throughout; in case of multiple comparisons, the significance criterion was corrected using the Bonferroni-Holm α-adjustment (Holm, 1979). A stepwise discriminant function analysis was applied to identify those symptom scales that allow maximum separation of the two groups. All statistical analyses were performed on SPSS Version 8 for MS Windows.

RESULTS

Amalgam sensitivity and symptoms

In the SCL-90-R, the amalgam sensitive subjects scored significantly higher on the subscales Somatization ($F = 23{\cdot}26$, $P < 0{\cdot}05$) and Obsession–Compulsion ($F = 10{\cdot}62$, $P < 0{\cdot}05$) than the non-sensitive controls (Table 1). They also had significantly higher scores in the Beck Depression Inventory (BDI) than the controls ($F = 9{\cdot}15$, $P < 0{\cdot}05$), but their mean score was far below the usually assumed level of clinical significance of a BDI score of at least 18. In the Screening for Somatization Symptoms (SOMS), amalgam sensitive subjects reported on average 13·5 (S.D. 8·1) medically unexplained physical symptoms for the last 2 years, the non-sensitive controls only 5·1 (S.D. 3·8). This group difference was not only statistically ($F = 32{\cdot}22$, $P < 0{\cdot}05$) but also clinically very significant: the prevalence of severe syndromes with more than 12 medically unexplained symptoms in the SOMS was 50% in the amalgam sensitive group *versus* 4·7% in the control group ($\chi^2 = 26{\cdot}43$, $P < 0{\cdot}001$). The prevalence of depressive syndromes (BDI score $\geqslant 18$) did not differ significantly between the two groups (15% in the amalgam sensitive group *versus* 4·7% in the control group, $\chi^2 = 2{\cdot}55$, $P = 0{\cdot}110$).

A stepwise discriminant analysis was conducted to identify those symptom scales that would maximally contribute to the separation of the two groups (amalgam sensitive *versus* non-sensitive). The objective was to correctly reclassify the subjects into the two groups on the basis of the four symptom scales (SCL-90-R Somatization scale, SCL-90-R Obsessive–Compulsive scale, SOMS symptom total score and BDI global score) on which the groups differed in the univariate tests (ANCOVAs). The SOMS symptom total score entered at step one, no other variables entered in the subsequent steps. The correct classification, based on this variable, was 80·7% (canonical correlation = 0·566; Wilk's lambda = 0·68; $\chi = 31{\cdot}04$; $P < 0{\cdot}001$). More subjects of the control group (88·4%) than of the amalgam sensitive group (72·5%) were classified correctly.

Table 1. *Comparisons of psychological symptom scales and bodily complaints scales for amalgam sensitive and non-sensitive subjects*

Symptom scales	Amalgam sensitive subjects ($N = 40$) Mean	(S.D.)	Non-sensitive controls ($N = 43$) Mean	(S.D.)	ANCOVA† F value (group)
Symptom Check List (SCL-90-R)‡					
Somatization	57·6	(13·6)	45·4	(10·4)	23·26*
Obsessive–compulsive	56·6	(11·6)	47·1	(13·7)	10·62*
Interpersonal sensitivity	50·9	(10·9)	49·4	(11·5)	0·93
Depression	53·3	(12·8)	46·4	(12·7)	4·88
Anxiety	53·3	(12·2)	47·7	(11·2)	6·55
Anger – hostility	50·7	(10·4)	47·5	(10·1)	2·31
Phobic anxiety	51·7	(10·1)	48·4	(8·6)	2·14
Paranoid ideation	51·7	(10·9)	50·2	(10·5)	0·14
Psychoticism	50·5	(11·7)	46·7	(10·0)	1·60
GSI (global severity index)	54·4	(12·6)	46·0	(13·8)	7·70
PSDI (positive symptom distress)	57·8	(9·65)	51·5	(11·9)	7·95
PST (positive symptom total)	52·6	(12·3)	45·0	(13·5)	6·39
BDI Depression (global score)	9·2	(6·5)	4·7	(5·7)	9·75*
SOMS symptom total score	13·5	(8·1)	5·1	(3·8)	32·22*

† Age was used as a covariate in all ANCOVAs, but had no significant influence on any of the comparisons. Levels of significance (2-tailed) are corrected for multiple comparisons using Bonferroni-Holm α-adjustment: $*P \leqslant 0{\cdot}05$.

‡ SCL-90-R values are t transformed on the basis of population norms, corrected for education and gender.

BDI, Beck Depression Inventory; SOMS, Screening for Somatization Symptoms.

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Table 2. *Comparisons of mercury (Hg) concentrations in blood, urine and saliva for amalgam sensitive and non-sensitive subjects*

Group		Hg-blood (μg Hg/l)	Hg-urine* (μg Hg/l)	Hg-urine* (μg/g creatinine)	Hg-saliva (μg/l)
Amalgam sensitives ($N = 40$)	Mean ± S.D.	2·93 ± 2·90	2·46 ± 3·30	2·33 ± 2·80	107 ± 97
	Median	2·35	1·70	1·55	76·4
	Range	0·25–13·4	0·10–19·1	0·06–14·7	6·7–406
Non-sensitive controls ($N = 43$)	Mean ± S.D.	2·64 ± 2·17	2·98 ± 4·15	2·24 ± 1·93	100 ± 123
	Median	2·40	1·40	1·88	57
	Range	0·25–10·5	0·10–19·4	0·20–8·43	2·8–559
P (t test)		0·602	0·566	0·883	0·768
P (U test)		0·913	0·680	0·634	0·307

* Thirteen subjects with creatinine values < 0·5 g/l or > 2·5 g/l were excluded from the Hg-urine analyses (seven amalgam sensitives, six controls).

Table 3. *Comparisons of psychological risk factors for the development of medically unexplained somatic symptoms between amalgam sensitive and non-sensitive subjects*

Psychological variables/risk factors	Amalgam sensitive subjects ($N = 40$) Mean	(S.D.)	Non-sensitive controls ($N = 43$) Mean	(S.D.)	ANCOVA† F value (group)
Trait anxiety (STAI)‡	58·1	(8·01)	50·9	(9·81)	13·76*
Environmental sensitivity (ESQ)§	12·0	(4·81)	7·58	(4·71)	13·78*
Catastrophizing cognitions (CABAH 1)	14·5	(6·33)	13·0	(6·36)	0·99
Intolerance of bodily complaints (CABAH 2)	6·30	(3·60)	5·21	(3·29)	2·75
Bodily weakness (CABAH 3)	9·10	(3·90)	4·91	(3·58)	23·40*
Autonomic sensations (CABAH 4)	4·56	(2·21)	3·49	(2·76)	3·39
Health habits (CABAH 5)	7·35	(2·27)	6·93	(2·18)	0·38

† Age was used as a covariate in all ANCOVAs, but had no significant influence on any of the comparisons. Levels of significance (2-tailed) are corrected for multiple comparisons using Bonferroni-Holm α-adjustment: *$P \leqslant 0{\cdot}05$.

‡ STAI values are t transformed on the basis of population norms, corrected for age and gender.

§ Global score without amalgam-item.

In the amalgam sensitive group 32·5% met the DSM-III-R criteria for a somatoform disorder (2·5% conversion disorders, 5·0% undifferentiated somatoform disorders, 25·0% somatization disorders) *versus* 2·3% (undifferentiated somatoform disorders) in the control group. The criteria for a current depressive disorder (dysthymia or major depression) were fulfilled by 15% of the amalgam sensitive subjects and 4·7% of the controls.

Amalgam sensitivity and mercury levels

The two groups did not differ with respect to the number of amalgam fillings and surfaces ($t < 1{\cdot}30$, $P > 0{\cdot}196$). The amalgam sensitive group had on average 9·48 fillings (S.D. = 4·01) and 19·68 surfaces (S.D. = 9·49) *versus* 9·09 fillings (S.D. = 3·33) and 17·14 surfaces (S.D. = 8·25) in the control group. The same results were found with non-parametric tests (number of amalgam fillings: $z = 0{\cdot}29$, $P = 0{\cdot}770$; number of amalgam surfaces: $z = 1{\cdot}11$, $P = 0{\cdot}268$). The mercury concentrations in blood, urine and saliva are shown in Table 2. Mercury levels did not differ significantly ($P > 0{\cdot}30$) between the amalgam sensitive group and the non-sensitive control group. In each group three subjects showed elevated Hg-urine values (> 5 μg/l Hg).

Correlations between mercury levels and somatic symptoms

Parametric as well as non-parametric correlations between different mercury exposure indicators and somatic symptoms reported in the SOMS and the SCL-90-R Somatization scale were generally weak and not significant. There was only one significant correlation in the control group, but in an unexpected direction:

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Table 4. *Correlations between psychological risk factors, somatic symptoms and mercury concentrations in blood (Hg-B), urine (Hg-U) and saliva (total sample)*

	Somatic symptoms		Mercury levels		
Psychological risk factors	SOMS score ($N = 83$)	SCL-90-R score ($N = 83$)	Hg-B μg Hg/l ($N = 83$)	Hg-U† μg/g creatinine ($N = 70$)	Hg-saliva μg/l ($N = 83$)
Trait anxiety (STAI)	0·50***	0·51***	−0·11	−0·01	−0·09
Environmental sensitivity (ESQ)‡	0·38***	0·41***	−0·10	−0·05	0·18
Bodily weakness (CABAH 3)	0·50***	0·52***	−0·06	−0·07	0·01

† Thirteen subjects with creatinine values $< 0{\cdot}5$ g/l or $> 2{\cdot}5$ g/l were excluded from the Hg-urine analyses (seven amalgam sensitives, six controls).

‡ Global score without amalgam-item.

Level of significance (2-tailed): ***$P \leqslant 0{\cdot}001$.

higher mercury concentrations in saliva were correlated with lower physical symptoms in the SCL-90-R Somatization scale ($r = -0{\cdot}31$, $P = 0{\cdot}046$).

Amalgam sensitivity and psychological risk factors

Table 3 shows means and standard deviations (S.D.) of both groups for the psychological risk factors. As expected, the amalgam sensitive subjects were significantly more anxious (STAI; $F = 13{\cdot}76$, $P < 0{\cdot}05$), had higher scores in the CABAH subscale Bodily Weakness ($F = 23{\cdot}40$, $P < 0{\cdot}05$), and showed a higher self-reported environmental sensitivity ($F = 13{\cdot}78$, $P < 0{\cdot}05$) than the non-sensitive controls.

Correlations between psychological risk factors, somatic symptoms and mercury levels

All psychological risk factors which discriminated between amalgam sensitive and non-sensitive subjects were significantly related to the number and intensity of somatic symptoms, with r values ranging from 0·38 to 0·52 (Table 4). Thus, individuals with higher scores on the psychological measures had more medically unexplained somatic symptoms. None of these psychological variables were correlated with the mercury levels in the biological media.

DISCUSSION

In this study, persons with self-reported amalgam sensitivity were characterized by features of somatoform disorders. They reported a high number of medically unexplained somatic symptoms for the last 2 years, and also increased scores on the SCL-90-R Somatization scale for the last 7 days. The prevalence of more than 12 medically unexplained somatic symptoms was 50% in the amalgam sensitive group *versus* 4·7% in the control group. Despite the fact that our sample of amalgam sensitive subjects was not self-referred, our findings are in close agreement with those of previous studies which also found high prevalence rates of mental disorders (ranging from 58% to 89%) and increased symptom scores on standardized somatization, anxiety and depression scales in patients with self-diagnosed 'amalgam illness' (Hickel *et al.* 1991; Cascorbi *et al.* 1994; Kraus *et al.* 1995; Bagedahl-Strindlund *et al.* 1997; Bratel *et al.* 1997*b*; Malt *et al.* 1997).

In the present study, the number of amalgam fillings and the mercury levels in body fluids were not significantly different between the amalgam sensitive group and the controls. Also, the mercury concentrations obtained were far below levels at which negative health effects could be expected. Furthermore, there was no positive correlation between different mercury exposure indicators and the severity of the reported physical complaints. Thus, mercury released from amalgam fillings was not a likely cause of the symptoms reported by amalgam sensitive subjects. These findings are in line with previous studies, in which also no positive correlations were found between the number of amalgam fillings or amalgam surfaces and the frequency of reported symptoms and complaints (Ahlquist *et al.* 1988; Björkman *et al.* 1996; Bratel *et al.* 1997*b*; Langworth *et al.* 1997; Malt *et al.* 1997; Melchart *et al.* 1998).

One may argue that 'amalgam illness' is caused by an increased sensitivity to low doses

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of mercury released by amalgam fillings. But up to now, there is not sufficient empirical evidence for this hypothesis. On the contrary, the results of a recently published double-blind induction test study by Strömberg *et al.* (1999) do not support that short-term exposure to low doses of mercury vapour promotes clinical illness in subjects who themselves suspected to suffer from 'amalgam disease'.

While our results do not support an organic explanation of the reported symptoms, they are well in accord with the notion of a psychological aetiology of the reported symptoms and complaints (Bailer *et al.* 1995). First, amalgam sensitive subjects reported higher trait anxiety than controls. This personality trait is associated with high levels of both somatic and emotional distress. Secondly, the amalgam sensitive individuals were characterized by a self-concept of being weak and unable to tolerate stress. This specific cognitive style was found to be typical for patients with somatization syndrome (Rief *et al.* 1998). Thirdly, the amalgam sensitive group had significantly higher scores in the Environmental Sensitivity Questionnaire than the non-sensitive controls. This finding suggests that amalgam sensitivity is more a variety of a general environmental hypersensitivity than an isolated or specific environmental illness (Bailer *et al.* 2000). In comparison to the non-sensitive controls, amalgam sensitive subjects reported increased sensitivity to various neutral or noxious environmental stimuli (such as diverse dental materials, electrosmog and chemicals). Negative thoughts and images of a threat to health by exposure to 'dangerous' amalgam fillings and other 'poisonous' substances or physical components of the external environment will be accompanied by anxiety and increased physiological arousal which may lead to increased somatic attention. Normal bodily variations and anxiety symptoms may then be interpreted as further evidence of an 'amalgam disease' or 'environmental illness'.

Several limitations of this study should be pointed out. First, the generalization of results is limited by the sampling procedure, the inclusion and exclusion criteria, and the case definition. One consequence of these restrictions could be an over-inclusion of somatoform disorders, because male subjects, who in general have a reduced prevalence of somatoform disorders and persons with a somatic disease that could account for the reported symptoms were excluded from the study. Another concern is that the findings obtained from only moderately impaired non-clinical amalgam sensitive subjects may not generalize to patients suffering from a more severe 'amalgam illness'. A further limitation of the current study is the cross-sectional design, which allows no causal interpretations of the findings. Thus, it does not allow to disentangle to which extent the psychological abnormalities of amalgam sensitive subjects are cause or consequence of the more or less persistent somatic complaints; only longitudinal studies may clarify this issue.

In summary, psychological factors may play an important role in the development and maintenance of 'amalgam illness'. The self-reported symptoms could not be explained neither by the mercury concentrations in body fluids nor by somatic diseases. This does not imply that the only appropriate diagnosis is a psychiatric or psychosomatic one. In studies with less restrictive inclusion and exclusion criteria an increased prevalence of diagnosed somatic diseases was found among patients with 'amalgam illness' (Bratel *et al.* 1992*a*; Bagedahl-Strindlund *et al.* 1997).

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REFERENCES

Ahlqwist, M., Bengtsson, C., Furunes, B., Hollender, L. & Lapidus, L. (1988). Number of amalgam tooth fillings in relation to subjectively experienced symptoms in a study of Swedish women. *Community Dental Oral Epidemiology* **16**, 227–231.

American Psychiatric Association (1987). *Diagnostic and Statistical Manual of Mental Disorders, 3rd edn. Revised.* APA: Washington, DC.

American Psychiatric Association (1994). *Diagnostic and Statistical Manual of Mental Disorders, 4th edn.* APA: Washington, DC.

Bagedahl-Strindlund, M., Ilie, M., Furhoff, A. K., Tomson, Y., Larrson, K. S., Sandborgh-Englund, G., Torstenson, B. & Wretlind, K. (1997). A multidisciplinary clinical study of patients suffering from illness associated with mercury release from dental restorations: psychiatric aspects. *Acta Psychiatrica Scandinavica* **96**, 475–482.

Bailer, J., Rist, F. & Staehle, H. J. (1995). Kasuistik und verhaltensmedizinisches Erklärungsmodell zur Entstehung von dentalmaterialbezogenen somatoformen Beschwerden. *Verhaltenstherapie* **5**, 217–225.

Bailer, J., Rist, F., Rudolf, A. & Staehle, H. J. (2000). Amalgamsensitivität, allgemeine Sensitivität gegen Umweltstoffe und psychische Beeinträchtigung. *Zeitschrift für Klinische Psychologie und Psychotherapie* **29**, 24–34.

Beck, A. T., Ward, C. H., Mendelson, M., Mock, J. & Erbaugh, J. (1961). An inventory for measuring depression. *Archives of General Psychiatry* **4**, 561–571.

Björkman, L., Pedersen, N. L. & Lichtenstein, P. (1996). Physical and mental health related to dental amalgam fillings in Swedish twins. *Community Dental Oral Epidemiology* **24**, 260–267.

Bratel, J., Haraldson, T., Meding, B., Yontchev, E., Öhman, S. V. & Ottoson, J. O. (1997*a*). Potential side effects of dental amalgam restorations (I). An oral and medical investigation. *European Journal of Oral Sciences* **105**, 234–243.

Bratel, J., Haraldson, T. & Ottoson, J. O. (1997*b*). Potential side effects of dental amalgam restorations (II). No relation between mercury levels in the body and mental disorders. *European Journal of Oral Sciences* **105**, 244–250.

Cascorbi, I. C., Knorr, U., Schiele, R. & Petschelt, A. (1994). Ergebnisse aus dem Erlanger Untersuchungszentrum Amalgam. *Deutsche Zahnärztliche Zeitung* **49**, 936–939.

Derogatis, L. R. (1977). *SCL-90-R: Administration*, *Scoring*, *and Procedures Manual for the Revised Version*. Johns Hopkins University: Baltimore.

Franke, G. (1995). *Die Symptom-Checkliste von Derogatis*, *Deutsche Version*, *Manual*. Beltz Test: Göttingen.

Göthe, C. J., Molin, C. & Nilson, C. G. (1995). The environmental somatization syndrome. *Psychosomatics* **36**, 1–11.

Hautzinger, M., Bailer, M., Worall, H. & Keller, F. (1994). *Beck Depressions Inventar* (*BDI*). *Testhandbuch*. Huber: Bern.

Hickel, R., Meier, C., Schiele, R., Raab, W. & Petschelt, A. (1991). Nebenwirkungen von Amalgam? – Eine interdisziplinäre Studie. *Deutsche Zahnärztliche Zeitung* **46**, 532–544.

Hiller, W., Rief, W., Elefant, S., Margraf, J., Kroymann, R., Leibbrand, R. & Fichter, M. M. (1997). Dysfunktionale Kognitionen bei Patienten mit Somatisierungssyndrom. *Zeitschrift für Klinische Psychologie* **26**, 226–234.

Holm, J. (1979). A simple sequentially rejective multiple test procedure. *Scandinavian Journal of Statistics* **6**, 65–70.

Kraus, T., Anders, M., Weber, A., Hermer, P. & Zschiesche, W. (1995). Zur Häufigkeit umweltbezogener Somatisierungsstörungen. Ergebnisse einer interdisziplinären Querschnitt-studie. *Arbeitsmedizin Sozialmedizin Umweltmedizin* **30**, 147–152.

Langworth, S., Sällsten, G., Barregard, L., Cynkier, L., Lind, M. L. & Södermann, E. (1997). Exposure to mercury vapor and impact on health in the dental profession in Sweden. *Journal of Dental Research* **76**, 1397–1404.

Laux, L., Glanzmann, P., Schaffner, P. & Spielberger, C. D. (1981). *Das State-Trait-Angstinventar*. Beltz: Weinheim.

Lewalter, J. & Neumann, H. G. (1996). Biologische Arbeitsstoff-Toleranzwerte (Biomonitoring). Teil VIII: Bewertung der Hintergrundbelastung bei beruflich nicht-exponierten Personen. *Arbeitsmedizin Sozialmedizin Umweltmedizin* **31**, 418–432.

Malt, U. F., Nerdrum, P., Opedal, B., Gunderson, R., Holte, M. & Löne, J. (1997). Physical and mental problems attributed to dental amalgam fillings: a descriptive study of 99 self-referred patients compared with 272 controls. *Psychosomatic Medicine* **59**, 32–41.

Margraf, J. (1994). *Mini-DIPS. Diagnostisches Kurz-Interview bei psychischen Störugen*. Springer: Berlin.

Melchart, D., Wühr, E., Weidenhammer, W. & Kremers, L. (1998). A multicenter survey of amalgam fillings and subjective complaints in non-selected patients in the dental practice. *European Journal of Oral Science* **106**, 770–777.

Reif, W., Hiller, W. & Heuser, J. (1997). *SOMS – Das Screening für Somatoforme Störungen. Manual zum Fragebogen*. Huber: Bern.

Reif, W., Hiller, W. & Margraf, J. (1998). Cognitive aspects of hypochondriasis and the somatization syndrome. *Journal of Abnormal Psychology* **107**, 587–595.

Sandborgh-Englund, G., Dahlqvist, R., Lindelöf, B., Söderman, E., Jonzon, B. & Vesterberg, O. (1994). DMSA administration to patients with alleged mercury poisoning from dental amalgams: a placebo-controlled study. *Journal of Dental Research* **73**, 620–628.

Siblerud, R. L. (1989). The relationship between mercury from dental amalgam and mental health. *American Journal of Psychotherapy* **XLIII**, 575–587.

Siblerud, R. L., Motl, J. & Kienholz, E. (1994). Psychometric evidence that mercury from silver dental fillings may be an etiological factor in depression, excessive anger, and anxiety. *Psychological Reports* **74**, 67–80.

Spielberger, C. D., Gorsuch, R. L. & Lushene, R. E. (1970). *Manual for the State-Trait Anxiety Inventory*. Consulting Psychologists Press: Palo Alto.

Strömberg, R., Langworth, S. & Söderman, E. (1999). Mercury inductions in persons with subjective symptoms alleged to dental amalgam fillings. *European Journal of Oral Science* **107**, 208–214.

Triebig, G. & Schaller, K. H. (2000). Mercury, metallic mercury and inorganic mercury compounds. In *Biological Exposure Values for Occupation Toxicants and Carcinogens. Critical Data Evaluation for BAT and BKA Values. Deutsche Forschungsgemeinschaft* (ed. H. Greim and G. Lehnert). Wiley-VCH: Weinheim.

Visser, H. (1993). *Quecksilber-Exposition durch Amalgamfüllungen*. Heidelberg: Hüthig.

WHO. (1991). *Environmental Health Criteria 118 – Inorganic Mercury*. World Health Organization: Geneva.